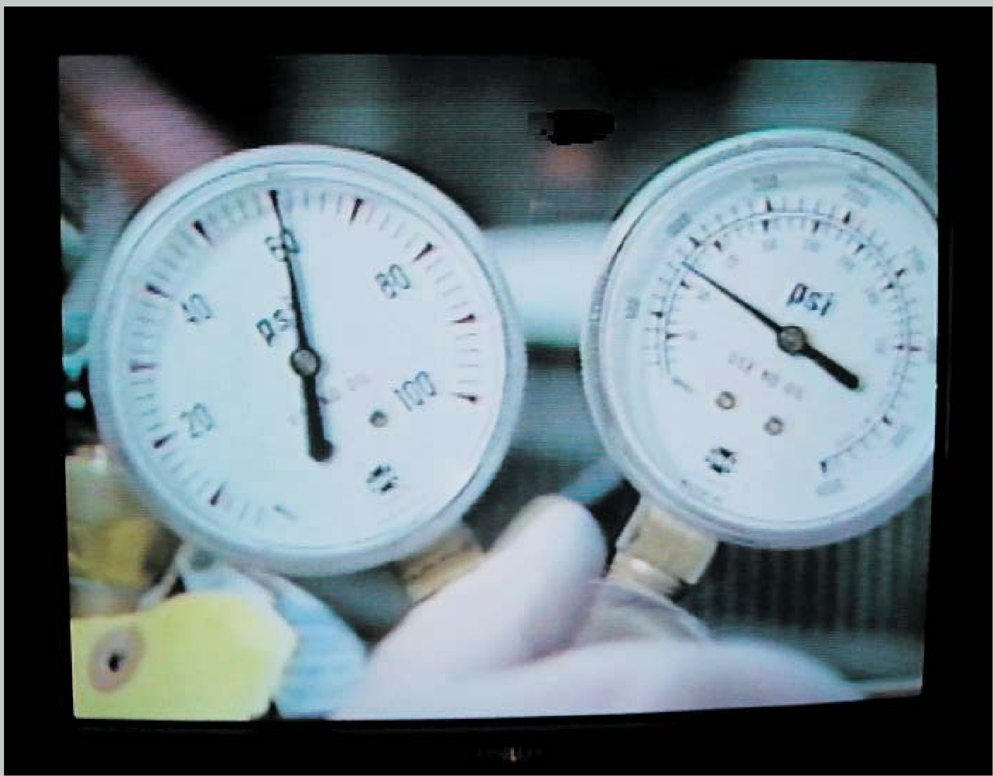
JYVÄSKYLÄ STUDIES IN EDUCATION, PSYCHOLOGY AND SOCIAL RESEARCH

216

Sauli Puukari

Video Programmes as Learning Tools

Teaching the Gas Laws and Behaviour of Gases in Finnish and Canadian Senior High Schools



UNIVERSITY OF JYVÄSKYLÄ

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UNIVERSITY OF JYVÄKYLÄ

JYVÄSKYLÄ 2003

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ABSTRACT

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Video programmes as learning tools. Teaching the gas laws and behaviour of gases in Finnish and Canadian senior high schools.
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The main object of this experimental study was to test how video programmes used in a Physics minicourse dealing with gases affect learning outcomes. The theoretical framework was based on cognitive psychology, particularly schema theories, science learning studies, and educational technology studies, especially studies concerning television and videos in instruction. The treatment groups were two task groups and four video groups, altogether 8 groups. One of the task groups had written learning tasks prior to viewing a video programme section or teaching and the other had no tasks. Three of the video groups each had a different version of the video programme dealing with gases and the fourth group was a control group using no videos. Sixteen physics groups (total n = 358) from the province of Central Finland, Keski-Suomi, were randomly selected and assigned to the treatment groups. All the physics groups used the same "Student Textbook" and "Student Workbook" specifically developed for the study. Data were collected with a number of quantitative and qualitative methods, of which a combined concept map + essay represented a new type of method. The validity and reliability of the data collection methods were considered to be quite good. Also the internal and external validity of the experimental design were reasonably good. The main results suggested that students using video programmes did not learn more than students not using video programmes when learning about the gas laws, whereas in learning about the kinetic theory of gases, students using a video programme learned more than students not using video programmes. Students using learning tasks prior to viewing a video programme section/ teaching of a sub-topic often learned significantly more than students not using learning tasks. Senior high school students' knowledge of gases was not particularly good. Students' attitudes towards school and physics were quite positive. Most students had either positive or neutral attitudes towards studying gases. The results imply that with proper planning and pedagogical approaches, video programmes can considerably facilitate physics learning

Descriptors: physics instruction, senior high school, video programmes, learning outcomes, goal-orientation

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TIIVISTELMÄ

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Tämän kokeellisen tutkimuksen päätavoitteena oli tarkastella, kuinka kaasuja käsittelevän fysiikan lyhytkurssilla oppimateriaalina käytetyt video-ohjelmat vaikuttavat oppimistuloksiin. Tutkimuksen teoreettinen viitekehys perustui kognitiiviseen psykologiaan, erityisesti skeemateorioihin, luonnontieteiden oppimista käsitteleviin tutkimuksiin sekä oppimisteknologian tutkimuksiin, joissa tarkastellaan television ja videoiden käyttöä opetuksessa. Tutkimuksessa käytetyn koeasetelman käsittelyryhminä oli kaksi tehtäväryhmää ja neljä videoryhmää, yhteensä kahdeksan ryhmää. Toisella tehtäväryhmistä oli ennen videojaksojen katsomista/opetusta kirjallisia oppimistehtäviä ja toisella ryhmällä ei ollut lainkaan tehtäviä. Kolmella videoryhmistä oli kullakin erilainen versio kaasuja käsittelevästä video-ohjelmasta ja neljäs ryhmä oli ilman videota toimiva kontrolliryhmä. Keski-Suomesta poimittiin satunnaisesti 16 fysiikan ryhmän otos (n = 358), jonka ryhmät sijoitettiin satunnaisesti eri käsittelyryhmiin Kaikki fysiikan ryhmät käyttivät tutkimusta varten kehitettyä opetusmonistetta ja harjoitustehtävä-monistetta lyhytkurssin ajan. Aineisto kerättiin useamman kvantitatiivisen ja kvalitatiivisen menetelmän avulla, joista käsitekartan ja esseen yhdistelmä edusti uudentyyppistä menetelmää. Aineistonkeruumenetelmien validiteetin ja reliabiliteetin katsottiin olevan suhteellisen hyviä. Myös koeasetelman sisäinen ja ulkoinen validiteetti olivat melko hyvät. Tutkimuksen päätulosten mukaan video-ohjelmia opetuksessa hyödyntäneet ryhmät eivät oppineet kaasulakeja opiskellessaan kontrolliryhmiä enemmän, kun taas kineettistä kaasuteoriaa opiskeltaessa video-ohjelmien käytöllä oli enemmän vaikutusta oppimiseen kontrolliryhmiin verrattuna. Lukiolaisten tiedot kaasuista eivät olleet erityisen hyvät. Oppilaiden asenteet koulua ja fysiikkaa kohtaan olivat kuitenkin varsin positiivia. Useimmat oppilaista suhtautuivat kaasujen opiskeluun joko positiivisesti tai neutraalisti. Tulokset viittaavat siihen, että oikein suunniteltuina ja sopivia pedagogisia lähestymistapoja hyödyntämällä video-ohjelmat voivat merkittävällä tavalla edistää fysiikan oppimista.

Hakusanat: fysiikan opetus, lukio, video-ohjelma, oppimistulokset, päämääräsuuntautuneisuus

ACKNOWLEDGEMENTS

An active stage of this research project towards a doctoral dissertation started in 1995 in Finland at the University of Jyväskylä. The first empirical phase was conducted in Edmonton, Canada at the University of Alberta in 1991, and the Finnish data were collected in 1992 from the province of Central Finland, Keski-Suomi. Analyses of the Canadian data were reported as part of my licentiate thesis in 1994. This dissertation focuses mainly on the Finnish data including also some comparisons with the Canadian data.

I want to thank professor Jouko Kari, Ph.D. from the Department of Teacher Education, University of Jyväskylä, who has been a positive and encouraging supervisor during the whole dissertation process. I also wish to thank the Department of Teacher Education for its support of my research: Professors Seppo Hämäläinen, Jorma Ojala and Pauli Kaikkonen have - in a positive way - reminded me about completing the dissertation, senior lecturer Glyn Hughes has given me very valuable feedback on the English language, and the other staff members, especially my closest colleagues, Dr. Marjatta Lairio, senior lecturer Matti Partanen, senior lecturer Juha Parkkinen and university teacher, Pia Nissilä, together with our school counsellor educator colleagues from Jyväskylä polytechnics, have provided me with a positive working environment. Dr. Pentti Nikkanen from the Institute for Educational Research and Dr. Vesa Rahkonen from the Department of Teacher Education gave me important feedback as examiners of my licentiate thesis, and chief statistical analyst, Antero Malin, from the Institute for Educational Research, has given me useful ideas for planning and carrying out statistical analyses. I am also grateful for the useful comments on the manuscript for this dissertation given by the reviewers, professor-emeritus Robert Mulcahy, Ph.D. from the University of Alberta, Canada, professor Eero Ropo, Ph.D. from the University of Tampere, and docent Jari Lavonen, Ph.D. from the University of Helsinki.

The learning materials (texts, assignment papers and video) and the data collection methods used in the project were developed in Canada in 1991 - and then translated into Finnish in 1992. For the year in Canada I am very grateful. I wish to express my gratitude to many supportive experts: Professor Wytze Brouwer, Ph.D. and professor Heidi Kass, Ph.D., both from the department of Secondary Education, University of Alberta. Professor Heidi Kass also gave permission to use some items from questionnaires used in IEA/SISS study. The Instructional Technology Centre, Faculty of Education, University of Alberta, gave valuable ideas and feedback about the video manuscript and produced the video programme versions for the research project. For this I want to thank the director David A. Mappin, Dr. Terry T. Tang, and Mr. Dave Trautman. I also want to thank the president of DB Robinson Research Ltd., Heng-joo Ng, Ph.D., P.Eng. for giving permission to use parts of their videotape presenting use of a PVT cell. The following persons gave valuable ideas and feedback about the learning materials: Henry Dembicki, M.A., R.L. (Roman) Guzman, B.Sc., Ch.E., R.E.T., Peter, M. Hohn, P.Eng., Heng-joo Ng, Ph.D., P.Eng. John E. Ollerenshaw, and Maurice Slack, P.Eng.

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Without the cooperation of school boards, principals, physics teachers and senior high school physics students in Edmonton and its surrounding communities, and in the province of Central Finland, the study would not have been possible - thank you for your cooperation!

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Gloria in Exelcis Deo!

Jyväskylä, Spring 2003

Sauli Puukari

CONTENTS

SEPARATE APPENDIX PRINTOUT

The following appendices can be found in a separate printout which is available for reading upon request at the University of Jyväskylä Library. The first four appendices are Finnish versions of some questionnaires used for data gathering. The remaining appendices contain the instructional materials used during the experiments.

S1 General Questionnaire - Finnish version
S2 Multiple-Choice Questionnaire 1 (and 2) - Finnish version
S3 Experience Questionnaire - Finnish version
S4 Teachers' Experience Questionnaire - Finnish version
S5 Physics curriculum of the public high schools of Alberta (Gas related topics)
S6 Communal curriculum for high schools of Jyväskylä: Physics (Gas related topics)
S7 Questionnaire for companies - Pilot Study 2 for planning the "Student Textbook"
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S9 The "Student Textbook" - English version
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S13 The "Student Workbook" - English version
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S15 Manuscript for the video programme versions (Finnish narration in brackets)
S16 Permission to use a videotape
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1 INTRODUCTION

Development of cognitive psychology and other areas of study have produced new knowledge that can be utilized in the planning and implementation of instruction. The developments in technology, on the other hand, have made it possible to increase the number of video recorders and other video equipment in schools. To design better educational video programmes and to use these programmes more efficiently and meaningfully in schools we need more research. These were the reasons for starting this study. The main object of this research project is to study the effects of different versions of an educational video programme and use of instructional tasks on physics learning in a minicourse dealing with the behaviour of gases and the gas laws. A meaningful context for learning was obtained by deriving the objectives and content of the minicourse from actual physics curricula and by carrying out the minicourse in real schools at a time when gases were being dealt with as a study topic.

Although the target group of the present study is physics students, it also has relevance for chemistry learning, since the behaviour of gases is in a sense between physics and chemistry. The study also produces general knowledge which can be used in planning educational video programmes aimed at teaching new content areas.

The idea for selecting physics and the specific topic, the behaviour of gases, for the present study originates from two sources:

1) IEA/SISS studies indicate that school achievements in physics in Finland "begin to fall" below the international average at junior high school, and the same trend continues at the senior high school (Laurén, 1986, 1990). Similar results were obtained in Canada, as well (see Connelly 1989, 6-9).
2) School physics contains many topics, such as the behaviour of gases discussed in the present study, where it is possible to illustrate how certain principles and processes work in practice, and how they can be utilized in real life. This second reason for choosing physics is particularly important concerning educational video programmes: the behaviour of gases, as a phenomenon, brings a variety of aspects that can be visualized in an educational video programme.

This study uses data obtained from senior high schools in Alberta, Canada, and in in the province of Central Finland, Finland. Due to some problems in the Canadian data (details to be explained in later chapters), most of the analyses will be based only on the Finnish data. Some comparisons will be made between the Finnish and Canadian data.

From the point of view of instruction, there are two main factors influencing students' learning in video viewing situations:

1) The programme itself (structure, content, cognitive level, etc.)
2) The way the programme is used (activities before, during, and after viewing the programme)

It is important to see these two aspects as "partners" in an interaction process between students and programmes and students and teachers.

Since the topic of this study requires knowledge from many fields, the research project was not based on just one theory. The approach used in this study utilizes research conducted in different fields of science, such as psychology, education and educational technology. The attempt is to combine the available information in a way that gives tools to design and evaluate educational video programmes in physics instruction. This type of approach may help to find:

1) practical solutions for making better educational video programmes,
2) theoretical ideas for evaluating educational video programmes, and
3) theoretical ideas for describing students' learning processes in physics.

The theoretical background of this study consists of three important components:

1) *cognitive psychology*, particularly schema theories (chapter 2),
2) *science learning studies regarding physics*, particularly studies dealing with learning of gas laws and the kinetic theory of gases (chapter 3),
3) *educational technology*, especially studies and theoretical considerations regarding television and video programmes in instruction (chapter 4).

The purpose of the schema theories, here, is to provide a general, interpretative theoretical framework for the research project. This first theoretical component can be seen as an umbrella under which the other two theoretical components provide more specific perspectives for the study. All three theoretical components form the theoretical framework on which the planning of the minicourse "the behaviour of gases and the gas laws" and the design of the study were based. An important aspect in this study is the role of animation as part of educational video programmes. Animation and videos are a topical issue is research dealing with physics learning (see e.g. Christian & Belloni 2001).

The central theoretical elements of this research project will be discussed in the following way: each key element of the theoretical framework will be dealt with in a separate chapter. Each chapter begins with a discussion of the meaning of the element and continues with a presentation of its functions, and ends with a short summary including the implications for the present study. The discussion of the three main components will be followed by a methodological discussion regarding the available research methods for studying learning processes. This chapter provides the theoretical basis for selecting the research methods for this project. The last chapter of the theoretical framework summarizes the main aspects of the theoretical framework in order to build links to the research problems and to the implementation of the research project.

2 LEARNING PROCESSES

This chapter deals with the first important theoretical component, learning processes, that forms the general interpretative theoretical framework for the present study. Cognitive psychology has pointed out the importance of studying not only the outcomes, but also the process of learning. The information on learning processes of students in this study is obtained from different sources, some of which will be discussed in detail in chapters 3 and 4. The discussion of learning processes will mainly be based on schema theories that have proved to be a fruitful way to look at learning processes. The main idea in schema theories is that the knowledge we acquire is organized around some broader concepts or ideas, called schemata. This is typical of human information processing and it makes a person's memory work more efficiently since one does not have to memorize isolated units of knowledge, often called propositions, but one can relate these propositions to each other and combine them into larger units, schemata, instead.

One important aspect in taking schema theories as an important basis for the discussion of learning processes in the present study, is that the main ideas presented in schema theories can quite readily be applied to school situations and the results can be communicated also to those teachers who are not specialists in learning theories. Some schema theorists, such as Rumelhart (see e.g. McClelland, Rumelhart & the PDP research group 1986; Rumelhart, McClelland & the PDP research group 1986), have shifted their theoretical thinking from schema theories towards a more accurate and more micro level analysis of proposition networks, which comes close to the tradition of learning studies using computer simulations to imitate human cognitive processes. One main reason for rejecting (though not completely) "traditional" schema theories has been the difficulty to define a schema for measurement purposes (see also Miettinen 1984). These types of new approaches have raised a number of important questions and produced valuable information on human thinking and information processing. However, these studies may lack pedagogical power: How can we apply the micro level knowledge of human information processing to the complex reality of school teaching? Since the present study is aiming, along with its theoretical objectives, at practical applications, schema theories were chosen to be the starting point of the theoretical discussion.

The discussion of learning processes will start with a brief definition of ‘learning’ and ‘learning processes’ and the concept of schema, followed by a discussion of the role of schemata in acquisition of knowledge. Section 2.3 "Affective and cognitive factors in learning" contains two important factors that have been shown to influence the learning processes, particularly in school settings: students’ perception of their intelligence (Dweck & Henderson 1989), and students’ approaches to learning (Biggs 1987a, 1987b). These two factors, along with some factors dealing with students’ attitudes, will be included in the implementation of the research project to provide an understanding about factors affecting the learning processes and learning outcomes. This will be followed by a discussion about means to influence the learning processes. This discussion will be utilized in designing some aspects of the learning materials to be used in the empirical phase and in writing the instructions for teachers according to which they will be expected to teach. The discussion will end with a summary that gathers the main aspects in a concise form and links them to the empirical phase of the present study.

2.1 Learning and the concept of schema

Learning can be understood as an active, constructive, cumulative, goal-oriented process. Shuell (1988, 277 - 278) puts it this way: "It [learning] is *active* in that the student must do certain things while processing incoming information in order to learn the material in a meaningful manner. It is *constructive* in that new information must be elaborated and related to other information in order for the student to retain simple information and understand complex material. It is *cumulative* in that all new learning builds upon and/or utilizes the learner’s prior knowledge in ways that determine what and how much is learned [researcher’s comment: in the case of radical schema changes when the whole structure of the schema changes, “cumulation” is not an appropriate term]. It is *goal oriented* in that learning is most likely to be successful if the learner is aware of the goal (at least in a general sense) toward which he or she is working and possesses expectations that are appropriate for attaining the desired outcome." Shuell’s definition follows the paths of “new learning theories”: the common feature of theories of cognitive psychology is that they all have an underlying assumption that people are active, goal-seeking and purposive (Bower 1975; Gardner 1987; Miettinen 1984). This is one reason for concentrating on learning processes in this study. It is useful to recognize that learners themselves quite often make the major difference, although the influence of teachers, learning materials and other factors is important.

‘Learning process’ or ‘learning processes’ can in a sense be understood as an equivalent to ‘learning’. By speaking of ‘learning processes’ instead of ‘learning' one can emphasize the process nature of learning. The concept of learning processes in this study refers to an interpretation of learning which includes:

1) Recognition of various individual routes to learn something. Even if the end result of learning as measured by school tests, for example, is the same, the way *how* two individuals reached this goal can be quite different.

2) Learning involves a number of psychological processes, which together form an all-inclusive learning process. For instance, Shuell (1988) differentiates three general psychological processes that are involved in human learning: a) cognitive, b) metacognitive, and c) affective. All of the processes are needed and interact with each other in successful learning. In the present study, the main focus is on cognitive processes, but also metacognitive and affective processes are studied, often in order to explain the cognitive processes or learning outcomes. For the purposes of experimental design used in this study, affective factors were often technically separated in analyses as independent factors affecting the dependent factor (learning outcomes regarding gases). The separation of cognitive and affective factors was made by knowing the limitations and artificiality of this procedure. As West and Pines (1983) responded to an article by Posner et al. (1982), where they claim that learning and conceptual change are rational processes: feelings or more generally affects are an integral part of cognitive processes. West and Pines (1983, 38) note that feelings "are integral parts of what learning *is*, and not simply motivational, attitudinal, or affective antecedents upon which learning depends. Learning *is* feeling good, proud, satisfied, etc. as much as it is Posner et al.'s four conditions; and feelings are never entirely rational."

3) Learning can be seen as a continuous process, a series of mental events, where previous knowledge guides the acquisition of new knowledge of the world. New knowledge of the world is acquired through our senses, but this perceiving is in no way a mechanical act. Our perceptions are always selective (see e.g. Neisser & Becklen, 1975). We do not receive all the information from a given scene or situation. We select the information by using our prior knowledge and intention.

Learning requires remembering. We cannot keep all the details and facts in mind simultaneously (Miller 1956). Still many people can handle complex and difficult problems containing much more information that could possibly be kept in one's working memory simultaneously. To understand and explain how all this information can be processed, we have to assume that people in one way or another put the information in a more concise and often more abstract form.

Schemata are often used to describe and explain cognitive processes and memory. Neisser (1976) has used the concept 'schema' in his theoretical discussions concerning cognitive processes. His considerations cover also perceptual processes that are important in the present study since it deals with watching video programmes. This was a reason to begin from Neisser's view. Referring to Bartlett's (1932) classical studies, Neisser uses 'schema' as a label for the central cognitive structure in perception.

Another central concept in Neisser's work is the perceptual cycle that can be seen in figure 1. A look at the figure makes it easier to understand the following definition of schema: "A schema is that portion of the entire perceptual cycle which is internal to the perceiver, modifiable by experience, and somehow specific to what is being perceived. The schema accepts information as it becomes available at sensory surfaces and is changed by that information; it directs movements and exploratory activities that make more information available, by which it is further modified" (Neisser 1976, 54). In the "visual area" schemata have been used, for example, in organizing memories of pictures showing that it is typical of human beings to group separate items, pictures in this case, around more general concepts, or schemata (Mandler & Johnson 1976).

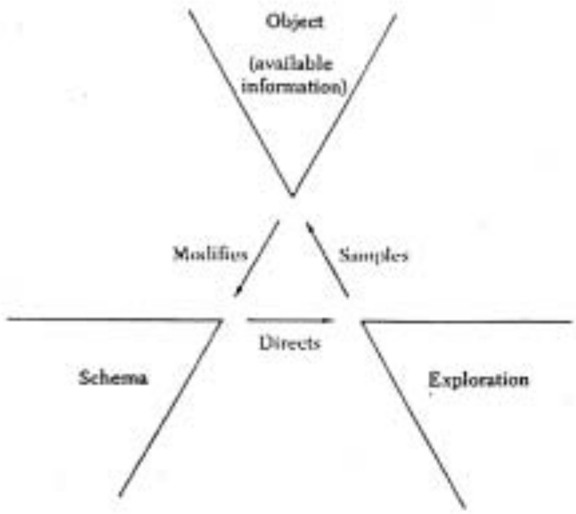


FIGURE 1 The perceptual cycle (Neisser 1976, 21)

Hewson and Posner (1984,120) selected the concept 'schema' as the central psychological concept in their attempt to (a) develop a "generative schema that could be used by students to integrate most, if not all, of the physics content; and to (b) design a means for representing and teaching that schema" in their instructional materials. They use the term 'conception' in the meaning that includes the following concepts: " 'script' when the individual is faced with understanding a series of events, a 'frame' or 'schema' when the individual is faced with a perceptual task, and a 'schema' when the individual is faced with a paragraph understanding task" (p. 120). According to Hewson and Posner (1984, 139-130), learning from the perspective of schema theory is analogous to an architecture based on steel frame construction. The steel frame is constructed first, before walls, floors, ceilings and stairs. This approach to learning is in contrast to the brick-by-brick-and-mortar approach representing more inductivist perspectives.

Another definition for the concept 'schema' is the one used by Fiske & Taylor (1984, 39): Schema is a "cognitive structure that represents organized knowledge about a given concept or type of stimulus" abstracted from prior experience. Some definitions postulate that schema may theoretically be conceived as a set of interconnected propositions centring around a general concept (e.g. Gagné 1986, 12). Gagné (1985) describes schema in terms of the domains of learning outcomes (intellectual skills, verbal information, cognitive strategies, attitudes, and motor skills). A schema is formed around a general concept (domain of intellectual skill). Concepts are intellectual skills in that they provide rules for classifying incoming information. Such a function is known as "ideational scaffolding" (Anderson R. C. 1984) for which the "slot" structure of schema is utilized. This means that a schema is used for connecting different concepts related to some aspects of reality so that the schema gathers sometimes seemingly separate concepts around a meaningful basic idea that to a certain extent forms a coherent description or explanation of the aspects of reality it represents. This schema is then used for interpreting the new incoming information by using the existing concepts for classifying the new information and connecting it to the existing structure of the schema.

Gagné (1985) also states that each schema is likely to be accompanied by an affective proposition about that schema (see also Briggs & Wager 1981). This influences personal choices associated with the schema. In other words, along with the "purely intellectual" aspects embodied in a schema, we also bring our attitudes and emotions connected to them. An example of this could be attitudes and feelings about formulas: Only seeing a mathematical or a physical formula makes some people feel uncomfortable and may arouse feelings of helplessness and strong negative attitudes, even when the level of difficulty is suitable from the standpoint of a person's intellectual abilities and skills. These affective components of schemata can be one plausible explanation why sometimes people may react so differently to the same features of reality. For instance, it is very common that feedback obtained after an educational course may reveal totally opposite reactions to the methods of teaching or to the materials used in the course.

According to Vosniadou and Brewer (1985) a major defining characteristic of schemata is what Brewer and Nakamura (1984) refer to as "molar assumption". It assumes that the theory of human cognition cannot be an atomistic theory, which postulates that the more complex aspects of human activity can always be derived from combinations of basic mental elements, but that there is a need to postulate larger theoretical entities, which operate as units in the theory (see also Anderson, J. R. 1980; Minsky 1975; Rumelhart & Ortony 1977). If this position is accepted, the propositional view of schema proposed by Gagné (1986, 12) is questionable. However, it is very difficult to prove which of these two views is correct. If we could investigate what happens at the very micro level during cognitive processes, we might be able to "see" if the schema construction is based on connecting individual propositions together or if it is a more general and complex one that cannot be explained by referring to propositions. Perhaps learning is first more based on propositions and with practice and age develops in a more holistic direction. For example, when musical notations are studied, novice students often start learning them note by note, whereas experts perceive the notes as larger units.

Some researchers have used other terms instead of schema. Cantor and Mischel (1977) describe active information processing and retrieval by using the term 'prototypes'. Schank and Abelson (1977) use 'script', which refers to the memory structure a person uses in encoding his or her general knowledge of a certain situation-action routine or events. They hold a view that part of our knowledge is organized around hundreds of stereotypical situations with routine activities, like going to a shop or to a concert. This idea is supported by empirical studies (Anderson, R. C. & Pichert 1978; Bower et al. 1979; Fiske et al. 1979). There is also evidence that individual differences provide for substantially different levels of processing of information based on script development (Fiske, Kinder & Larter 1983; Graber 1984; Markus 1977). Although these studies are not able to offer any final solution to the problem of the existence of schema as a psychological entity or to the precise structure of schema, they have shown that schema may serve as a useful tool in constructing theories of learning and memory.

Yet another concept that seems to have connections to the concept of schema is the concept of knowledge object, first described by Entwistle and Marton (1994). Their article describes how students experience the understandings of study material they develop during revision. They identified the following five forms of understanding (Entwistle & Marton 1994, 163):

1) Absorbing facts, details, and procedures related to exams without consideration of structure.
2) Accepting and using only the knowledge and logical structures provided in the lecture notes.
3) Relying mainly on notes to develop summary structures solely to control exam answers.
4) Developing structures from strategic reading to represent personal understanding, but also to control exam answers.
5) Developing structures from wide reading which relate personal understanding to the nature of the discipline. Entwistle and Marton (1994) discussed these five categories of understanding in terms of three main characteristics, breadth, depth, and structure. Further, it appeared that the students used the following attributes to describe the nature of their understanding: Feelings of satisfaction; meaning and significance; coherence, connectedness, and 'provisional wholeness'; irreversibility; confidence about explaining; flexibility in adapting and applying.

Entwistle and Marton (1994, 166) define the knowledge object in the following way: "They [students] were describing a feeling that the material being revised had become to tightly integrated that it was experienced as an entity with form and structure. Only some aspects of these entities could be visualised, but additional associated knowledge was readily 'available' when needed. It was this recurring experience among the students which we came to describe as a knowledge object. The term was chosen to draw attention to the tight integration of knowledge achieved through intensive study, to the quasi-sensory nature of 'perceptions' involved, and to the awareness of substantial amounts of related knowledge not immediately at the focus of attention."

Entwistle and Marton (1994, 175) want to make a difference between the concept of schema and their concept "knowledge object". They note that the concept of schema has been "extended in cognitive psychology to describe internal mental representations inferred from the student's experience in terms of concepts held in long-term memory". They cited J. R. Anderson (1990, 134, 136) to specify the concept of schema: "Schemas are ... ways of encoding regularities in categories, whether these regularities are perceptual or propositional. They are abstract in the sense that they encode what is generally true rather than what is true about a specific instance. ... Schemas are designed to facilitate making inference about the concepts, (yet) we are still in the process of trying to understand the psychological significance of this representational construct."

After this quotation Entwistle and Marton note that "knowledge objects, in contrast, while describing a hypothetical construct, do not rely on a raft of other abstract constructs to make sense of them. There is no reason to describe them as internal representations: they are experiental entities existing in their own right. They are not adequately described simply in terms of bundles of associations, pre-existing concepts inferred from past experiences, or facets of neurological structure. ... knowledge objects exist, not underlying, but *in* people's awareness." Further, Entwistle and Marton note that their "knowledge object" is closer to "Bartlett's functional and dynamic notion of schema, in which 'structure' refers to the structure of acts or ways of understanding and experiencing something, and not to the structure of some hypothetical mental entities within long-term memory.

Considering the above notions of Entwistle and Marton, it seems there are also other ways to interpret the idea of knowledge objects with regard to the concept of schema. Even though there are some reasons to state that knowledge objects and schemata more or less describe different aspects of students' cognitive processes, the emphasis on differences may be misleading in that it prevents seeing the substantial connections between these two constructs. It must be added that Entwistle and Marton do recognize that some similarities and connections exist between them and also between "knowledge objects" and "scripts" that were introduced by Schank and Abelson (1977) (for more on scripts see above, p. 17). Nevertheless, Entwistle and Marton (1994) do put the emphasis on the differences, and they seem to emphasize that knowledge objects are "in awareness", implying that schemata are underlying awareness, more related to the long-term memory than the working memory.

Given all the above, one could propose an interpretation that sees knowledge objects as conscious notions of well-developed schemata, which are stored in the long-term memory, but which have the potential of becoming more conscious if they are intensively developed through processes of learning that involve an intention to understand the phenomena or events the schemata are representing. This would mean that both the knowledge objects and schemata could be understood as outcomes of learning processes, the difference being that knowledge objects evolve only after *intensive* construction of schemata. If this conceptualization is correct, then knowledge objects should *not* be treated as "entities existing in their own right", but rather as *conscious experiences of schemata* that are developed to the extent that students become so well aware of them that they start experiencing "awareness of a tightly integrated body of knowledge" and the other features that characterize this conscious experience (see Entwistle and Marton 1994, 166-169 for more about these other features).

Yet another concept connected to schema is "mental model". According to Tweney (1987) all science has to do with constructing a testable mental model of some aspects of reality. He studies the role of mental models in scientific thinking from five perspectives: 1) mental models constructed representations of the perceptual world, 2) mental models can be verbal, visual, or mathematical, in nature or combinations of these, 3) mental models are based on existing scripts and schemata in the knowledge base, 4) inferential extensions are not based on formal processes, and 5) the ways the new data is sought depend on the nature of the current mental model.

Gagné (1987) provides a useful list of central features of a schema, which serves as a summary. These features are related also to the acquisition of knowledge, a theme to be discussed in more detail in the next section. 1) A schema provides a framework for taking new information, including "slots" for thematic ideas (Restaurant schema - waiter). 2) A schema helps the selective allocation of attention (where to pay close attention). 3) A schema provides a basis for making inferences (go beyond the literal, abstractiveness). 4) A schema makes possible efficient memory search (recalling, for example, events containing many details). 5) A schema facilitates summarizing. 6) A schema permits learner to generate hypotheses about missing information.

In this research project, *schema is understood as a cognitive tool or structure that combines a set of smaller units of knowledge into a larger and at least somewhat coherent form with the affective aspects embodied in the schema*. It should be noted that schemata are not static, but dynamic and they can interact with other schemata during learning and thinking processes. The changes occurring in schemata during thinking or acquisition of knowledge will be discussed in the following section.

2.2 Schemata and acquisition of knowledge

This section discusses one of the most important aspects of this research project, the role of schemata in knowledge acquisition. To have a good understanding of the question we have to discuss schemata from several perspectives that clarify the functions of schemata in acquiring new information. Schemata themselves result from a cumulation of prior learning and experience (Resnick, 1985). Schemata have connections with metacognition, which refers to a person's knowledge or awareness of his or her own cognitive processes and activities (see e.g. Brown 1978; Flavell 1976; Weinert & Kluwe 1987). Hacker (1998, 11) summarizes the notions of metacognition which are widely agreed: "knowledge about one's knowledge, processes, and cognitive and affective states, and the ability to consciously and deliberately monitor and regulate one's knowledge processes, and cognitive and affective states". To improve knowledge acquisition, it is important to develop metacognition and to better control cognitive processes involved in learning. As to the schemata, there is reason to assume that the more conscious a person is of functions of schemata the more efficiently he or she can utilize them in acquisition of new knowledge.

Schema affects both comprehension and memory (e.g. Bransford and Johnson 1972; Royer & Cable 1975, 1976). Schemata actually have a central role in the whole learning process. They affect: 1) the amount of attention allocated to a particular type of information, 2) what information is selected for processing, 3) integration of new information with existing information, and 4) how the process of retrieving is guided to locate the information retained in memory (Alba & Hasher 1983; Brewer & Nakamura 1984).

Probably the most often mentioned aspect concerning schema is the central role of prior knowledge in learning (e.g. Bransford 1979; Gagné 1987; Pichert & Anderson 1977). This prior knowledge enables us to interpret and retain the incoming information; it serves as a basis to which one can connect the new items of information (see also point three in the list above).

A considerable amount of information concerning schemata has come from studies of reading. These studies offer a good opportunity to understand how schemata work in cognitive processes, such as reading. These studies are also important in that reading is a central part of school learning, when understood not only as a mechanical skill, but as an active and critical way of knowledge acquisition.

As we are reading a text, we have to infer the missing links between the propositions provided by a text. Only this active (or partially automatic) inference helps us to build coherence. Kintsch and van Dijk (1978) and their colleagues have developed a theory of the process of building coherence. Working memory has a limited capacity for holding information. Therefore, building a representation (coherence) cannot be based on bringing all the propositions to working memory at the same time. Instead of this, reading and representation building occur in cycles (see also Neisser's perceptual cycle), where each cycle can be seen as an attempt to connect one or more new (just read) propositions to the representation already built. If the text to be read does not provide a proper reference to which the next proposition can be linked, the reading process takes more time due to a new choice of propositions that have to be made. (Resnick 1985.)

Central ideas, or key concepts are essential in reading a text. They organize the propositions and are helpful in encoding and retrieval. Finding this hierarchy in text is important while reading. It was also found that competent readers are better in finding this hierarchy than incompetent. (Meyer 1984.) Ausubel utilized these ideas already earlier in his considerations of advance organizers (see e.g. Ausubel 1968). Based on these kinds of ideas, some attempts have been made to create aids for facilitating learning and understanding of television and video programmes. These things will be discussed in chapter 4.

Rumelhart and Norman (1978, 1981a) have identified three possible ways in which existing knowledge can be modified by new experience:

1) *Accretion* refers to the gradual accumulation of factual information by the process of activating an existing schema and assimilating another instantiation of that schema.
2) *Tuning* means a kind of evolution of a schema. These evolutionary changes in schema are due to different processes, like generalizing or constraining the extent of a concept's applicability or otherwise improving the accuracy of the concept resulting in better connections to the actual data.
3) *Restructuring* refers to creation of new structures designed for reinterpretation of old information or construction of new information. The use of restructuring increases as a function of age and requires more expertise.

Schema changes have also been studied concerning stereotypes that people attribute to groups. People tend to view social groups in a certain prototypical manner. Wicks (1986b) presents three models of schematic change:

1) The bookkeeping model: Each discrepant encounter changes the schema gradually (e.g. Fiske & Taylor 1984). (Note the similarities with tuning),
2) The conversion model, A single concentrated encounter with incongruous information can change a schema totally (Rothbart 1981). (Note the similarities with restructuring)
3) The sub-typing model. Incongruence causes the perceiver to form subcategories within the overall schema (Taylor, 1981) (This might be seen as a partial restructuring, which is not mentioned in the list of the previous passage; See also the short discussion at the end of the next paragraph).

The sub-typing model has received more empirical support when these models were compared with each other (Weber & Crocker 1983). Especially the sub--typing model could be possible to apply to the study of learning in school. It represents a kind of partial restructuring of a schema. However, for example, Rumelhart and Norman (1978, 1981a) do not identify it as a category in their discussion of schema changes. We could think about a schema that includes a wide range of objects and concepts representing factual information. Let us assume that a certain portion of the objects and concepts within the schema appears to be represented incorrectly, to be in conflict with reality or with a reliable (at least somehow empirically observed) picture of reality. Apparently, in order to solve that conflict, we have to change the schema, but maybe that broad schema of ours need not to be reconstructed as a whole. Maybe we could reconstruct only those "wrong" parts of it; If we can reconstruct (in the sense that Rumelhart and Norman use the term) only that portion of the schema that includes those defective parts, without changing the structure of the whole schema, (apart from the portion at hand), then we would have made a partial reconstruction of a given schema.

Much of what we know about the acquisition of new knowledge by restructuring, has come from studies comparing novices and experts in different fields. Vosniadou and Brewer (1985) identified two different interpretations of what kind of restructuring occurs in knowledge acquisition:

1) Knowledge acquisition consists of *accretion* of more abstract knowledge on an impoverished base, during which the structure of that base is modified (e.g. Chi et al. 1982; Larkin 1981). This has also been called "weak restructuring".
2) *Radical restructuring*. The theories of novices and experts are different in terms of their structure, different in the domain of phenomena they explain, and different in their individual concepts (e.g. Disessa 1982; McCloskey 1983a; Wiser & Carey 1983).

These radical changes in schemata have been compared to T. S. Kuhn's (1970) view of paradigm changes, and accretion or "articulation", as it is also called, has subsequently been compared to the minor changes in individual theories during "normal science". (Vosniadou & Brewer 1985.)

Experts' knowledge is denser (they have more knowledge and concepts are better integrated) than the knowledge novices have. This enables experts to draw on more schemata when processing information than novices do (Chi & Koeske 1983). Experts also use schema-discrepant information and schema-congruent information efficiently while novices tend to rely more on schema-congruent information (Fiske et al.1983). Experts, on the other hand, tend to be less willing to alter schema when confronted with discrepant information since they have invested more in their schemata than the novices.

Schemata may resist change although people rarely find a precise link between a schema and a piece of information (Crocker, Fiske & Taylor 1984). Further it has been found that a moderate mismatch between the schema and the message typically leads to message assimilation, and, especially if the discrepant information may be viewed as situational, or an exception to the schema, it will have little impact (Crocker, Hannah & Weber, 1983). From the point of view of children's education, the inability to shift a schema may lead to difficulties in learning situations as pointed out, for example, by Kinzer (1983), who found that presenting a known meaning of a word, before requiring to learn a new meaning, seems to make it more difficult to learn these new meanings. This problem of not changing the schema when needed is common in science learning and will be discussed more thoroughly in section 2.2.

For the development of a schema (supposing that it is an appropriate schema without a need for radical restructuring) it is desirable that the schema structure grows in complexity, becoming more abstract and more general. Thus the development of schemata (by accretion and tuning) can be viewed as growing from concrete to general, until they are highly sophisticated. A more structured schema including more intellectual skills (see also Gagné 1985, 1986) helps the learner to transfer the structure to formulate another schema when needed. (Abelson 1976; Suzuki 1987.) School education should reinforce the development of highly structured schemata to enable the use of acquired knowledge. The better the structure of a schema and the more abstract and general it is, the better it can facilitate learning and creation of new schemata. For school education it is very important to find efficient ways to make students build schemata of this type. In section 2.4 different means to influence the learning processes will be discussed in more detail.

The ideas presented in this section will be used in interpreting the empirical results of the present study, especially the results dealing with learning outcomes studied using qualitatively oriented data collection methods (see section 8.5).

2.3 Affective and cognitive factors in learning

This section deals with affective and cognitive process factors in learning based on research conducted by Dweck and Henderson (1989) and Biggs (1987a, 1987b). Dweck and Henderson (1989) have presented a systematic way to describe and measure peoples' beliefs about their intelligence that has proved to be a useful way to explain and predict learning behaviours referred to as mastery-orientation and learned helplessness. This is an area where people's emotions have an important role. Biggs (1987a, 1987b) has studied learning processes and developed a systematic way to describe and measure students' approaches to learning. Both Biggs' and Dweck and Henderson's theoretical models have been tested in school settings and their data collection methods have been successfully used in many studies. Given all this, and that their approach and measures seemed to be suitable for the purposes of the present study, they were chosen as a basis for discussing affective and cognitive process factors in learning.

It should be noted that all these affective and cognitive process factors are related to schema changes described in previous sections. Students' perception of their intelligence, as described by Dweck and Henderson (1989), can be understood as a kind of background factor with an emotional loading that can either facilitate desirable schema formation or make it more difficult. Students' approaches to learning, which according to Biggs (1987a, 1987b) consist of two interconnected components, motives and strategies, regulate the ways students go about learning. These approaches have direct connections to schema formation: The stronger and the more efficient motives and strategies students have, the better schemata they can construct. The following discussion gives a more detailed review of the theoretical models proposed by Dweck and Henderson (1989) and Biggs (1987a, 1987b).

2.3.1 Students' perception of their intelligence

Dweck and Henderson (1989) have developed measures to study people's perception of their intelligence, their implicit beliefs, or what they call 'theories' about intelligence. Two theories have been studied most, '*entity theory*' and '*incremental theory*'. People that think about intelligence according to the entity theory believe that intelligence is something that is given and permanent so that an individual cannot change or develop, whereas people with the incremental theory see intelligence as something one can develop through one's efforts.

Entity theorists tend to be more concerned about documenting their intelligence and emphasizing "performance" goals. Incremental theorists are more oriented toward "learning" goals, in a way toward developing their intelligence. Research has shown that children holding an entity theory and performance goals, more often experience 'learned helplessness', particularly if they have low confidence in their intelligence. When they encounter failures in learning, they believe it is because they lack the ability. This leads to deteriorated performance and their perception of themselves as low ability learners strengthens. Children with an incremental theory of intelligence are more mastery-oriented and when encountering failures or problems in learning they maintain a positive affect, try harder and spontaneously develop better strategies for problem-solving. (Diener & Dweck 1978; Dweck & Bempechat 1983; Elliot & Dweck 1988.) Table 1 below presents the factors described above showing the connections between them.

TABLE 1 Theories of intelligence, goal preferences, confidence in intelligence or in task ability, and behaviour patterns

Type of theory	Goal preference	Confidence in Intelligence or in Task Ability	Behaviour pattern
Entity theory	Performance goal	If high confidence	Mastery-orientation
		If low confidence	Learned helplessness
Incremental theory	Learning goal	If high or low confidence	Mastery-orientation

Though the table seemingly suggests existence of clear-cut categories, the reality is different: people's beliefs about their intelligence should be understood as a continuum. People are more or less "incrementalist", may select performance goals in some situations in spite of their general preference for learning goals, and can be more or less confident in their intelligence. The model is to be used as a probabilistic model that helps to identify some typical relations between students' perception of their intelligence and learning behaviours, mastery-orientation and learned helplessness. Mastery-learning refers to study behaviour that generally is capable of constructing well-organized schemata, whereas learned helplessness leads to poor schemata construction.

In an experimental study Elliot and Dweck (1988) tested the hypothesis that different goals lead to helpless and mastery-oriented patterns. Generally the results provided support for this hypothesis. More specifically, when the value of a performance goal was highlighted and children believed they had low ability, they attributed their mistakes to a lack of ability and responded negatively to the mistakes and often gave up putting effort into overcoming mistakes even though they could have done it. When children believed their current skills were high and the performance goal was emphasized, they did not give up while confronting obstacles showing mastery-oriented behaviour, but even these "high-ability" children did not use the opportunity to improve their skills on a task where mistakes were made public. In contrast to performance goals, it appeared that when the learning goal was highlighted, children opted to increase their competence whether they perceived their skills as being low or high. Even in situations involving a public recognition of mistakes, they selected challenging tasks. Generally, these children reacted to failures with mastery-orientation and were able to develop their problem-solving strategies in a more sophisticated way.

Dweck (1986) notes that too often education aims at creating high-confidence performers and attempts to do so by programming frequent success and praise. She suspects that the situations may have been caused by the belief in positive reinforcement and secondly by misleading conclusions based on teachers' expectancies that were not the ones the original researchers (Rosenthal & Jacobson, 1968) proposed. Dweck (1986) notes that continued success on easy tasks or even difficult ones when performance is emphasized is ineffective in producing stable confidence, challenge seeking, and persistence. It is more effective to use approaches "that incorporate challenge, even failure, within a learning-oriented context and that explicitly address underlying motivational mediators" (Dweck 1986, 1046).

The meaning of students' personal learning goals has proved to be an important factor in determining the learning strategies to be used. For instance, in Nolan's (1987) study science students from three different grade levels were given questionnaires measuring their levels of task orientation, ego orientation, and work avoidance and their belief in the utility of deep processing and surface-level processing. Only task orientation was positively correlated with belief in the utility of deep processing. This type of study supports the idea of paying attention to motivational factors that for their part facilitate interest in learning.

Motivation to learn can be understood both as a general trait and as a situation-specific state. Although these two aspects are in many cases closely interrelated, it is also possible that a student that could be considered as highly motivated (in the "trait" sense) may not have motivation to learn in specific situation and *vice versa*. The situation-specific motivation, on the other hand, is linked to a goal. Brophy (1986, 5) suggests that "readers who desire a more clear separation between motives and goals might wish to reserve the term 'motivation to learn' for the motive and substitute a term such as 'mastery orientation' ... to refer to the learner's situational adoption of mastery of the content or skill as a goal."

Regarding student motivation the present study focuses on situation-specific motivation as articulated in theories constructed around goal-orientation (e.g. Ames and Archer 1988; Dweck & Henderson 1989; Dweck and Leggett 1988; Elliot & Dweck 1988). According to Dweck and Leggett (1988, 257) "the model represents an approach to motivation that it is built around goals and goal-oriented behaviour. At the same time, it represents an approach to personality in that it identifies individual differences in beliefs and values that appear to generate individual differences in behavior." Since the approach in this study is focussed on the learning of a specific topic (gases) and on learning materials (particularly video programmes), it was considered best to concentrate on situation-specific motivation. This is also supported by researchers that have - based on their empirical studies - proposed the study of motivation in a domain-specific paradigm (e.g. Young et al. 1992).

Young et al. (1992) conducted a study investigating 600 6th and 7th grade students' motivational orientation and cognitive strategy use in four academic domains. It appeared in further analyses that students' learning-focussed orientation was significantly higher in math and in science compared with English or Social Studies. However, there was also interaction with gender suggesting that girls are more likely to have learning-focussed goals in English, math, and science than boys. With respect to connections with strategies, there was a significant negative relationship between learning-focussed goal-orientation and ability-focussed goal-orientation.

Garcia and Pintrich (1992) studied college students' (n= 758) critical thinking and its relationship to motivation, learning strategies, and classroom experience. Results of the Motivated Strategies for Learning Questionnaires, administered at the beginning and at the end of a school semester, indicated that there was a positive relationship between an intrinsic goal-orientation and critical thinking (a sort of "deep" processing). However, there were differences between different domains: Intrinsic goal-orientation predicted (positive correlation) critical thinking for biology and social science students, but not for English students. Metacognitive self-regulatory strategies were positively correlated to critical thinking across the domains and at the two time points.

Ames (1992) discusses student motivation from the perspective of the achievement goal theory of motivation. She notes that different labels have been used to describe two achievement goal constructs. The labels are learning and performance goals (Dweck 1986; Dweck & Leggett 1988; Elliot & Dweck 1988), task-involvement and ego-involvement goals (e.g. Maehr & Nicholls 1980; Nicholls 1984), and mastery and performance goals (Ames & Archer 1987, 1988). Learning goals, task-involvement goals, and mastery goals are all labels for the type of goals which are characterized by the learner aiming at deeper understanding of the content to be learned. Ames (1992) notes that central to the mastery goal is a belief that effort is essential to outcomes and that this belief is the motivational force that maintains achievement-directed behaviour. Performance goals and ego-involvement goals, on the other hand, are characterized by the learner aiming at doing better than others or at achieving success with little effort. Public recognition of achievements, in particular, is important and it supports the learner's sense of self-worth, which is in close relation to his or her ability demonstrated by the achievements.

Teachers' own perception of learning and their goals also have a considerable effect on students motivation and learning. Therefore, it is important to help student teachers and teachers develop their thinking about motivation and learning and encourage them to use strategies that support mastery goal-orientation in students. Ames also points out that too often motivation is equated with quantitative changes in behaviour, such as higher achievement instead of qualitative changes in students' ways to view themselves in relation to the task at hand and how they are involved in the process of learning. Above all, enhancing motivation means supporting students' in valuing of their effort and in their commitment to effort-based strategies by designing mastery-oriented classroom structures. (Ames 1992)

Dweck and Leggett (1988, 270) compare their construct of personality and motivation to other existing ones. They identified the following constructs and interpret them as follows:

1) Schema approaches (e.g. Cantor 1981; Markus 1977, 1983). According to schema approaches people describe themselves as having certain characteristics, such as "I am talented", use these characteristics in structuring their experiences and generally are inclined to behave according to these characteristics.
2) Trait approaches (e.g. Bem & Funder 1978; Buss and Craik 1983) assume that people have traits, such as shyness or friendliness, that are typical of their personalities and are expressed in the form of coherent behavioural patterns across situations.
3) Motive approach (Atkinson 1964; McClelland 1955). According to Dweck and Leggett it "identifies classes of goals (achievement, affiliation, and power) that individuals differentially value and seek, or more specifically it postulates internal motives whose strength determines the vigor with which these classes of goals are pursued."

Dweck and Leggett (1988, 270) note that their approach, although it has many common features with these other approaches, is different in that it proposes that people may value certain characteristics even though they may not consider themselves to possess high levels of those characteristics. The approach also adds aspects regarding individuals' attributes, namely implicit theories, and goals relating to them (schema approaches); it does not support as strong behavioural consistency across situations (trait approaches), and suggests more specific analysis of goals (motive approach). The core of the model is "its depiction of the manner in which underlying personality variables can translate into dynamic motivational processes to produce major patterns of cognition, affect, and behaviour" (Dweck & Leggett 1988, 271).

TABLE 2 Percentage of subjects with each theory of intelligence selecting each achievement goal (Dweck & Leggett 1988, 263)

	Goal choice		
Theory of intelligence	Performance goal (avoid challenge)	Performance goal (seek challenge)	Learning goal (seek challenge)
Entity theory (n= 22)	50.0	31.8	18.2
Incremental theory (n=41)	9.8	29.3	60.9

According to Shuell's (1988, 277-278) definition of learning as a goal-oriented activity, learning is most likely to be successful if learners are aware of the goal (at least in a general sense) toward which they are working and have expectations that are appropriate for attaining the desired outcome. Also the theory of student motivation described above is strongly constructed around goal-orientation (e.g. Ames and Archer 1988; Dweck & Henderson 1989; Dweck and Leggett 1988; Elliot & Dweck, 1988). As Dweck and Leggett (1988, 257) themselves note "the model represents an approach to motivation that it is built around goals and goal-oriented behaviour".

It is also possible to discuss goal-orientation from the standpoint of long-term career orientation. Studies on science learning and attitudes on school science have considered the importance of career orientation in the field of science (e.g. Crocker 1990; Haladyna & Shaughnessy 1982; Raphael and Wahlstrom 1989; Simpson & Oliver 1985). There is reason to assume that those students who consider science (physics, chemistry, etc.) as their career in the future are more motivated in studying science subjects than students whose career orientation is in other fields. Goal-orientation, when linked with long-term career plans, can in a sense be considered stronger than when not linked to career plans. Therefore, in studies dealing with learning and motivation, it is important to pay attention to strongly goal-oriented students as compared with those students whose goal-orientation is weaker in terms of their career plans.

In the present study the motivational variables are treated as independent variables explaining (for their part) the learning results. It is not the intention in this study to investigate intensively the motivation to learn or to use it as a dependent variable as, for example, Brophy (1986) has proposed. However, some aspects of motivation based on Dweck and Henderson (1989) will be dealt with *per se* to provide understanding of the role of motivation in learning physics in senior high school.

2.3.2 Students' approaches to learning

Biggs (1987a, 1987b) has studied learning processes and developed the Learning Process Questionnaire (LPQ) for research and school use. A thorough review of the theoretical aspects on which the Learning Process Questionnaire in based can be found in Biggs (1987b). The manual of the questionnaire (Biggs, 1987a) also has a brief overview of the theoretical aspects, but concentrates more on how to use the questionnaire.

Based on empirical research regarding learning strategies applied in schools and at universities and other similar settings, Biggs (1987a, 1987b) ended up with a three-factor model of learning approaches, namely *the Surface*, *the Deep*, and *the Achieving* approaches. Each approach is divided into Motive and Strategy components (see table 3).

Biggs (1987a, 3) pointed out that the surface and the deep strategies describe how students deal with the actual task itself, whereas the achieving strategy describes how students organize the temporal and spatial contexts in which the task is carried out. Thus the Achieving Approach can be combined either with the Surface Approach or the deep approach. Particularly the composite approach, Deep-Achieving, has been shown to be an efficient approach to learning and is typical for many successful students. With regard to learning outcomes, the Surface Approach typically produces retention of factual details without structural relations that would connect the details and affective outcomes are feelings of dissatisfaction, boredom, or outright dislike. The Deep Approach leads to an understanding of the structural complexity of the task and to positive feelings about it. Finally, the Achieving Approach, particularly when combined with the deep, is characterized by good performance in examinations, a good academic self-concept, and feelings of satisfaction.

These learning approaches are fairly consistent orientations or learning styles, although sometimes situational factors may strongly influence them and change the orientation. Metalearning is important in applying the learning approaches: When students are well aware of their own learning processes and try actively to control them, the Deep and the Achieving Approaches are most effective. (Biggs 1987a, 4)

To get a more complete picture of student learning, it is useful to look at figure 2 which presents a general model of student learning. The model is divided into three main sections that are inter-related: presage, process and product performance. Presage consists of three elements: Personal factors, situational factors and tactics. The process section includes the three learning approaches, which lead to certain products described in the third section of the model. These outcomes are typically connected to the approaches in a systematic way so that the Deep Approach leads to a deep outcome or deep-achieving outcome and the Surface Approach leads to a surface outcome or surface-achieving outcome, with the achieving outcome lying in between. (Biggs 1987a, 5-7.)

TABLE 3 Motive and Strategy in the approaches to learning and studying (Biggs 1987a, 3)

Approach	Motive	Strategy
SA: Surface	Surface motive (SM) is to meet requirements minimally; a balancing act between failing and working more than is necessary.	Surface strategy (SS) is to limit target to bare essentials and reproduce them through rote learning.
DA: Deep	Deep motive (DP) is intrinsic interest in what is being learned; to develop competence in particular academic* subjects.	Deep strategy (DS) is to discover meaning by reading widely, inter-relating with previous relevant knowledge, etc.
AA: Achieving	Achieving motive (AM) is to enhance ego and self-esteem through competition; to obtain highest grades, whether or not material is interesting.	Achieving strategy (AS) is to organize one's time and working space; to follow up all suggested readings, schedule time, behave as 'model student'

* comment: can be other areas, as well.

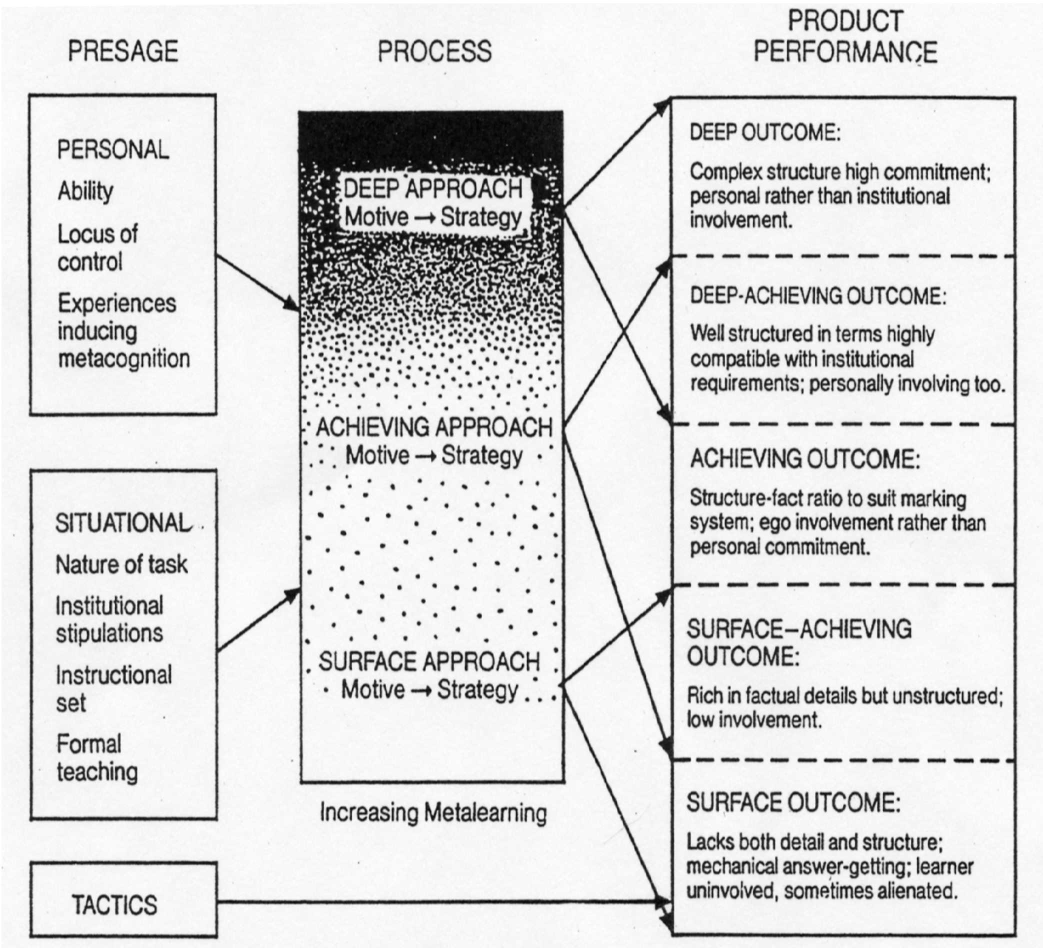


FIGURE 2 General model of student learning (Biggs 1987a, 6)

From the perspective of schema construction it seems obvious that the Surface Approach leads to schemata with poor structure, whereas the Deep Approach, particularly combined with the Achieving Approach, is capable of constructing schemata with a clear structure. Based on the model we could also assume that schemata constructed using the Deep Approach are more probably characterized by meaningfulness and positive emotional loading. The increase of metalearning when moving towards the Deep Approach is also an important feature in Biggs' model. The role of metalearning is also related to the improvement of schema construction.

Biggs (1988, 134) points out problems in regarding metacognition as an end state instead of a process. He criticizes Brown (1984) and Wagner and Sternberg (1984) for their recommendations (as interpreted by Biggs) to teach metacognitive rather than cognitive skills, noting that this is potentially misleading. Biggs (1988, 134) sees that "'metacognitive' is better used as an adverb, the point being to teach cognitive skills 'metacognitively', not to build a new 'metacognitive curriculum' ".

Biggs (1988) conducted two studies to investigate the effects of a metacognitively based intervention on students' (secondary and tertiary) motives and strategies. The results indicated that the greatest changes were seen in deep motive and achieving strategy with accompanying enhancement of academic performance. Based on these and other studies Biggs notes that student learning can be facilitated in three main ways:

1) Discouraging the Surface Approach. Certain practices may drive students into minimal involvement, leading them to adopt a surface approach. Particularly the ways students are assessed and their workload seem to be reasons for turning to a surface approach. Too low or too high workloads are not desirable and assessment should be based on methods that encourage deep learning not rote learning of fragmented details.
2) Encouraging the Deep Approach. Many techniques, such as using the teacher as a model, deriving heuristics that suit the task, are available for teachers to encourage their students' metalearning and use of a deep approach.
3) Developing the Achieving Approach. Teaching study skills can be useful provided this is done in a metacognitive context. As Biggs (1988, 136) notes, "the target is the achieving approach, with self-management of students' learning and study contexts, while alerting students towards a meaning orientation".

In this study the students' approaches to learning will be used as independent variables in explaining the learning outcomes regarding studying of gases. In addition, descriptive information on the approaches will be presented, and the factor structure obtained from the original population (Biggs 1987a, 1987b) will be compared with the factor structure obtained from the population used in the present study.

2.4 Means of influencing learning processes

This section provides an overview of means of influencing learning processes in order to give a general perspective on how schema changes can be facilitated.

Many aspects presented here were used in designing the materials used during the empirical phase of this study. Domain-specific notions regarding means to affect learning will be dealt with in chapter 4.

As Vosniadou and Brewer (1985, 19) state, "the process of learning is one of constantly relating incoming information to what is already known, and of actively testing hypotheses generated by one's current schemata". This testing of hypotheses has been viewed as a crucial part of learning and development of thinking. Its success depends heavily on how active a role children are willing to take in the process, as can be seen from many studies. For instance, D. Kuhn (1981) found that children who reflected on their own guesses improved more than children who were asked to reflect on identical guesses provided by a teacher. The power of testing hypotheses is clearly indicated in that even false "theories" or hypotheses may be of help in learning. Children who made the most progress in constructing the relation between weight and balance, temporarily held strongly to a wrong theory based on the visual symmetry of asymmetrically weighted blocks; this false theory caused children to be surprised at an unexpected success and then go on to construct a new theory that could account for these exceptions (Karmiloff-Smith & Inhelder 1975). The power of hypothesis testing where reflection on observations and experiences is used has been indicated in many studies (see e.g. Inhelder et al. 1974; Piaget 1976, 1977). More generally, problem-oriented knowledge acquisition is better than fact-oriented in developing thinking. It may also be better in activating students' spontaneous use of relevant information to solve problems (Bransford et al. 1986).

Another major mechanism in construction of new schemata is use of analogies. In learning by analogy, a restructured schema is patterned on an existing schema from a different domain with the necessary modifications. Analogies can facilitate both the spontaneous discovery of a new schema, and the explicit teaching of a new schema in new domains for adults and children (Gick & Holyoak 1980, 1983; Rumelhart & Norman 1981b; Vosniadou & Ortony 1983). The spontaneous use of analogies has proved to be very useful also in construction of a theory for individual scientists (e.g. Darden & Maull 1977; Gertner 1980). Clement and Brown (1984) analysed tutoring interviews, where analogies were used for helping students to overcome their misconceptions about physical phenomena and found that they can be useful in helping students to overcome their misconceptions. For instance, many student found it difficult to believe and understand that a "rigid" object such as a table exerts an upward force on a book resting on the table. An example of an analogy that may be helpful in this situation is having the students hold a book (or several books, if one is not enough to convince them) on the hand to realize that one has to push up to prevent the book/s falling down.

At the beginning of a study module, it is important to assess learners' pre-existing schemata (for the role of misconceptions in students' pre-existing schemata see section 3.1). This assessment is often informal and is based on what, for example, a teacher already knows about his or her students. The best way to assess the learners' existing schemata is to have them demonstrate how much and how well they know about a particular topic. According to Langer (1980) a learner's prior knowledge could have three different levels:

1) Diffused organized knowledge (lowest level). At this level learners can only report personal experience or tangential cognitive links.
2) Partially organized knowledge. At this level the learner can provide examples of a concept and define it in terms of its main characteristics.
3) Highly organized knowledge. At this level elaborations of the concept are provided to its superordinate and related concepts, and the concept is defined precisely.

Langer (1981,1984) and others, such as Hare (1982), have used and validated this measure in predicting students' recall and comprehension (For a review see Li 1987).

Prior to or during learning, appropriate schemata should be activated in order to produce the best learning results. First comes schema recognition or schema access (Cunningham 1984). If no cues are provided, one has to induce a schema. Activation of different types of schemata produces remembering of different kinds of information. For example, learners with a home buyer perspective and a burglary perspective better recalled items that were consistent with their perspective. After changing the perspectives the learners could increase their recall of those items that were inconsistent with their original perspective (C. Anderson, Pichert & Shirey 1983). This gives a clear indication of how important it is to find a proper schema to be activated depending on the objectives. From the point of view of school learning teachers should try to think which of the possible schemata to be activated would be the best to allocate students' attention to the most important aspects. Activating an inappropriate schema may have significant negative affects on learning: for example, students that were given inappropriate contextual information recalled less information than did those who were given no contextual information (Townsend 1980).

The lack of a relevant context may have a dramatic impact on learning, as Bransford and Johnson (1972) have indicated. They compared groups with or without prior exposures to reading context provided by showing a picture that helps to relate the individual parts of the story together, thus giving a basis for a meaningful interpretation. Also other researchers, such as Christopherson, Schultz and Waern (1981), have noticed that the absence of a meaningful context decreases the recall of textual information and results in differences in text processing. In another study students who related the discussed topics to a larger context, a macro-context, had a better free recall. (Bransford et al.1985). These results show that it is important to provide students with a relevant and meaningful context. Apart from the aid it brings to the memory, it may also help in understanding why certain details are important to learn. This kind of support for "meaningful motivation" may sometimes be critical to the basic question: To learn or not to learn?

Other ways of giving the learners the needed context, thus helping them form an expectation of the type of incoming information and to process the information in the intended way, include: 1) providing a set of pre-passage questions asking about the context of the reading materials (e.g. Wilhite 1983), 2) appropriate titles for the text to be learned in order to indicate the context of coming text (e.g. Kozminsky 1977), and 3) incorporation of students' existing schemata into the instructional process so that the materials are close to their experience and knowledge; for example, instruction should contain examples familiar to students to elaborate concepts rather than examples from unfamiliar contexts (e.g. Ross 1983). In addition to using familiar contexts, there may be a need to use unfamiliar contexts to facilitate transferring from known areas to unknown areas. One must first have time enough to develop good basic knowledge or schemata by using contexts. As the basis is ready, "unfamiliarity" may appear to be useful in the tuning of schemata.

Coherence of learning materials is important, as well. This is especially important in educational texts. Armbuster (1985) defines coherence as the flow of ideas in text and distinguishes two levels, local coherence and global coherence. Local coherence refers to the flow of ideas in paragraphs and sentences, whereas the global coherence indicates how well ideas are integrated across large sections of text (whole chapters of lessons). Among other important factors in determining the quality of a text are unity and audience appropriateness (see e.g. Osborn, Jones & Stein 1985). The better a text is centred around a single or unified purpose and avoids including irrelevant and distracting information that does not follow the purpose, the better unity the text has. Audience appropriateness means that a text considers the existing knowledge of the target group in terms of familiarity of topics, sentence structure, complexity of concepts, length, and vocabulary.

It is important to pay attention also to the quality of the examples used in texts and tasks in learning materials and in verbal instruction. Well-defined examples containing information that explicitly refer to a principle, which the examples try to clarify, facilitate free recall remarkably better than ill-defined examples that contain many irrelevant details or do not explicitly indicate the principle (Twohig 1982). Examples that teachers find compelling may not be useful for students; even when the example is understandable for the students, they may not be able to see the connection between the target problem and the example (Brown and Clement 1987). Brown (1992) studied the ways examples should be used to successfully produce conceptual change by interviewing 21 high school chemistry students. Based on the results he concluded that teachers must try to find examples that students can easily understand, believe and see them as analogous to target problems drawing out a misconception. If possible, the examples should be based on students' valid, intuitive conceptions that can be further developed. Examples are important also in designing learning materials, such as textbooks, video programmes, and computer programs. A careful analysis of the proposed examples can help in selecting the examples that best facilitate constructing well-structured schemata.

Pictures can be very helpful in learning materials. However, the usefulness of pictures in textbooks is not self-evident, but depends on how well they are integrated with the text. If the pictures are irrelevant or unclear in relation to the texts, pictures may even decrease comprehension. On the other hand, pictures that are well linked to the text in terms of the content and ideas expressed in the text, can substantially increase comprehension. (e.g. Levin & Lesgold 1978; Schallert 1980.) Teachers may quickly pass over the pictures used in textbooks, in which case many students may also consider them as unimportant additional material. However, if teachers point out the usefulness of the pictures by discussing them and giving assignments that include the use of pictures (naturally supposing they are relevant in the sense described above), students may also realize how pictures can be beneficial in developing understanding of the given topic. Pictures may also be useful in developing visualizable, qualitative models of physical phenomena (Brown and Clement 1987).

Physical models may also be used in construction of a new schema, particularly if there is no easily identifiable generative analogy available. Physical models may be of great help, for example, in teaching planetary mechanics in which the structure of the solar system and its operation can be presented by using a physical representation. A schema can be constructed by internalizing this physical model. After this, its implications can be further elaborated. Also visual models can be of great help in facilitating schema construction. These visual models can be drawings, photographs, diagrams, flowcharts, video animation, etc. Usually these visual models are presented with verbal or written descriptions providing information on how one should interpret the model and what things are related to it and in what way. Further discussion regarding visual models and other visual aspects will take place in chapter 4.

Use of well-defined questions and tasks can facilitate learning (see e.g. R. C. Anderson 1977; Biggs & Collis 1982; Kari 1987; Wittrock 1987). One very important aspect of questions is their cognitive level (Hougham 1992; Leiwo et al. 1987a, 1987b). For example, in a classroom discourse study conducted by Leiwo et al. (1987a, 1987b), it appeared that the cognitive level of the questions used by the teachers had a strong influence on the cognitive level of classroom discourse. Also Merrill (1985) showed that high level questions (requiring students to infer, to compare, etc.) were more efficient than low level questions (requiring only simple mental operations, such as retrieving individual facts or a list of facts) in recalling and more often led to deep processing of knowledge. Furthermore, students' performance can be significantly improved when questions adjunct to the studied science material are used (charts in this particular study) (Holliday and Benson 1991). On a more general level, by using proper questions in learning tasks, students' attention can be directed and appropriate schemata activated.

Many researchers have recognized the usefulness of cognitive maps or concept maps in facilitating learning (see e.g. Cullen 1983; Novak 1976, 1980a, 1981; Stile & Alvarez 1986). Novak (1985) noted that the original theoretical basis for the development of his style of concept mapping and the "Epistemological Vee" developed by Gowin (1981) lies in Ausubel's cognitive learning theory presented in his 'Psychology of Meaningful Verbal Learning' (1963) and 'Educational Psychology: A Cognitive View' (1968), where the focus is on the nature of meaningful learning, as contrasted with rote learning. Also other researchers, such as Cullen (1983), have emphasized how concept mapping can be used for making learning more meaningful by integrating and linking the material and concepts studied: with concept maps it is possible to visually present hierarchical relationships of concepts. Concept maps have also been used as advanced organizers, particularly in cases where the content is not well organized and the students are below average (see e.g. Gagné 1986). In these situations it is recommended that the concept maps include only concepts already familiar to the students.

Willerman and Mac Harg (1991) reviewed a number of empirical studies concerning the use of concept maps at elementary and secondary school levels, primarily in science subjects. These studies (e.g. Lehman, Custer & Kahle 1985; Mayer 1979; Novak, Gowin & Johansen 1983; Sherris 1984) and some meta-analyses (Barnes & Clauson 1975; Walberg 1984) have produced contradictory results: Some results suggest that the use of concept maps has facilitated learning, whereas some others showed no significant differences between students who used concept mapping and students who did not. Willerman and Mac Harg's (1991) own results indicated a significant difference in favour of concept mapping. Generally it seems that efficient use of concept maps requires a rather careful introduction of the method to teachers and students, and the results may only be seen in the long run, not immediately. Concept maps may also serve as a data collection method, an aspect discussed in more detail in chapter 5 and section 7.5.

Concept maps is closely connected to semantic mapping, a term often used in the field of reading instruction. Heimlich & Pittelman (1986, 3) note that "semantic mapping is a method that activates and builds on a student's prior knowledge base. This strategy provides an alternative to traditional pre-reading and vocabulary building activities typically included in basal reading series." Semantic mapping has already been used for years under varying labels, such as 'semantic webbing', 'semantic networking', or 'plot maps'.

A number of large scale programmes containing a variety of materials and activities have been designed over the last two decades for facilitating development of learning strategies and metacognition needed in successful schema construction. For instance, Mulcahy et al. (1987) developed a large scale programme "Strategies Program for Effective Learning/Thinking (SPELT). With its theoretical basis in the work of researchers, such as Deshler (Deshler et al. 1983) Dansereau (1985), and T. H. Anderson (1980), the SPELT instructional model was built to include three phases. During the first phase several strategies are directly taught to students. The main objectives of the second phase are to have students evaluate their strategy use, to facilitate modifying/extension of strategies learned at the first phase to different settings and situations and to encourage the students to be actively involved in their learning processes. At the final phase students are expected to monitor, evaluate and generate effective and efficient strategies to improve learning. Mulcahy's (1991) review of empirical studies on the SPELT program showed that students in the program gained better results compared with controls. SPELT and other similar programs (e.g. Langer 1984; Cunningham 1984) are designed to gradually develop students' metacognition and learning strategies and they require long term activities.

In summary, what is essential in facilitating schema construction is the intention to help students recognize the key elements, the structure and relations between the different things they are studying. They also need to be encouraged to control their learning processes and to develop effective and efficient learning strategies. For the present study it was important to develop learning materials (the video programme versions, the “Student Textbook”, the “Student Workbook”, learning tasks) that could facilitate construction of well-structured schemata regarding gases. A number of studies reviewed here were applied in designing these learning materials which were used during the empirical phase. However, there is reason to believe that it is the students who make the most difference. Therefore, it is probable that attempts to influence learning processes by developing learning materials and ways to use them can have only limited effects. Nevertheless, learning materials can - for their part - make a considerable difference that has relevance to instruction given in schools.

3 LEARNING PROCESSES IN SCHOOL PHYSICS

This chapter focuses on learning processes as seen from the perspective of science learning, physics in particular. Section 3.1 contains some theoretical aspects that are common to all science subjects. In section 3.2 the importance of students' attitudes towards school and physics are discussed. Section 3.3 focuses on physics, especially on research findings regarding learning about gases and related topics, such as thermodynamics and molecules. It should be noted that some fundamental aspects related to these sections have already been discussed in the previous chapter dealing with learning processes. The purpose of chapter 3 is to provide the necessary empirical and theoretical discussion of domain-specific elements needed in understanding students' learning of physics, gases in particular.

The decision to discuss these inter-related aspects in separate sections was based on two theoretical articles (Brown, Collins, & Duguid 1989; Perkins & Salomon 1989) arguing for situated cognition and context-bound cognitive skills. It seems that although there exist some general cognitive factors that explain our thinking and learning, many aspects of our conceptual knowledge are context-bound, related to the situations where the learning takes place. One indication of this is the fact that it is usually quite difficult to transfer cognitive skills to situations and settings, that differ from the ones where the skills were learned, or to apply the knowledge to new content areas. Therefore, we can assume that some aspects of science learning or of physics learning are unique and should be discussed as domain-specific matters. These general and domain-specific aspects are, of course, related to each other, but in a way reflect the nature of human information processing: we need general cognitive abilities, specific skills and strategies and prior knowledge to learn efficiently and to gain deep understanding of the things studied.

Mayer (1992) points out the importance of domain-specific knowledge, or as Mayer says using a broader expression "psychologies of subject matter". Teaching thinking has been criticized in that it happens at the expense of curriculum content. Presseisen (1988) discusses the topic based on research literature and notes that both content and thinking skills are needed. They need not to be seen as opposing each other, but rather thinking can be develop in contexts involving meaningful contents. Dumas & Caillot (1989) studied how "cognitive aids" could be used in solving physics problems. The four cognitive aids studied were goal analysis, motion analysis, event strip, and body-interaction diagram. Separate teaching of these four cognitive aids was compared with an integrated teaching approach. The results indicated that learning was more successful when the cognitive aids were an integral part of the teaching.

3.1 General aspects of physics learning

Wittrock (1985, 261-265) summarizes the main aspects of science learning studies and their theory formation in the mid 80's:

1) "We are developing an understanding of science learning that distinguishes it from learning in some other areas of study and that emphasizes the importance of accommodative learning, as well as assimilative learning.
2) Students have culturally transmitted and idiosyncratically generated models or preconceptions of science that influence science learning and teaching.
3) The ancillary and tacit knowledge involved in learning concepts and principles in science is being discovered and articulated.
4) The interaction between students' alternative structures and scientific concepts influences the understanding and meaning acquired in science classes.
5) We are beginning to develop new ways to facilitate science learning using cognitive models of teaching and instruction."

Nowadays this summary still describes the situation rather well. The following section presents some central findings about students' science learning, physics learning in particular. This review contains both older 'classic' studies and more recent studies.

One major problem in science teaching is that students' pre-instructional knowledge is often in conflict with the knowledge offered within the subject-matter domain. Studies of science learning indicate that students' preconceptions may persist even after science instruction (Driver & Easley 1978). Other terms used for preconceptions are, for example: misconceptions, world knowledge, alternative conceptions/ frameworks/ schemas, naive conceptions, and children's science. In a large longitudinal classroom study the role of students' preconceptions in learning mechanics concepts was investigated (De-Jong & Gunstone 1988). The results indicated that conceptual change was often, though not universally, achieved. Furthermore, analyses of individual students showed that the conceptual change was idiosyncratic, complex, and often unpredictable.

It is important that teachers are aware of alternative conceptions of their students to be able to help them restructure their schemata to match scientific views. Research has shown that this awareness of students' misconceptions among science teachers is not very good, though many misconceptions are recognized by them (e.g. Brouwer & Berg 1990; Kass 1990). Possible misconceptions of teacher trainees and teachers should be discussed during their teacher education and in-service training. This would also help teachers to be aware of students' misconceptions and the importance of taking them seriously in science teaching. (Gilbert 1983; Kirkwood, Carr & McChesney 1986) However, all preconceptions are not misconceptions: some of the preconceptions may be useful "anchoring concepts" that should be utilized in connecting new information to the existing cognitive structure. Only those conceptions and examples that provide the opportunity to transfer to other more difficult areas should be accepted as useable anchors.

Reif and Larkin (1991, 755) discuss cognition in scientific and everyday domains and note in their summary: "many of these difficulties [to learn science in school] arise because students do not adequately understand the goals of science, nor the kinds of cognitive processes needed to deal with this unfamiliar domain". It is also worth noting that science taught in schools differs both from real science and from everyday life, which makes the situation even more complicated. To improve the situation, both teachers and students and book authors should explicitly discuss the similarities and differences between the domains of science and everyday life. Reif and Larkin agree that "science is nothing more than a refinement of everyday thinking". More specifically they suggest that aspects of everyday life similar to those in science could be identified to refine them systematically, carefully avoiding confusions and reversions. It is also important to recognize those aspects of everyday life that cannot be readily refined, to discuss why they are deficient or inadequate in science, and to construct more proper scientific conceptions. One concrete implication of these ideas is to see that students not only learn scientific constructs, such as concept, laws, models and theories, but also become aware of the conditions under which they are valid and learn to use the terminology in a coherent way (see also e.g. Kurki-Suonio & Kurki-Suonio 1994). Finally, Reif and Larkin recommend explicit teaching of scientific metaknowledge including explicit instruction about the goals of science and the type of thinking processes useful in science. These activities could best be done in actual science courses, not separately.

To bridge the gap between students' misconceptions and scientific views, it may be of use to follow how scientific knowledge has developed through centuries. In classical mechanics, for example, one may notice how the Aristotelian view of motion gradually developed, and the modern view of motion was eventually achieved. This way of analysing traditional instructional tasks may help specify the underlying cognitive processes and structures that are necessary for the successful completion of the task. (Driver & Easley 1978; Nersessian & Resnick 1989.) This notion can be useful in designing learning materials on topics that have developed over a long period of time. A good example of this kind of topic is the gas laws, which were used in the present study. (see also section 7.4).

Recognition of anomalies in one's knowledge can be used in knowledge acquisition. This process can be described as the restructuring of a schema: As we recognize that the new information provided by experience or, for example, by the teacher, cannot be interpreted by the existing schema (= recognition of anomalies), we are "pushed" to reorganize the schema. There have been many studies concerning the recognition of anomalies in the science domain that have indicated its usefulness in acquisition of knowledge (Anderson R. C. 1977; Champagne, Klopfer & Gunstone 1982; Karmiloff-Smith & Inhelder 1975; Posner et al. 1982.) Although useful in schema reconstruction, the recognition of anomalies cannot be the only way of learning for children. Recognition of anomalies is an inevitable and essential part of actual scientific work, but as for children, it is already known what kind of theory they must eventually develop (Vosniadou & Brewer 1985). This kind of discovery learning takes far too much time to be widely used in school with children. However, as a part of instruction it is indispensable, because it may be used in teaching the formation and testing of hypotheses.

Hewson and Posner (1984, 127) note that it is typical of physics that students learn “small units of information and are provided very little explicit instruction in building up successively larger functional units”. This has to do with one of Larkin’s (1979) ideas about features that make an expert in physics, namely ‘large-scale functional units’ that enable storing, accessing and coherent use of related bits of information. According to Larkin (1979) it is also important to learn ‘condition-action units’ to become an expert in physics. This means that it is not only important to learn different actions, but also to learn *when* these actions should be carried out; that is, one should not just specify actions, but also the conditions under which those actions are to be carried out.

Larkin’s (1979) idea of ‘low-detail qualitative reasoning’ has to do with students’ ways to approach problems. They should first study a problem qualitatively before entering a more detailed quantitative level, including the mathematical equations used in solving the problem. The use of different representations, such as pictures, may be useful in these situations. Hewson and Posner (1984) note that the importance of this type of qualitative approach is supported by Clement (1977), who suggests that students should have different types of knowledge including practical knowledge, qualitative physical models and concrete mathematical models in addition to formal symbolic equations. Hewson and Posner note that in other words this means that students should be able to represent their knowledge in different ways. From the perspective of the present study this is closely connected with the development of the learning materials, particularly the “Student Textbook” and the video programme versions, where different representations are used to present the core information on the gas laws.

To better understand the process of science learning, studies have been conducted that compare experts and novices. Experts transform the surface features of the problems into a more abstract representation, which includes the scientific principles required for the successful solution of the problem (Halliday & Resnich 1974). The problem schemata of novices can be described as object-oriented, while the schemata of experts are principle-oriented. It is worth noting that novices may have the same information about the physical principles as the experts, but novices fail to link objects and concepts with physical principles because they lack the necessary relations between these elements. Experts have information relating to conditions under which the principle is applicable, and this information is associated with the principle. Further, experts' knowledge is organized hierarchically along the dimension of abstractness: this allows either 'bottom-up' or 'top-down' processing. (Champagne, Klopfer, & Gunstone 1981.)

It seems that experts' schemata are, apart from other important features, richer and more "practical" in the sense that they carry the information about application criteria with them. Suzuki (1987) has paid attention to this kind of cohesiveness of schema, which is one essential part of Gagné's (1985, 1986, 1987) schema conception, as well. Suzuki deals with different skills, such as intellectual skills and verbal skills, which can be seen as types of 'capabilities' within a schema. He identifies four conditions under which a target skill can be utilized; a learner must

3) be able to perform the skill (terminal skill)
4) know when the skill can be applied (contextual knowledge, verbal information)
3) be able to use the skill when needed (initiating internal processes, cognitive strategies)
4) choose to use the skill (positive attitude toward using the skill).

Experts and novices differ also in that experts make a qualitative analysis after the problem statement before proposing equations for the quantitative solution of the problem, whereas novices start searching for equations immediately after the problem statement. Furthermore, experts tend to have more additional formal instruction, more extensive practice in solving problems, and more extensive verbal interactions about physics. The last of these means that experts have had experiences that require either verbal interaction with others or the organization of physics information to communicate it to others. Understanding physical situations as physicists understand them requires both that the relevant schema is present, and that the features of the physical situation evoke the schema. One way to help students is then to provide them with proper background information, and to arrange situations that are deliberately modified to facilitate schema activation. (Champagne, Klopfer, & Gunstone 1981.)

In an analysis of understanding scientific concepts Reif (1985) discusses the interpretation of a concept. The following list contains the elements Reif considers to be essential in explicit teaching of a scientific concept (Reif 1985, 135):

Specification
- Specification of concept
  - Summary description
  - Informal description
  - Procedural specification
  - Applicability conditions
- Specification of concept values
  - Ingredients and symbolic expression (elements specifying type, units)
  - Possible values (and typical values)

Specification of independent variables
Basic independent variables and symbolic expression
Relevant properties of independent variables

Instantiation
Various values of independent variables and of their properties
Various symbolic representations

Error prevention
Warnings about likely errors (see the list of errors below in the text)
Discrimination between each error and correct case
Helpful symbolism

The following paragraphs provide brief descriptions of the points listed above. A Summary description refers to a compact and precise definition, typically expressed in the form of a formula. Informal descriptions are qualitative statements of the core ideas and relations expressed in summary descriptions. These informal descriptions are useful in providing links to more familiar knowledge and in recalling the concept in complex situations. A Procedural description is made by means of a step-by-step procedure specifying how to identify or exhibit the concept. Reif emphasizes that this is the most explicit and detailed specification of a concept and notes that it is also important in that it specifies what must actually be done to determine whether a concept is properly identified. These operational definitions are very important for scientific thinking and research. Applicability conditions should be included in the specification of concepts in order to avoid misinterpretations and errors. These conditions explicitly express the limits of the applicability of a concepts in various situations. (see also the ideas of Kurki-Suonio & Kurki-Suonio 1994 in section 3.3.1)

The reason for specification of concept values is to avoid errors that are rather common if the knowledge about the values is not made explicit. Value ingredients are needed in specifying a concept in a proper way. These ingredients are the elements that express the type of value and the units needed for specification. Systematic and explicit symbolic expressions are one important aid in supporting correct understanding and remembering of value ingredients of a concept. Reif (1985, 139) takes the concept acceleration as an example and suggests the following symbolic expression for it: acceleration is "(magnitude with unit of length/time^2) along (direction)", as for instance in 1.6m/sec^2 along the northern direction. Possible values of a given concept are useful in avoiding errors. For example, it is useful to know that the concept "kinetic energy" can assume all non-negative numerical values. Also knowledge about typical values is useful for making qualitative predictions and for rough estimation of correct values while solving science problems, such as in estimating acceleration of vehicles and falling objects.

Explicit specification of independent variables is important to avoid errors and ambiguities. First, one must recognize and specify the basic independent variables, which in the case of the concept acceleration are particle, time, and reference frame. One good way to facilitate proper understanding and to prevent errors and confusions is consistent use of full symbolic or verbal expressions. It is also important to know which particular properties of the independent variables are needed in a complete specification. For instance, in the case of the concept force, the basic independent variables are the particle on which the force acts and the particle by which it is exerted. Irrelevant properties of these two variables are their colour and their velocities.

Instantiation of a concept is needed to make the concept effectively usable in practice. According to Reif (1985, 142) Proper instantiation of a concept involves the ability to (1) "identify or exhibit the concept for various possible values (or relative values) of the independent variables or of their properties", and to (2) "do this in various possible symbolic representations, for example, in words, in pictures (diagrams or graphs), or formal mathematical symbolism". Error prevention includes warnings about likely errors, which are listed here (Reif 1985, 144):

Errors in specification of concept
- Gross confusions
  - Confusion with concept denoted by similar symbol
  - Confusion with concept describing different features of same situation
- Errors in specification rules
- Errors in applicability conditions

Errors in specification of values
- Errors in specifying ingredients
- Errors in possible values

Errors in specification of independent variables
- Omitted independent variables
- Wrong independent variables or properties thereof

It is also useful to make explicit discriminations between the likely errors and the correct application of the concept. A typical confusion that can be avoided by this procedure is the one between 'velocity' and 'acceleration'. Reif (1985, 146) summarizes that consistent use of clear and accurate symbolic forms can help in avoiding many errors of omission or commission in the application of concepts.

The many challenges of physics learning described in this section are part of the everyday life of physics teachers. A number of the aspects from this section were applied in writing the Teacher Manuals for participating teachers (see appendices S22 and S23). In addition, ideas presented here were used in planning the learning materials used during the empirical phase of the present study. Finally, the review in this section will be used in discussing the results.

3.2 Students' attitudes towards school and physics

Attitudes or affective factors are an important part of learning in school - including physics learning. Generally, attitudes can be understood as affective reactions (including also cognitive and psychomotor components) to different objects, situations, etc. Definitions of attitudes of this type have often been used in studying attitudes (see e.g. Kari 1973; Saari 1983). Typically the concept of attitude has been operationalized by using items such as 'I like school', 'I don't enjoy physics' or 'it is interesting to study geography'. Sometimes attitude variables such as these have been used to *directly* explain human behaviours, such as learning outcomes. This approach, however, has received criticism from researchers, such as Good, Biddle, and Brophy (1975), Bloom (1976), and Fraser (1982).

More recently, attitudes have been defined as a mental and neural state of readiness, organized through experience, exerting a directive or dynamic influence upon the individual's response to all objects and situations with which it is related; they are predispositions to respond (Zimbardo & Leippe 1991). Zimbardo & Leippe (1991) see attitude positions as a system consisting of four components, which are interrelated: affective responses, cognitions, behaviours, and behavioural intentions.

Students' attitudes towards school and physics are factors that may be used to predict learning outcomes (e.g. Kelly 1978; Napier and Riley 1985). Many researchers have treated attitudes also as dependent variables and explained attitudes by achievement and other factors (see e.g. Bloom 1976; Saari 1983). Fraser (1982, 558) noted that correlations between attitudes and achievements in science have generally been very low: He advises teachers to "attack" the problem directly, rather than attempting to enhance achievement by first changing students' attitudes to science. However, some studies regarding 'learned helplessness' suggest that the teacher should first overcome students' problems in social interaction and in the affective area, before starting to guide the student in cognitive learning (e.g. Salonen, Olkinuora, & Lehtinen 1982; see also Heckhausen 1987 and section 2.3.1). White and Tisher (1986, 893) reviewed studies dealing with students' attitudes and summarized the results in the following way: "In sum the relation between attitude and achievement is low to moderate, and is affected by variables such as age, school system and country. The details of how these variables influence the relation remain to be discovered."

Contradictions between research results may exist because of differences in the choice of variables and in the approach to the study of learning and affective factors. A quantitative approach using correlations obtained from large samples is very different from qualitative studies that emphasize unique factors and try to get a deeper understanding of individual students. Science teachers should use their eyes and ears to detect when they should emphasize affective and/or cognitive aspects in finding solutions to the problems they encounter with their students. Often these affective and cognitive factors may go hand in hand and have a reciprocal relationship. To give another perspective, Pope and Gilbert (1983) discuss the role of students' personal experience in science teaching and indicate that significant learning occurs if facts have personal relevance. They suggest that a cultural transmission approach to teaching and knowledge dominates science education. The role of students' personal experiences should be better considered in their construction of knowledge.

Attitudes towards science. Generally, younger students have more positive attitudes towards school than do older students. The same trend has been detected in students' attitudes towards science, as well (Yager & Yager 1985). Raphael and Wahlstrom (1989, 196) referred to two publications (Haladyna & Shaughnessy 1982; Simpson & Oliver 1985) and noted that "a remarkably consistent picture has begun to emerge: students, especially the younger ones, indicate generally positive attitudes towards science, boys have more favourable attitudes towards science than do girls, and most students do not want careers in science." More detailed analyses have revealed that at about grade eight boys start showing more positive attitudes towards physical sciences while girls tend to have more positive attitudes towards biology (Smail & Kelly 1984). Also Tarmo (1983) in her review of gender differences in Finnish school studies detected the same type of basic trends in the differences between boys and girls.

Raphael & Wahlstrom (1989, 196) conclude that though older students generally have less positive attitudes towards science it should not be seen as an indication of science teachers' failure at the higher levels, since "we can expect older students to be more critical of the science taught in school, but have little reason to assume that their attitudes towards science in general are less favourable". Nevertheless, teaching physics in senior high school is a challenge to physics teachers.

Slavin (1991) noted that students of higher socio-economic status (SES) have better school achievements and are better supported by their parents in terms of school achievement than students with lower SES. Based on a larger national sample of students in the United States, higher education of parents was related to better achievements in physics: Achievement was significantly higher for children of college graduates than high school dropouts (Gorman & Yu 1990).

Girls tend to be academically better in school than boys, particularly in the elementary and high school (Mussen, et al. 1990). However, the results of the Second International Science Study (SISS) that was conducted during the 1980's (IAE, 1988) indicate that boys are performing better in science subjects (see e.g. Crocker 1990, 39,40). Girls' attitudes towards school tend to be more positive than those of boys, but boys seem to have more positive attitudes towards school science experiences and towards science as a career (Crocker 1990, 44-50).

In his article about the relationship of various background variables and science attitudes to science process skills, German (1994) presented a useful summary of relationships among certain variables obtained in recent studies. The following table contains selections from this summary presenting relationships that are of interest in the present study. Parents' education is a background variable of a general nature which does not specify the processes that actually take place at home. However, there is reason to believe that parent with higher education generally value education more than parents with lower education (e.g. German, 1994, 758-759).

TABLE 4 Relationships between science achievements and other variables selected from a summary table by German (1994, 752, 755)

Relationship between science achievement and ...	r	Reported in
SES[1] (income)	.30	Fleming & Malone (1983)
SES[1] (income) (high school)	.30	Fleming & Malone (1983)
Parent's education (13-year-olds)	.20	Borger & Walberg (1983)
Parent's education (17-year-olds)	.30	Borger & Walberg (1983)
SES composite	.40	Staver & Walber (1986)
Home activities	.30	Staver & Walber (1986)
Parents' interest	.24	Staver & Walber (1986)
Homework	.20	Staver & Walber (1986)
Parents' education	.40	Schibeci & Riley (1986)
Science attitude (WASP) x report grade	.20	Wareing (1990)
Science attitude (NAEP[2]) x 13-year-old science achievement (NAEP[2])	.20	Borger & Walberg (1983)
Science attitude (NAEP[2]) x 17-year-old science achievement (NAEP[2])	.30	Borger & Walberg (1983)
Science attitude (ATSSA[3]) x SRA-Science	.20	German (1988)
Science attitude (ATSSA[3]) x semester grade	.40	German (1988)

1 SES = Socioeconomic Status
2 NAEP =National Assessment of Educational Progress
3 ATTSSA= Attitude Toward Science in School Assessment

Leung (1993) studied children's attitudes toward schoolwork and their perception of parental behaviours supporting schoolwork. 140 students from 4th through 8th grade classes participated in the study. School attainment value, which was measured by asking students to indicate how important it was for them to do well in school, was the single best predictor of school achievement (students own estimation). Parents' interest in their children's school work and their positive sense of good school performance were positively correlated with their children's attitudes toward school.

Rennie and Punch (1991) developed and tested a model regarding students' science-related affect. The affect was a compiled term and measure that was based on students' attitudes toward, interest in, and perceptions of science at school. According to the model, students' enjoyment of and enthusiasm for science are explained by their perceptions of their past performances in science, their expected future performance in science, and the perceived usefulness of science in school. The LISREL-based path analysis was used with data on 8th grade students and it gave support to the developed model. Further regression analysis indicated that affect is more strongly related to previous than subsequent achievement and it also showed that a considerable amount of the common variance of achievement can be explained by students' perceptions of their competence in science.

Piburn and Baker (1993) conducted a study of students' attitudes toward science based on student interview. The general approach of the study was qualitative. The results showed that students enjoyed the social aspects of science activities and they also wished that their opinions would be taken more seriously by the teachers. One difficulty many students felt was the increasing abstraction of science content. Based on the interviews Piburn and Baker (1993) recommended avoiding topics that are too advanced or theoretical. This recommendation, however, as it is presented directly and based only on student interview, seems too simple and premature. As, for example, Kurki-Suonio & Kurki-Suonio (1994) have pointed out, the theoretical aspects are an essential part of science instruction; the problem is usually not the theory as such, but the way it is treated and how well it is connected to the existing knowledge of students and to the observations obtained through experiments. Therefore, these types of direct conclusions about the role of theory in science instruction, without specifying what is meant by theory and without considering other aspects of science instruction, do not seem very fruitful, even though the knowledge about students' attitudes and experiences must always be taken very seriously.

Simonson and Mausak (1996, 994) provide a good summary on the role of attitudes in education: "It would be inappropriate to assume that the development of new attitude positions will directly and predictably influence educational behaviours. Rather, attitudes are one component of a system that predicts behaviours. For those interested in predicting behavior from attitudes, the literature provides guidelines. First, single general attitudes are not likely to predict general actions. At the very least, very specific attitudes and very specific behaviors should be identified for correlation. Second, general attitudes are probably related to a collection, an aggregate of behaviors. Finally, other variables such as motivation, intention, and personality traits are intervening forces that should be considered in the attitude-behavior formula."

In the present study, attitudes (including both general and specific attitude items) were used as independent variables explaining learning outcomes regarding studying of gases. Changes in attitudes towards studying gases were also studied during the experimental phase of the study. Some descriptive information on attitudes was presented, as well. Guidelines for measuring attitudes by Henerson et al. (1987) provided useful information for planning the attitude items. However, since the role of attitudes was not at the core of the study, not all aspects of the guidelines were applied. Finally, it is important to note that attitudes - in real life - should be considered as an integral part of learning processes (see e.g. section 2.1 about schema), whereas here, for the sake of empirical design, they will be treated as independent or dependent variables in analyses, an aspect further commented on in the discussion chapter.

3.3 Knowledge structures and students' learning about gases

This section deals with a central question in all learning: what is knowledge and how is it structured. The first sub-section focuses on knowledge structures and the second discusses knowledge structures related to learning about gases, a central topic in the present study. This section, especially the second sub-section, will provide the necessary background for comparing the results of the present study.

3.3.1 What is knowledge and what are knowledge structures?

The term knowledge has a variety of dimensions that characterize this central concept of the human mind and its brain prints in the numerous fields of human culture. According to the American Heritage Dictionary of the English Language (1992) knowledge refers to 1) The state or fact of knowing, 2) familiarity, awareness, or understanding gained through experience or study, 3) the sum or range of what has been perceived, discovered, or learned, 4) learning; erudition: teachers of great knowledge, 5) specific information about something, or 6) carnal knowledge. Synonyms for knowledge are information, learning, erudition, lore, and scholarship. These nouns refer to what is known, as having been acquired through study or experience. Knowledge is the broadest concept; it includes facts and ideas, understanding, and the totality of what is known, whereas information is usually construed as being narrower in scope than knowledge; it often implies a collection of facts and data (the American Heritage Dictionary of the English Language 1992.)

One traditional philosophical and partly also psychological question has been that of the locus of knowledge: does knowledge exist only in a human mind or is there knowledge also outside the human mind? From a practical viewpoint, we can say that school learning involves both of these. The curriculum and learning materials represent the knowledge outside a human mind (naturally as a result of using the human mind) and each learner has his or her knowledge, which hopefully has some overlap with the preceding. The other important aspect is the nature of knowledge, which refers to the different types of knowledge. One basic distinction is between procedural knowledge (or algorithmic knowledge) and propositional knowledge (or declarative knowledge or semantic knowledge). Shuell (1985) notes that this distinction was already present in Ryle's (1949) distinction between "knowing what" and "knowing how". Other researchers have proposed a variety of other distinctions, some of which are presented in this sub-section and some elsewhere in this report. (Shuell 1985.)

Pines (1985) emphasizes the meaning of relations in analysing knowledge structures. He notes that "concepts are packages of meaning; they capture regularities (similarities and differences), patterns, or relationships among objects, events, and other concepts" (Pines 1985, 108). Each concept we have adopted into our cognitive structure has a multitude of relations to other concepts, and this network of relations is essential in our understanding of a particular concept. Its is also important to note that the meaning of a given concept varies from context to context. A concept is a locus of meaning in Pines' analysis. Pines points out that in defining concepts as typically carried out in science one can artificially restrict the meaning, but essentially concepts are context-dependent and thus have multiple meanings. This is why concepts should rather be treated as parts of semantic networks.

West et al. (1985) have concentrated on cognitive structures constructed during school learning with specific aims in mind. Since this study is also focussed on school learning, their discussion is relevant for developing a theoretical basis for the empirical phase of this study. West et al. (1985) note that cognitive structures are so extensive and complicated that it is possible to describe only part of them. Typically the descriptions have either been rich in detail with little emphasis on the structure (e.g. Lindsay & Norman 1977) or vice versa (e.g. Novak 1980b). In other words one could say that cognitive structure consists of two components, knowledge bits and their organization. Concept learning according to West et al. (1985) is more than just mastering the formal definition of a concept that has a certain label. It is understanding the concept and this also involves the other bits of knowledge that a person relates to the concept at hand. This is why cognitive structures are highly idiosyncratic, even though the public knowledge consisting of formal definitions and other shared components is the basis of most of the individual cognitive structures.

West et al. (1985) use the term "node", which refers to a knowledge bit of indefinite size in a person's memory. "Node compression" in their ideas means that, for example, while interpreting incoming information we can concentrate on a certain node under which we have "compressed" all the other bits of knowledge we have linked with that particular node. In this way all the nodes we carry in our memory have in a sense a more complex cognitive structure compressed under them. While interpreting the new input we use that part of the compressed knowledge bits that is needed in making an interpretation of the input. (West et al. 1985, 33-35.)

Based on Gagné and White (1978), who proposed four types of memory structures, propositions, images, episodes, and intellectual skills, West et al. (1985) use three types of knowledge bits as nodes (note the similarities with the term memory structure), propositions, algorithms (or skills) and images. In addition, they have used examples, which can be seen as a special type of proposition, as separate nodes. In their studies they have described students' cognitive structures constructed during courses, taking the course itself as a starting point. The following four types of "public knowledge" were extracted from the syllabus, lectures, examinations, and handouts to students: 1) propositional statements, 2) algorithms (often called problems in science), 3) examples (e.g. glycine is an example of an amino acid), 4) images (visual representations presented as part of the course).

In their analyses West et al. often focussed only on a limited number of main propositions depending on the specificity they aimed at. The cognitive structure representation itself was based on a propositional skeleton, where algorithms and examples were added at appropriate points. Students were first given group tests and then an individual interview consisting of free definition-type questions (e.g. what is an amino acid) and typical science problems (skills questions). Students were also asked to inform which (if any) of the skills questions were closely related to each of the free definition questions. The inter-relations between the prepositions identified by the students served as a basis for compiling the structure of the propositional skeleton. Students were asked to rate all pair relationships between propositions on a 0 to 3 scale that was later simplified to a 0 to 1 scale. Using a simple algorithm this matrix was transformed into an hierarchical representation.

In their further analyses of the propositional skeletons obtained from students, West et al. extracted five quantitative indexes of dimensions of cognitive structures:
1) integration of propositional knowledge,
2) differentiation of propositional knowledge,
3) differentiation of skills/examples knowledge,
4) articulated propositional relatedness, and
5) depth of propositional knowledge.

Integration of propositional knowledge, which describes the degree to which ideas are inter-related, could have been estimated simply by counting the number of links students identified between the propositions. However, the problem was that some students could have identified links that are not so important or even irrelevant and thus the number of existing links as such is not a good measure. Instead, West et al. generated an ideal propositional skeleton for each study. This was done by the researchers who attended all the lectures and went through all the materials presented to students. The ideal skeletons were then given to lecturers to check the validity of the skeletons. This way the skeleton provided the ideal number of links between the propositions and was then used as the denominator in a ratio index.

Differentiation is estimated separately for propositional knowledge and for skills/examples knowledge. Generally, differentiation means that more specific ideas are subsumed under more general ideas. Thus the propositions have a hierarchical organization, which is used for obtaining the index for the differentiation. The ideal propositional skeleton again provides the basis for determining the hierarchical order of the propositions. Then the propositions at the highest levels (which are linked to other additional propositions) are given the highest ranks. Finally, the index for differentiation of propositional knowledge is obtained by computing Spearman's correlation between the two ranks for each proposition.

Skills and examples are supposed to be linked with particular propositions so that a well-differentiated cognitive structure has each skill and example linked to its particular preposition. The 'index for differentiation of skills/ examples knowledge' is calculated as follows: C + 0.5A - I, where C is the number of skills and examples linked to its particular preposition, A is the number of skills and examples linked to an appropriate (but more general or more specific) preposition, and I is the number of skills and examples linked to inappropriate prepositions. Negative scores in the numerator are given the value of zero.

Articulated propositional relatedness indicates how well students can articulate and give a reason for the links they identified between different propositions. Its index is obtained by calculating the proportion of validly (validity is judged by the researchers) articulated links over the total number of links presented on the student's map.

Depth of propositional knowledge was determined by using the average number of correct, relevant (on the basis of public knowledge) propositions (per main proposition) the student produced in the interview.

White (1985, 51-52) notes that many of the techniques used for exploring cognitive structures produce too much information to be used in studies where cognitive structure is used as a dependent variable, and therefore they must be reduced to sets of scores trying to determine an optimal number of dimensions in order to sustain the richness of the original data without drowning in it. This is what will be attempted in the present study, as well. White (1985, 54-57) himself proposed a set of nine dimensions to describe cognitive structures:

Extent. Some know more, others less. *Precision.* Some people can, for example, more precisely define a concept and describe it. *Internal consistency.* The elements of a particular subject area can have contradictions between each other or they can be consistent, for example, while learning new things the learner may have difficulty in relating the new information to the knowledge he or she already has due to the contradictions that must be solved before an internally consistent cognitive structure can be constructed. *Accord with reality* or generally accepted truth. A person may have extensive, precise and internally consistent knowledge about a given topic and yet it may not be in accord with reality. *Variety of types of element.* Some people may possess only verbal propositions regarding a particular topic while others also have skills and episodes related to the topic. *Variety of types of topics.* This could be relevant, for instance, in comparing students who are experts in a narrow field to students with a broad general knowledge without possessing depth in any particular field. *Shape.* The form of organization of cognitive structure. *Ratio of internal to external associations.* Internal associations are links between elements that are obviously part of the subject matter, whereas external associations are links that relate the subject matter to other elements outside the subject matter. *Availability of knowledge*. The ease with which the stored elements can be recalled.

Kurki-Suonio & Kurki-Suonio (1994) strongly criticize physics teachers for using mathematical equations in the wrong way, which they call "equation disease". This equation decease means that physics is almost entirely taught by writing down equations without paying attention to the qualitative aspects and without linking the equations to measurable quantities and observable natural laws, a problem recognized also by other researchers (e.g. Tsuma, 1983). The concepts used in physics have hierarchical levels that should be recognized and students should receive help in linking these different levels with each other to produce a coherent understanding of the physical phenomenon to be learned. The following figure presents the hierarchy of physical concept formation.

More generally, there are three hierarchic levels in physics concepts (Kurki-Suonio & Kurki-Suonio 1991, 24):

1) Qualitative knowledge, which describes phenomena verbally,
2) Quantitative presentation, where quantities and laws are used, and
3) Quantitative explanation, which is based on theories and theoretical models.

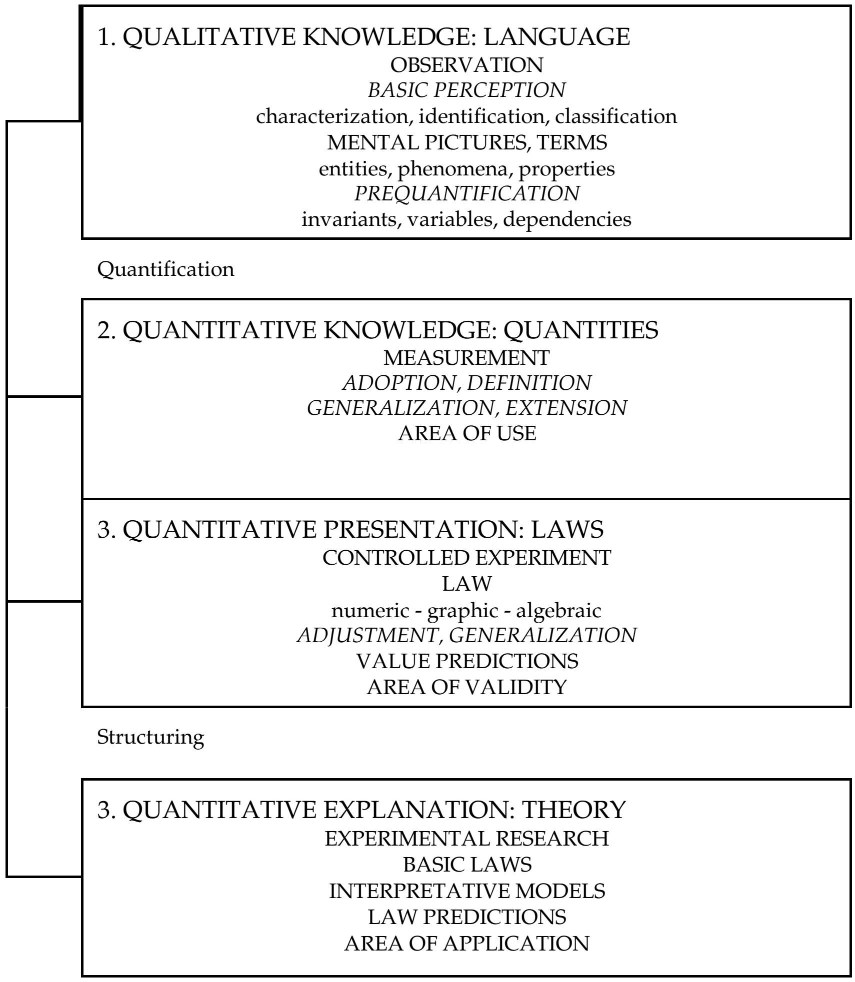


FIGURE 3 Hierarchical levels of physics concepts (Kurki-Suonio & Kurki-Suonio, 1994, 159)

Kurki-Suonio & Kurki-Suonio (1988, 1994) emphasize the importance of an experimental approach in physics teaching which includes gradual movement from observations to theories. They note that students should learn the meaning of both directions in this continuum: science includes both inductive and deductive processes. They also pay attention to the fact that not all the contents in physics can be taught using the experimental approach. Many phenomena and the related experiments are far too complex and difficult to be thoroughly discussed and conducted at school. A large portion of physics teaching necessarily describes experiments in a simplified and incomplete way.

Given these aspects, one could propose the use of properly designed video programmes as one supportive solution that provides opportunities for students to develop their understanding of how certain important experiments are conducted and how they have improved our understanding of certain physical phenomena.

3.3.2 Knowledge structures of gases

The studying of the gas laws is a multi-variable learning situation, which requires consideration of several quantities at the same time. Typically these quantities are volume, temperature, and pressure. The system is assumed to be a closed one so that it is possible to keep one quantity constant and study the systematic changes in the other two quantities. These processes include an "isothermal" process, where temperature is kept constant, an "isobaric" process, where pressure is kept constant and an "isochoric" process where volume is kept constant. In a more complicated situation also the amount of a gas (the number of moles) is taken into consideration. The ideal gas is assumed in the basic equations of the gas laws. For real gases the equations are more complicated. Particularly at low temperatures and under high pressures the behaviour of real gases differs considerably from that of the ideal gas. The kinetic theory of gases explains why gases behave the way they do. This theory can be presented both qualitatively and quantitatively. In high school courses the gas laws do not usually cover the behaviour of real gases and often the kinetic theory of gases is discussed qualitatively, supplemented perhaps with some basic mathematical models regarding the movement of molecules. These topics, apart from the quantitative aspects of the kinetic theory, are parts of the minicourse "The behaviour of gases and the gas laws" used in the empirical phase of the present study.

This section deals with learning about gases based on studies regarding junior and senior high school level students. Some studies have discussed the basic quantities of pressure and temperature (crucial quantities in understanding the gas laws) and the observable behaviour of gases regarding, for example, changes in a gas in a container when the volume is changed using a piston. This has to do with the gas laws (Boyle's law, Charles' law etc.). Other studies have dealt with students' knowledge concerning atoms and molecules, a topic closely connected with the kinetic theory of gases.

Tiberghien (1985) summarizes results of studies regarding junior high school pupils' understanding of temperature and heat stating that students often have difficulties to understand temperature correctly (see also Ahtee 1994a). It is typical that pupils think it is the substance (or material) that primarily determines the temperature and possibly the temperature is also related to the surroundings. Tiberghien (1985, 82) saw the following implications:

1) Sometimes pupils do not recognize that the same object can have different temperatures.
2) They reason in terms of substance and case by case, i.e. according to the experimental situation; they do not establish a systematic causal link between the heating of a substance and the fact that its temperature increases.

3) They do not recognize that several objects in contact (with only one thermostat) move towards the same temperature. As the concept of temperature is unclear for many pupils they have later difficulties in understanding heat, for example, when learning about conduction of heat and insulation. Tiberghien's proposition is to help students to pay attention to the interaction between objects until they learn that the temperature of an object depends necessarily on its surroundings.

Taber (2000) discusses the problems in teaching about heat and temperature and points out that it is important to find an optimum level of simplification in teaching about heat and temperature.

Séré (1985) presents results of studies dealing with pupils' conceptions about matter in the gaseous state. These studies have to do with the basic concepts needed in describing the state of a gas: quantity, volume, mass, pressure and temperature. Since these concepts are crucial in understanding the gas laws, a central topic of the present study, many of the main results will be summarized based on Séré's presentation:

a) *Variation in volume of a closed container at room temperature*. (Sample of 11-12 year old children). The nozzle of a syringe was blocked and the position of the piston was changed and the children were asked whether the amount of air was more, less or the same as in the previous position. Results: Before teaching only half of the children said the amount of air would remain the same. The number of correct answers increased when they were allowed to feel the sensation it produced on their hands, or to observe coloured gas inside a syringe. Children with correct answers usually suggested either of the following reasons:
   1) Nothing gets in, nothing gets out. This is similar to the 'idea of identity' after Piaget.
   2) If the piston is allowed to move backwards, it will come back to its original place again. This idea ('reversibility' after Piaget) was used less than the idea of identity. Children with incorrect answers (the quantity of air is not conserved) confused volume with quantity.
b) *Variation in temperature*. (Sample of 11-12 year old children). Do children understand variations in the temperature of air, a gas or a vacuum? This has to do with ambient temperature, which is actually the ambient temperature of air. Results: Before teaching, about one third of the children thought that air cannot be heated, and about two thirds thought that gas cannot be heated. When questioned some children explained that heated air is transformed into 'something else', like carbon dioxide, the majority of children explained that air becomes 'hotter' without any changes in its nature. Doing experiments where air is heated and commenting on them was enough for most of the children to learn that air can have different temperatures. Almost all children indicated that the temperature in an empty container (a vacuum) would not change even when heated. Children were also asked if the mass of air in a closed container increases when heated. Before teaching two thirds of the children gave a correct answer. However, many children had difficulties in

understanding that the quantity of air and its mass are conserved when it undergoes changes. With temperature constant they have few difficulties, but changes in the temperature seem to confuse them.

c) *Children's interpretations about forces exerted by gases/compressed air*. (Samples of 12-16 year old children). Results of children's interviews suggest that they have difficulties in understanding that gases exert forces irrespective of their state of pressure. Many children hold the following beliefs about gases:
   1) they exert forces only when they are set in motion, or
   2) if they undergo a force, a push, or if they are heated, indicating that in their mind, an external cause is necessary for gas to exert forces, or
   3) that gases exert forces in one direction only. The third belief makes it difficult for children to understand that gases exert a force in all directions. A partial explanation of this difficulty is that many experiments where air (or another gas) is compressed are such that the movement and the resultant force go in the same direction, and this may lead children to the wrong conclusions. For example, we can have a piston of a syringe pushed when a finger is blocking the nozzle. When the finger is removed from the nozzle, air flows to the same direction as the piston was pushed. After the state of equilibrium is reached, children do not often realize that pressure still exists.

d) *Notion of pressure in relation to temperature*. Transformations at constant temperatures are not difficult for children aged 12-15, but transformations at variable temperature cause them problems due to the number of factors they have to consider simultaneously. Séré notes that it is hard for pupils to distinguish between the phases of equilibrium and the transient period of disequilibrium and realize that at equilibrium the pressure inside and outside would be the same.

The overall implication for teaching about air and pressure would be "to first study air in movement and the forces it exerts, then study motionless air, its characteristic parameters and the forces it exerts as well" (Séré 1985, 123). Another implication is that children have to reason more with interactions between two or several systems (e.g. pressure and temperature) than with one quantity of air. Children should be taught that the comparisons with 'outside' are needed in interpreting what happens 'inside' a container.

De Berg and Treagust (1993) emphasize the use of a qualitative approach in developing students' understanding of the gas laws. (see also Niaz and Robinson 1992) According to their study, teachers do not often deal with the qualitative relationships in their teaching. Yet, the qualitative approach must usually be considered as a starting point on which the more quantitative approaches can be built. More generally, mathematics and science curricula are based on the idea of presenting information in various symbolic systems that help students better understand the subject matter than of using only one or few symbolic systems (see also Haapasalo 1991, 1994).

Shavelson et al. (1988) conducted a study of translation among symbolic representations in problem-solving dealing with the gas laws. The problems were presented using different symbolic representations (words, diagrams, tables, graphs and numbers). Students' mental representations and the accuracy of their solutions were studied. The required responses were either qualitative or quantitative (numerical). Subjects were 22 high school students. The results showed that the representations students used in solving the problems depended more on the type of the required response (qualitative vs. quantitative) than on the form of symbolic representation used in presenting the problem. In their concluding comments Shavelson et al.(1988) noted that if students are expected to use the same type of response, such as numerical, regardless of the symbolic representations used in presenting the problems, the use of multiple symbolic representations may have only limited benefit. Students should be required to use a variety of different representation forms in their problem solutions. The ideas presented here were applied in designing the "Student Textbook" and the video programme used in the present study: a number of different presentation forms – including qualitative and quantitative – were used in the materials. However, it should be noted that the way in which the concept of temperature was used in the learning materials represents a rather simplictic approach that links the temperature with the kinetic energy. For example, Lavonen & Koponen (2002) present a more sophisticated way to build links between perceptions, experimental laws and structured theory in learning about temperature.

Nussbaum (1985) refers to the slow refinement of the theoretical considerations regarding the particulate nature of matter in the course of history, and states how it shows the difficulty of changing children's misconceptions about the nature of matter. Nussbaum reviewed four studies investigating students' conceptions about the particulate nature of gas. The core aspects will be summarized here using Nussbaum's review as a basis. Students' explanations regarding the behaviour of gases were based on the particle model. Novick and Nussbaum (1978) interviewed 8th grade pupils about the extent to which they could use some aspects of the particle model to explain simple physical phenomena of gases. The students had taken a course dealing with the particulate model, or the kinetic theory of gases. The main results were:

1) Aspect 1: *Gas is composed of invisible particles*. 64% of the pupils spontaneously said that air is made up of particles, and 78% of them chose the correct diagram from diagrams representing the molecular nature of air.
2) Aspect 2: *Gas particles are evenly scattered in any enclosed space*. One sixth of the pupils, who supported a particle representation in the first two tasks, suggested that particles are not evenly scattered in an enclosed container, but that they are located in some part of a confined space. According to Novick and Nussbaum this response reflects some pupils' need to retain some sense of continuity in the structure of air.
3) Aspect 3: *There is empty space between the particles in gas*. Only about 45% of the particulate pupils (35% of the whole sample) firmly indicated there is empty space between the particles. 16% were unsure about the nature of the vacuum and suggested empty space only after being pressed. Pupils who did not understand the existence of empty space offered a variety of ideas of

what there is between the particles, such as 'dust and other particles' and 'unknown vapours'.

4) Aspect 4: *Particles in gas are in intrinsic motion*. Only about 50% of particulate students (about 40% of the sample) noted that gas particles have intrinsic motion. Many of them did not show understanding that the ability of gases to fill the space is due to the intrinsic motion of the particles.
5) Aspect 5: *The forming of a new substance from two different gaseous substances is pictured as the joining together of different kinds of particles*. Only 50% of the particulate students (about 40% of the whole sample) suggested that the white substance (ammonium chloride) was a compound made up of a combination of different particles. Often the explanation was received only after specifically asking about the nature of the white substance.

One explanation for students' difficulties in applying the ideas of the kinetic theory is that they have a resisting alternative model where matter is conceived as basically continuous and static, which is based on one's sensory perception of matter. Although most students knew that matter is made up of particles, many other aspects of the Kinetic theory were unclear to them.

A cross-age study of changes in students' conceptions concerning the particulate nature of matter was conducted by Novick and Nussbaum (1981) using a paper-and-pencil test based on the same phenomena described above. Generally, the number of students applying the ideas of kinetic theory increased with age. However, in several tasks there was no significant progress over time. As in the previous study, the majority understood that matter is made up of particles, but many failed to show understanding of the idea of empty space between the particles and about the intrinsic motion of the particles. Cosgrove and Osborne (1981) emphasize teaching of the particle model in such a way that it would be more throughly understood and particularly that it would be more related to their elementary ideas of physical change, and the relationship of these should have connections to children's everyday experiences.

The results of a study (Brook, Briggs, & Driver 1984) regarding 15 year old students' understanding of some aspects of the particulate nature of matter and the results of a study by Nussbaum and Novick (1982) on conceptual change in individual students both confirm the "trend" seen in the previous studies: It is often difficult to have students replace their alternative concepts with the desired scientific concepts. Nussbaum (1985) presented a way to analyse students' difficulties in understanding the kinetic theory, which concentrates on the structure of knowledge in this area. Concept maps or networks of concepts were utilized in these analyses. One of these concept maps seemed very useful for this present study (see figure 4).

More recent studies have also shown how frequently even grade 12 students have misconceptions about fundamental characteristics of atoms and molecules (e.g. Erätuuli 1994; Griffiths and Preston 1992). Erätuuli (1994) noted that senior high school physics students had difficulties in explaining for instance, what temperature is or why people blow on a hot drink to cool it, rather using the kinetic theory of gases. The results were worse among grade 12 students (16% correct in response to the hot drink question) than among grade 10 students (3% correct) who had studied the kinetic theory that year.

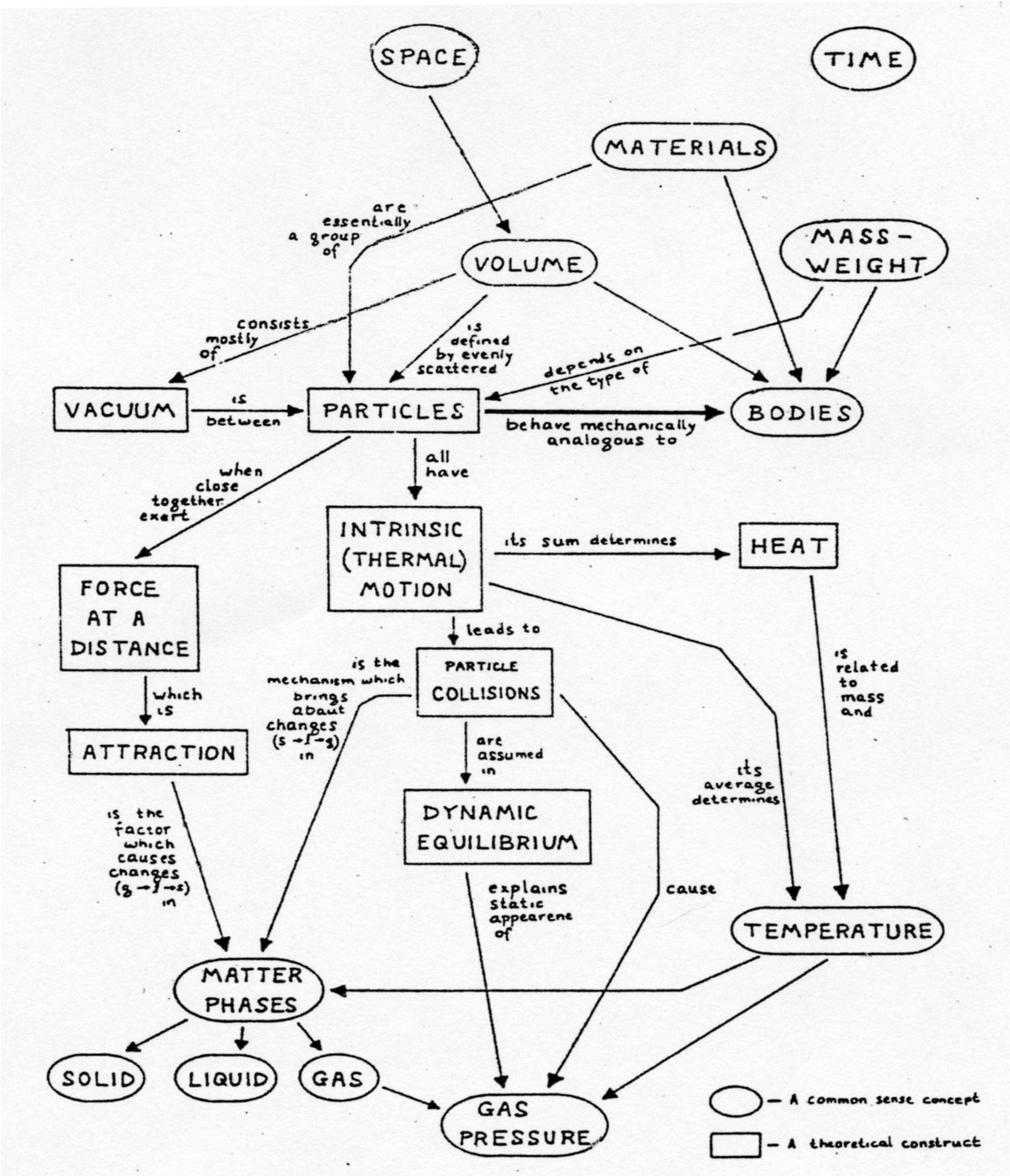


FIGURE 4 A combined network of common-sense concepts and some theoretical constructs of the particle-kinetic theory (Nussbaum, 1985, 139)

Griffiths and Preston (1992) identified 52 misconceptions in grade 12 students' answers to interview questions, and noted that some misconceptions were parallel with the historical development of scientific concepts. Similarities between students' learning of scientific concepts and the historical development of science have been noted by a number of other researchers as well (e.g. Griffiths & Preston 1989; McCloskey 1983b; Nussbaum 1983). Mas et al. (1987)

note that this idea is based on the hypothesis of genetic epistemology by Piaget (e.g. Piaget 1972). Nussbaum (1983) makes a critical comment by noting that although the existence of similarities has been widely accepted, little is known about how exactly these similarities are beneficial in terms of changing students' conceptions. It is also the case that the history of science itself is complex in the sense that it includes a variety of different conceptions of physical phenomena among scientists who lived at the same period of time and there are also differing conceptions inside the philosophy of science of how to interpret the history of science in terms of how science develops (Nussbaum 1983).

As opposed to proceeding in the order of historical development, de Berg and Treagust (1993) suggest teachers should more often use complex-to-simple knowledge structures. Their line of thought is based on Reif's (1983) notion that the pattern of association is more easily established down (complex-to-simple) rather than up (simple-to-complex) the hierarchy. They do note that this does not exclude also using simple-to-complex sequences in instruction. With regard to presenting the gas laws this means they should be presented by starting from more general representations, such as the combined gas law. Then one can demonstrate how it reduces to more specific gas laws when individual members of the equation are set to constant value. On the other hand, some researchers have proposed proceeding in the order of the history of science (see the preceding paragraph). If this line of thought is followed, it would be beneficial to present the gas laws in the order they were detected. Given the benefit of having an understanding of the historical development of the gas laws and the fact that using simple-to-complex sequence does not prevent using complex-to-simple sequences, it seems reasonable to select the historical presentation order together with the complex-to-simple order.

Novick and Nussbaum have proposed a strategy to overcome students' problems in understanding the nature of matter (Nussbaum, 1985, 143-144). The strategy has two basic assumptions: First, there must be a conceptual conflict between a person's previous conception and contradicting evidence, 'a discrepant event'. Secondly, students must be helped to expose and articulate openly their preconceptions. This helps them to become aware of their alternative conceptions. After this, students are gradually led to realize the existence of scientific explanations by proper experimentation and questioning (Nussbaum & Novick 1981).

Rozier and Viennot (1991) studied students' reasoning in thermodynamics, which involves multi-variable problems. These variables can be linked, at thermodynamic equilibrium, by certain relationships, for example, $pV=nRT$ for the ideal gas. While changes take place, one often has to consider several variables changing simultaneously under the constraint of one or several relationships. Research beginning from early studies by Piaget and Inhelder have shown how difficult multi-variable problems are for children, and even for graduate students. After careful analyses of students' reasoning, Rozier and Viennot came up with two important conclusions regarding the teaching of reasoning in science at any level:

1) One has to be *very careful about the degree of 'explanation' expected, and to specify what cannot be accounted for in the frame of the proposed description*. Rozier and Viennot gave some examples of explanations including necessary comments on the limits of the explanations: "Gases can change their volume to a large extent, but (without the beginning of a kinetic theory) we cannot explain why they resist compression [already] before molecules are in contact". "Solids expand when heated (or contract when cooled), but we cannot (yet) explain why. Knowing that thermal motion increases (or decreases) in such a case, it is not enough to explain why this makes the solid expand. Indeed, the particles might vibrate more intensely, and stay around the same place without drifting".

2) A second possibility is to *use 'soft' explanations, but avoid careless extension of such explanations to other cases*. Examples: An explanation that "at high altitude, there are fewer molecules, therefore pressure is lower" requires the addition: "This reasoning works only if molecules have (more or less) the same velocity in the two compared gases". "When a tyre is heated up, it becomes harder because the molecules have a larger mean speed" requires the addition "This reasoning works only if the same number of molecules is still in the same volume". This type of "harder qualitative reasoning" is more demanding, but it makes the reasoning and working with a variety of phenomena more consistent and helps in preventing possible undesired consequences of reasoning.

Students' difficulties in understanding the behaviour of gases and the kinetic theory of gases were also detected in a large international IEA/SISS study. For example, the results from Finland and Canada indicated that the percentages of correct answers in multiple-choice items concerning gases, particularly kinetic theory, were fairly low even though the content of the items should have been familiar to the students (Connelly, Crocker, & Kass 1989; Laurén 1987, 1990; Leimu & Laurén 1987a, 1987b). In the same IEA/SISS study in Canada, based on mean achievements, it was noted that boys outperformed girls in physics at all school levels (Kass 1989). However, reviews of some school studies (e.g. Tarmo 1986) have shown that sometimes there were no differences between females and males or the differences were rather small; school marks of females may be better than those of boys, but boys may do better in exams. Some individual items from the Canadian IEA/SISS data will be reviewed in the sections presenting the results of the present study.

Mas et al. (1987) studied students' (age range from 12 to 18) conceptions of gases and found that many students have misconceptions of gases that persist even after having the atomistic conception of material presented several times. For instance, it was noted that quite many students that understood substance conservation did not understand weight or mass conservation. Generally the older the students were the fewer misunderstandings they had. Yet, about half of the oldest students had misconceptions in many items used in the questionnaires. It seems that a great many of these misunderstandings probably stem from students' ideas of gases as substances without weight, an idea supported by examples, such as gas-filled balloons rising up in the air, and air regarded as 'nothing'. Mas et al. (1987) emphasize that students must first realize the material nature of gases if they are to overcome the difficulties in understanding the behaviour of gases and the principle of conservation of mass in physical-chemical reactions. They see the role of gases as a key to comprehension of the atomic theory of material in the same way as in the history of science.

4 LEARNING PROCESSES AND VIDEO PROGRAMMES

This chapter deals with the main focus of this study, learning processes from perspectives of video programmes. Video programmes can be used as learning tools and in order to make them work well, several perspectives are important. The purpose of this chapter is to provide a general overview of those important perspectives that are relevant for the present study. Section 4.1.1 gives a general description of various ways video programmes can be used for facilitating learning. Section 4.1.2 shows that making a good educational video or television programme takes a long time and requires careful planning and it discusses the planning process as it relates to the present study. A large number of studies have dealt with the effectiveness of television and video programmes compared with other forms of presentation. These studies will be reviewed in section 4.2. Section 4.3 discusses the role of animation in video programmes used for educational purposes. The discussion is partly based on studies in computer-based learning, where animation is also widely used. The last section 4.4 focuses specifically on the role of learning processes in television and video viewing.

4.1 Using videos for facilitating learning

4.1.1 Video programmes for different purposes

In science instruction videos can be used for many purposes. Puukari (1995) lists different uses for videos in science instruction (see also Puukari 1994). It should be noted that sometimes the same video can be used for more than one purpose. According to Puukari (1995) in science instruction videos can be used at least for the following purposes:

Clarifying complex theories, processes or working principles of devices. Video techniques, such as slowing down, zooming and animation can be useful in helping students to a) recognize the phases of a process, b) important details, c) relations and/or effects of theories, processes or components of devices.

Presenting dangerous and/or expensive experiments that are important in terms of understanding science topics.

Pointing out the practical meaning of theories and science knowledge. Presenting practical applications of scientific knowledge and theories, for example, before or after teaching a new topic, can help students to realize the meaningfulness of the topic and can be of help in further elaboration of the knowledge.

Introduction to a new topic or new concepts. The usefulness of a video for this purpose depends on the content and design of the video. Providing the video contains material and presentation techniques that help students to find the key aspects and important details that are important for understanding the new topic or concepts it may be very beneficial to use it as an introduction.

Preparing students for discussion in order to construct new concepts or to further elaborate already learned concepts or to help students discuss science-technology-society connections.

Providing a summary of the topic. If the content of a video programme is suitable, it can be utilized in providing students with a summary of the topic. A good video programme may help students in remembering the key concepts and their inter-relations and particularly the aspects having to do with application of scientific knowledge in real life situations.

Providing operational instructions for conducting laboratory experiments and for using devices. Teachers can videotape instructions for frequently used experiments and devices and utilize the available video techniques to better present important details. This type of use of video also gives teachers better opportunities to concentrate on individual support of students. In the case of complex devices and experiments it is possible to use an instructional strategy, called CMS-strategy (Critical Mental System), where the first part of the video presents a general overview of the process or the operation of a device and the second part contains only the critical incidents that are particularly important in terms of conducting the experiment or using a device correctly. This second part can then be utilized for mental rehearsals (for more about the CMS-strategy see Kari & Suonperä 1983; Suonperä, 1982a, 1982b).

Providing feedback about performance/behaviour. Using video for getting feedback about performance is very common, for example, in sports training, performing arts, and in family therapy. In science instruction this form of using videos is rather rare, but in carefully selected situations it could be of use. For instance, in teaching students to conduct an important experiment or to use a frequently needed, complex device, video feedback may help students and the teacher to correct the actions.

Enlarging objects. By connecting a video camera to a TV-monitor the video camera can be used for enlarging objects that the teacher wants to show to his or her students (for more see e.g. Faulkner 1993).

Video taping or production of a video programme by students as part of their science activities is one way of documenting or presenting the process and results of a science project, particularly if the students involved already have experience and interest in using videos.

Video-based anchors. One interesting and promising way of utilizing videos, which is quite different from the previously presented, is to use video-based anchors (video programmes containing science-related information included in stories) for teaching and learning (Cognition and Technology Group at Vanderbildt 1993). This approach has been used in many subjects, such as history, mathematics, social studies, literature, and science. This discussion concentrates on science.

The video programme works as a "macro-context" which provides a basis to apply different problem-solving activities and tasks through which students learn relevant science topics and methods in relation to a meaningful story. The idea is that students supported by the teacher can decide what aspects of the story are chosen for more detailed discussion including problem-solving activities. In a broad sense this type of learning can be seen as a form of situated learning. It is not the intention of the video story to teach scientific concepts directly, but to provide a rich context that can be used for approaching science-related topics (and other topics) from a multiple perspective chosen by students and the teacher. One important aim is to encourage and enhance students' ability to detect and formulate solvable problems and to develop the knowledge and skills needed in solving the problems. Problem-solving often involves also using many other sources along with the video programme. The main role of the teacher is not delivering information but guiding students in finding the information needed and to use it in solving problems. It is not rare that the teacher also has to search for information from different sources to be able to support the process. The approach is close to genuine problem-solving situations in that no direct answers are available and at first one has to work with formulating the problem. (Bransford et al. 1985, 1989; Cognition and Technology Group at Vanderbildt 1990, 1993; Hickey & Petrosino 1992.)

It seems clear that the types of problem-solving approaches described above are needed in developing students' problem-solving skills and higher-order thinking and also to develop students' understanding of how to apply information related to various subjects and to realize the inter-relations between different subjects in general. This is why these approaches should be used even when (as usually is the case) they are time-consuming and also demanding for teachers, probably especially due to the unpredictability of the process, which in a sense puts teachers in the role of a student.

Forman and Edwards (1982) identify two broad categories of video research: 1) filmic presentation studies and 2) self-monitoring studies. According to them, filmic presentation studies can be divided into three types: 1) *'Monitoring content'* studies are concerned with the effectiveness of messages presented on video tapes (Henderson, Swanson & Zimmerman 1975; Trullinger 1976). 2) '*Monitoring strategies*' studies include watching (through video tape) others solving a problem (Thomas 1974; Jovick 1976). 3) '*Medium modelling*' studies focus on the medium itself or its characteristics that are used to teach children new ways of processing information, such as "zooming" in on critical features of a visual display (e.g. Salomon 1979). Self-monitoring studies are divided in three groups: 1) *Motor skills studies* typically use video recordings in sports training to provide an accurate feedback of the performance for a trainee. 2) *Interpersonal skills studies* include, among others, family therapy, where video feedback has proved to be useful. 3) *Concept development studies* that use video feedback to facilitate reflective thinking. Forman and Edwards' own study is located in this group of self-monitoring studies. (Forman & Edwards 1982.) The present study belongs to 'filmic presentation' studies, 'monitoring content' being the main focus. Some aspects of 'medium modelling' studies are also involved.

Many classroom teachers in the United States have been sceptical about visual forms of learning, particularly with regard to television and video (Coder 1983; Seidman 1985). This seems to be the case among many students as well. For instance, Metcalfe (1990) conducted a survey of 111 high school students regarding their viewing patterns of science and technology television programmes and found out that the majority of the students did not watch these programmes. Particularly females appeared not to like these programmes (only 6,9 % experiences a liking). In Finland a rather large number of teachers at different levels of the school system have indicated that they use television and videos in their teaching in some way or another (see Anttila 1978, 1979, 1984; Puukari 1988). However, for instance in senior high schools in Canada, it seems that relatively few teachers use videos on a regular basis. The use of videos varies in different subjects and there is also quite a large variation in what purpose the videos are used for (see Puukari 1994, 85-86).

The present study also includes information on how frequently senior high school teachers in the province of Central Finland have used videos and how (for what purposes) physics teachers have used videos. These results will be compared with the previous studies (see section 8.2).

4.1.2 Planning educational video programmes

This sub-section deals with planning educational video programmes and includes some comments on the planning process of the video programme versions used in the empirical phase of the present study. It seems that it is not possible to develop a generic model for planning good educational video and television programmes. However, there are useful studies regarding various aspects of planning educational video programmes. The following is a brief review of these studies.

Specific aspects in planning a video programme

The role of music in educational video programmes. Boeckmann et al. (1991) studied the effects of background music on recall and appraisal in educational films. Based on their own results and results obtained by Brosius (1990) they conclude that "the widespread practice of using background music in educational films is counter-productive" (Boeckmann et al. 1991, 178). They note that the use of music neither improves recall nor appraisal, but may lead to impeded learning in some ways. It seems that these results are valid regardless of the type of music. The negative influences of music were also detected in the area of attitude and affective learning that are often regarded as the area where music is supposed to have its greatest positive effects. According to the results of Boeckmann et al. the only thing that was not impeded by the background music was the recall of visual content, which seems to be even aided by the music. However, as they note, this way of using music in programme sections that concentrate purely on visual aspects, is seldom met in educational films. Usually educational film mostly utilize verbal communication to provide the required educational information to the audience. In summary, Boeckmann et al. (1991, 179) conclude that "music will be of less assistance to a film the more seriously the film is interpreted as an educational situation, while in films that are not considered so important for educational purposes, music can be of some help". It must be noted that the study concentrated on 14-18 year old students of college of Tourism, which may not be representative with regard to high school students, for example. The authors themselves pointed out that further research and theory development is needed before a more decisive conclusion can be drawn.

The role of captioning, cutting and zooming. Print captions were superior to auditory captions for identifying parts of an apparatus in a movie (Hanneman 1970). In the present study this knowledge was applied by using captions (located on or beside the objects they referred to) in some animation sections. Some earlier studies have indicated that preservation of direction of movement across shots helped children to better reconstruct what they saw, compared with children who watched the same film with directional discontinuity (e.g. Frith & Robson 1970). This idea was applied in the present study as well. Salomon (1972) compared zooming and singling out details and noticed that zooming is more effective with children. Zooming could develop cognitive skills, in that it helps children to locate their eyes to central points (from the point of view of learning) of the screen, to pay close attention to meaningful events etc. Singling out details (using a cut between two shots), on the other hand, is harder to understand for children, particularly for young children, unfamiliar with the basics of film expression. Given the more mature target audience in the present study singling out details was quite frequently used in the video programme versions. Also zooming was used in some video shots.

Models developed for planning educational video programmes

Graham and Berry (1993) utilized a simple questionnaire in developing a model for production of video resources in science and mathematics (see also Berry & Graham 1990). They proposed the following five main guidelines: 1) There should not be a presenter; a good commentary [narrator] is better; 2) People on the video should be from the target audience; 3) The video should not include algebraic manipulations or numerical calculations since they can better be done by the students during or after viewing sessions. 4) Real physical examples should be used wherever possible not just showing experiments carried out in the studio; and 5) Visual explanations of concepts (e.g. vector summation) should be used wherever possible.

Their framework for the video was as follows: Step 1. Introduction using real situations in which the theory to be developed applies, Step 2. The development of the theory from the real situation. Step 3. The introduction of other relevant theory from the real situation. Step 4. The inclusion of data-collecting activities for follow-up work. Step 5. The posing of problems on the video for post-viewing workshop/discussion sessions. Step 6. Closing sequences of relevant real situations.

Based on results of their questionnaire study Graham and Berry (1993) note that bringing reality into the learning situation is one important aspect of the role of video in mathematics lessons. Responses of students (30 %) to the question "What did you dislike the most?" revealed that in one video programme the presenters and their appearance and in another programme the music were least popular. Based on their experiences Graham and Berry identified two main aspects with regard of successful educational video programmes: 1) The videos should be designed so that the target audience can relate to and learn from them, and 2) Pilot productions and thorough evaluation of these should precede the final production and large-scale distribution. Also Gould et al. (1981) recommend gathering feedback from the target audiences to have a better basis for developing better programmes in the future. Based on their data some recommendations for making programmes for teenagers were made: Producers and writers should "1) cast or feature teenagers as actors/actresses and/or narrators, 2) keep the productions uncomplicated and with simple themes, 3) use humour as much as possible, and 4) entertain the audience as much as inform them (pp. 41-42)." These conclusions can be criticized in that probably one of the reasons teenagers like uncomplicated and simple themes and entertainment is that so much of the production in television is simple and entertaining. If there were more well-made programmes of more complex nature, there might be more teenagers expressing their wishes to watch these programmes. Keeping this in mind, it is important to get feedback from programme audiences for future production plans.

Viglietta (1992, 126) reports a summary of experiences from designing and producing science education videos:

1) The message of the programme should be relevant to the concept and method of the discipline and this message should be conveyed through images and action (not by talk) so as to exploit the potential of the medium.
2) It a useful strategy to divide the programme into sections and to use 'flash forward' to implant information in advance, so that the aims of each section were explicit.
3) The programme should be planned to be as interactive as possible, with intervals for discussion and other activities.
4) The documentary style was the most suitable for sustaining attention, since showing pupils carrying out classroom or field-work activities was very effective. Interviews with experts were also found to be useful.
5) The choice of students' activities to be included should both take account of students' interest and expectation and be recognised as relevant and feasible by the teachers. Other criteria might be dictated by the medium. A new approach to astronomy teaching through the use of transparencies instead of traditional shadows is an example of a strategy devised during the process.

Obviously, activities to be filmed should be well prepared in advance, but the pupils should not be told what to say and how to act. The strategy - which proved to be useful - was to have students perform the activity for the first time.

6) The editing phase is essential to the final outcome. Educators brought in to write the preparatory script played a useful role in this stage in the project. Sound effects and commentary should not interfere with the authenticity of the documentary: for example, students' voices, and genuine and unexpected reaction should be saved.

Generally, Viglietta (1992) emphasized the close cooperation between professional film-makers and school people: the pupils, their teachers and science educators.

As noted, a number of the ideas presented in this sub-section were applied in planning the video programme versions which were used during the empirical phase of the present study (see section 7.4). The experiences of planning the video programme versions will be discussed in more detail in section 9.3.

4.2 Studies on effectiveness of video programmes

This section deals with selected research on educational video programmes and their use for learning purposes. The sources used here come both from television and video studies, the main focus being on video studies. The essential difference between programmes delivered through television and video cassettes is that with video cassettes the time of viewing and the process of viewing can be controlled more than in the case of television broadcasting. However, videotaped television broadcastings can be used in the same controlled manner as video programmes. Therefore, it was considered reasonable to utilize also television studies. After a brief general introduction, the text will be divided into short sections according to the type of comparisons made between different media forms or between different features of television- or video programmes.

Warren (1991) notes that empirical research on instructional video has done little to reach into the classroom as a basis for programme design. Many studies have examined the effects of different video production techniques on learning and have indicated that various elements, such as colour, motion, humour, text organizing devices, music, sound effects, camera zooms etc. may have a positive effect on learning. These type of studies represent a media attribute approach to instructional video and have been criticised on the following grounds: tested video production techniques (or many of them) are common also to other forms of media (Clark 1983), no single feature of a given medium seems to be vital for learning any cognitive skill (Salomon & Clark 1986), too little thought has been given to the role of the learner, and many experimental studies have disregarded normal classroom conditions (Wagner & Wishon 1987).

More specifically, earlier studies of television's impact on children were based on a simple cause-effect model. Much of this research was conducted in 1960's and 1970's, and was often based on a behaviourist model of television - viewing, which held a view that a viewer's response is a direct and measurable effect of the TV stimulus. The underlying assumption was "that the relationship of TV and the child is linear, mechanical and unmediated; that the child is a passive viewer whose responses to and learning from TV are determined by how much was watched" (Luke 1985, 92). In more recent studies, viewing is considered as an interaction between a viewer's schemata and the TV programme. (Luke 1985.)

Verbal vs. visual presentation forms. Using earlier studies (e.g. Case 1974, 1975; Miller 1956) as background material Hitch et al. (1989) and Neath and Crowder (1990) studied how children recalled information presented verbally and visually. Visual short-term memory appeared to be stronger than auditory short-term memory and auditory short-term memory was more unpredictable. Based on these and other previous studies, Bazeli and Bazeli (1992, 41) conducted a replicatory study regarding "the linear, age-related, development of short-term memory capacity in children and ... differences in capacity when information is presented verbally, visually, and in a format where the same information is presented simultaneously both visually and verbally". The results confirmed the growth of short-term memory capacity by age, but in this study the combined presentation format (verbal and visual) did not result in higher recall than visual presentation. It is important to note that most of these and similar studies are based on simple materials consisting of single numbers, words, and pictures. Therefore, it is not possible to make direct generalizations with regard to more complex situations, such as viewing an educational video programme presenting phenomena of a multivariate nature using different forms of presentations. Generally, there is little doubt that too much information is too much, particularly if it is new to learners. In this sense, the general notion of short-term memory limitations is correct and should be taken seriously by any educator or producer of educational materials. These type of studies, however, are limited with regard to "real life" learning situations in the sense that learners' motivation and relation to the content and many other aspects of learning may be quite different, and definitely more complex in the actual school setting and in other real life situations than in the more or less laboratory-like setting of many memory studies.

Television and video presentations versus standard classroom presentations. Many studies comparing television or video presentations with standard classroom presentations indicated that there were no significant differences in learning through these different presentation forms. However, the TV presentations in these studies were rather simple, sometimes even only a videotaped lecture. (for a review see McCain & White 1980.) When television or video presentations contain more possibilities offered by video techniques, such as animation and graphics, they may be more effective than standard classroom presentations, such as lectures (Morris 1984).

Audio-visual vs. visual vs. audio presentation and learning. Many researchers have studied the differences in learning produced by various combinations of different media forms or modalities. Most of these studies have utilized experimental designs. In earlier studies, from the mid 1950's to the early 1970's, audio visual presentation (television) was often found superior to audio only presentation (radio) - at least when the results were based on measurements right after the viewing and listening. Some controversial results were also obtained. For delayed recall, visual presentations have usually been better than audio presentation. On the whole, one of the major problems in these earlier studies was that researchers did not pay attention to equating the content and structure in the compared presentation forms. (For a review see McCain & White 1980.)

In more recent studies the success in equating the presentation forms has been at least somewhat better. For instance Bagget (1979) developed structurally rather equivalent print and movie versions and concluded that there were no significant differences in recall between these two versions of presentation. However, the recall deteriorated much faster with the text version compared with the film version. Carey and Hannafin (1981) noted in their study that an audio-visual condition (oral+visual) produced the best result both with concrete and abstract content. By using pictures only (visual condition) children learned either as much or more than with narration only (audio condition). Mislearning (e.g. a wrong answer in both measures) was more common when learning was based on pictures only than on narration only, and occurred least in the combination of these two.

Ditcham (1979) found that subjects recalled significantly more information from the video portion of a TV commercial than from the audio portion, although a greater proportion of marketing information was picked up from the audio track than from the video track. Drew and Cadwell (1985) noticed that viewers of television news were usually concentrated on the audio (narration of a news reader), and were not disturbed by the lack of continuity of the video portion. However, a close coordination between the video and audio portions, increased the recall of audio information and facilitated understanding of the television news (Drew & Grimes 1985). As to children, some studies have showed that their attention to TV is more strongly related to the visual track than the audio track (e.g. Zuckerman, Ziegler & Stevenson 1978). A reasonable conclusion, concerning the use of audio and video, was made by Bagget (1984): In dual-media presentations, the picture material should be presented before, or simultaneously with the text to be read by the narrator.

Winn (1982) provides a good *summary*, which suggests the same tendencies as most of the studies discussed in this sub-section. The relations between the media form, the sensory channel, and cognitive processing of information, are not linear. Media form does not determine the processing of information, unless the cognitive processes are deliberately modified by manipulation of media. Sensory channel affects processing and learning only in low-level tasks (that require a minimal mental effort), since the information, mediated through different media forms, and the sensory channels, are influenced by the learner's mental skills and learning strategies used. Winn strongly emphasizes the central role of cognitive processes, and calls for research concerning their meaning in learning and teaching when different media forms are used. Section 4.4 will discuss educational video and television programmes from this point of view.

4.3 The role of animation in video programmes

Animation can be defined as "the rapid display of slightly varied images in order to produce a continuous sequence of an object(s) in motion" (Mayton 1991, 550). In the present study, the video programme versions used during the empirical phase contain some computer-animated sections. All the animation sections were transferred to video format and were edited into certain sections of the video programme dealing with gases. These sections were used to illustrate the relationships between the temperature, volume, and pressure of a gas in a closed container while these quantities are systematically changed in order to highlight the main features of the gas laws. Also some aspects of the kinetic theory of gases were illustrated using animation. In this section studies on educational animation will be reviewed. Most of these studies deal with animation used in computer-based or computer-aided instruction. Even though the present study deals with video-aided instruction, the fundamental question in both areas of research is how animation can facilitate learning. Therefore, some aspects of the results obtained from this study can also be discussed from the perspective of modern learning environments where computer-aided and web-based multimedia presentations are used, and vice versa.

Mayer and Anderson (1992) emphasize the meaning of the contiguity principle derived from the dual coding theory presented by Paivio (1971). Later publications (Clark & Paivio 1991; Mayer & Anderson 1991; Paivio 1990) have presented further development of the dual coding theory and/or the contiguity principle. The contiguity principle is an instructional design principle according to which contiguous presentation of words and pictures in time or space in multimedia is more effective than isolated presentation of words and pictures (Mayer and Anderson 1992). The dual coding theory supposes that people have two distinct information-processing systems, one for verbal and one for visual representations (Clark & Paivio 1991; Paivio 1971, 1990). The following three representational connections may be constructed in learning situations where words and pictures are involved: 1) representational connections between presented verbal information and learner's verbal representation of that information, 2) representational connections between presented pictorial information and learner's visual representation of that information, and 3) referential connections between corresponding elements in the learner's verbal and visual representations.

Mayer and Anderson (1992) note that due to the limitations of working memory it may be easier for learners to construct referential connections when words and pictures are presented contiguously. Some studies have provided preliminary empirical support for the contiguity principle (Mayer 1989; Mayer

& Anderson 1991; Mayer & Gallini 1990). The results of two experiments where animation was studied suggest that animation alone does not necessarily lead to understanding of the content presented (Mayer & Anderson 1992). This was demonstrated in an experiment in which students who were shown an animation before or after narration did not succeed in solving transfer problems any better than students with no instruction. However, the students who were shown an animation including a concurrent narration had better results in problem-solving transfer than the group of students that had no instruction. These results support the importance of designing animation where narration and pictures go together well and are presented contiguously. Based on the results Mayer and Anderson (1992, 444) hypothesize that "contiguity between words and pictures during instruction encourages learners to build connections between their verbal and visual representations of incoming information, which in turn supports problem-solving transfer".

In their critical comments on their own work Mayer and Anderson (1992) note that the students in their experiments were students who had little prior experience with mechanical devices involved in the experiments. Results with more experienced students might not have produced support for the hypotheses. Secondly, they note that their results "may be limited to expository passages that describe how concrete physical, biological, or social systems work rather than descriptive or narrative passages" (Mayer & Anderson 1992, 451).

Mayer and Sims (1994) conducted two experiments involving high- and low-spatial ability students who watched an animation explaining how a bicycle tire pump (experiment 1) or the human respiratory system (experiment 2) works in one of the following two groups: concurrent group (narration and animation presented concurrently) or successive group (narration and animation presented successively). Based on the results Mayer and Sims conclude that "low-experience, high-spatial ability students are the most likely to benefit from instruction that carefully synchronizes the presentation of verbal and visual forms of scientific explanation (p. 400)".

Mayton (1991) studied the impact of animation in micro-computer based instruction on recall of cardiac system functions by comparing the use of animation with static visuals containing/not containing imagery cues. Imagery cues refer to the imagery cuing strategy developed by Taylor et al. (1987). In the experiment a special frame was shown periodically depicting an outline of the human heart containing a request to fill in the parts and operation of the heart mentally. All three treatment groups had also text included in the sequences to be learned. Subjects were 72 introductory psychology undergraduate students. The main results were that animated visuals were superior to static visuals which contained no cueing in cued recall of system functions (both immediate and delayed testing) and in a free recall task based on immediate testing and based on a verbal form of delayed testing. These results give support to the idea of using animation in cases where dynamic processes are to be learned.

Rieber (1991b) points out that animation may often be problematic and lead to poor learning results if the presentation is complex (e.g. contains text, narration, and multiple moving objects). He notes (Rieber 1991b, 682) that "animation is probably an effective attention-gaining device, especially for brief periods, but when animation is designed to be informational or instructive, learning demands sustained meaningful effort on the part of students. Students must be able to perceive important information and also actively select and process this information in the proper context." Therefore it is better if a presentation containing animation is designed to lead learners' attention to the main ideas the animation is supposed to illustrate. One strategy that can be used for this purpose is visual grouping of programme sequences in the way that the verbal and visual elements do not compete with each other, thus enabling the learner to concentrate on the process illustrated in the animation unit of the sequence. In a study by Rieber (1991b) consisting of 39 fourth grade students, this strategy was applied and the result was that students in an Animated Grouped condition had better learning outcomes than students in two Static Graphic conditions. As Rieber notes in his discussion, there are also many other strategies that can be used for helping students attend to the important information than the simple grouping strategy used in his study.

Kozma et al. (1993) studied the use of multiple, linked representations of a software system in facilitating students' understanding of chemical equilibrium, a topic students often find difficult and have misconceptions in. Typically these misconceptions were related to the state of equilibrium, to the effect temperature and pressure have on equilibrium, and to quantitative representation of equilibrium. The representational system used in the interactive learning environment (the software system) was designed in the following way: 1) A video of an chemical experiment corresponded to features of the real world of the chemistry laboratory. 2) Chemical symbols and graphs corresponded to symbolic expression that chemists use to represent chemical systems. 3) An animation corresponded to the conceptual entities and mental processes in the minds of experts. All these representations were linked by common literal symbolic elements. Generally, the results suggested that multiple, linked representations improve students' understanding of chemical equilibrium and reduce misconceptions. It appeared that particularly the animation was useful in helping students to overcome their misconceptions about chemical equilibrium in that the literal features in the animated sequences corresponded to the characteristics of mental representations of equilibrium held by experts.

From the perspective of the present study, it was interesting to see that the students in the study by Kozma et al. (1993) often had difficulties in understanding the relationship between pressure, temperature, and equilibrium. Student protocols provided support the idea that the linked, multiple representations helped students in constructing a qualitative understanding of this relationship. Particularly important seemed to be the activities of the students where they used the different representations to see the relationship between the heating (a video window on the computer screen), the movement and response of the molecules (an animation window), and the partial pressures (a graph window). This type of "real time -like" presentation of complex processes seems to be very effective and can be considered as one clear advantage of using computers.

Some studies have dealt with using computers in presenting real-time graphing (e.g. Brassell 1987; Breichner 1990). For example, Brassell (1987) studied the use of the extended microcomputer-based laboratory (MBL) in improving secondary level students' graphing skills of distance and velocity graphs. The results indicated that real-time graphing significantly improved these skills compared with traditional paper-and-pencil graphing. An interesting detail was that by comparing a normal MBL-condition with a delayed MBL-condition it appeared that only a delay of 20-30 seconds in presenting the graphing inhibited the improvement of graphing skills of a "standard- MBL student". According to the results real-time graphing of data seems to be important both for cognition and motivation. It is probably due to the opportunity it provides for processing information about a physical event and its related graph simultaneously rather than serially.

Schnotz et al. (1995) discuss the role of visualization in learning and instruction by studying the effects of graphic representation formats on the structure and application of knowledge. Based on the results they concluded that visualizations can be understood as "a process of structure-mapping of a system of external visuo-spatial relations onto a system of internal semantic relations" (p. 24). They note that also pictorial surface characteristics of the visualization are involved in this process of structure mapping, not only the actual information content. " Therefore, the required cognitive effort of mental model construction varies according to the kind of visualization, even when the respective visualizations are informationally equivalent" (p. 24). For instance, it appeared that in case of two themes, 'date differences on the earth' and 'date zones on the earth', circle pictures, where certain cities on the northern hemisphere were presented according to the geographical time zone locations, were more effective than carpet pictures, where the locations of the same cities were presented as in typical rectangle-type time zone maps. It also appeared that learners using the circle pictures processed the text more intensively than learners using the carpet pictures, which suggests that visualizations do not (necessarily) lead to decreased use of text, and vice versa. Rather it seems that appropriate type of visualizations may raise relevant questions that facilitate also deeper processing of the text describing the content for which the visualizations were designed.

The differences detected were stronger among learners with low prior knowledge than among learners with high prior knowledge. This suggests than learners with low prior knowledge are more dependent on the type of visualizations than learners with high prior knowledge, who are better able to concentrate on the actual information content irrespective of the type of visualization. Schnotz et al. (1995) suspect this may be due to the more experienced learners' better flexibility in the construction of mental models so that they construct different mental models based on the different visualization and apply one or the other depending on the task to be solved. Schnotz et al. (1995) note that Paivio's often cited theory of dual encoding cannot explain the results of their study. Instead they suggest that the comprehension of visualizations could be understood as a process of structure-mapping between an external visuo-spatial configuration - including also pictorial surface characteristics - and an internal semantic structure of a mental model. More research is needed to confirm whether this theoretical idea can be generalized or not.

Generally, as Rieber (1991b) notes, previous studies (e.g. Reed 1985; see also Rieber 1991a) have shown that the influence of animation on learning is not particularly remarkable. For instance, students sometimes have difficulties in paying attention to important details included in an animated section by the designer (Reed 1985; White 1984) Often the results have been somewhat controversial. This is partly due to the very complex nature of learning situations, where the differences in objectives, contexts, physical spaces, equipment, motivation and many other important aspects make it extremely difficult to systematically compare different studies in order to judge when they actually investigated the same phenomena in the same manner. Therefore, it seems reasonable to assume that many of the controversial results stem from those almost inevitable, often unintentional differences between the research designs and their implementation. This refers particularly to studies conducted in natural environments, where little or no control over the affecting variables is available. Given that the present study was done in natural school environment, it can be assumed that the effects of using animation are not dramatic. Yet, as some previous studies reviewed here have shown, animation may have significance, when carefully planned and used in pedagogically sound ways. The role of animation in the present study will be further discussed in section 9.3.

4.4 Learning processes involved in television and video viewing

During the last two decades studies on cognitive processes and schemata in television and video viewing have been carried out. A number of excellent books on these topics have been published (e.g. Bryant & Anderson 1983; Bryant & Zillman 1986, 1991; Comstock 1985, 1989). The perspective in many of these books is predominantly a mass media perspective, which does not provide much knowledge relevant for the type of research approach used in this study. Therefore the following discussion is based on studies that seem to have overlap with the role of cognitive processes and schemata in viewing educational television and video programmes, particularly from the point of view of knowledge acquisition. The review of studies begins with an overview on developmental aspects in television and video viewing where the educational perspective is not at the centre of attention.

Regardless of the specific content of the programmes viewed, young children have been found to process significantly less information presented in entertainment and dramatic shows (Calvert et al. 1982; Collins 1970; Collins 1983; Newcomb & Collins 1979). Second graders recognized significantly less plot-relevant (explicit central information) than did older children, adolescents, and adults (Collins et al.1978). As this is the case, attempts have been made to enhance children's understanding of the medium. Neuman et al. (1989) identify four different mediation strategies: 1) A dual audio system, 2) teaching of critical television viewing skills, 3) parent or 'significant other' intervention, and children's own 4) previewing strategy.

In a *dual audio* system children can listen to a radio programme, while watching a television show. A radio announcer assisted them by providing implicit plot-relevant information, defining difficult words, and encouraging prediction strategies to activate learning. (see Borton 1971.) In practice the system did not work: there were operational difficulties, and the transmission stations could not find proper solutions to problems in cooperation. *Teaching of critical television viewing skills* was designed to help children better understand the medium (e.g. Singer, Zuckerman & Singer 1980). Projects carried out in this area have focussed on visual literacy skills, and the syntax and grammar of television. The aim has been to help children better understand televised stories and become less affected by the medium. Assumptions underlying this critical viewing model have been criticized for having little to do with the way people actually use television (e.g. Anderson J. R. 1983; Newcomb 1981).

In the '*parent or significant other*' model teachers or parents provide children with explicit format information during the viewing of a televised story. Corder-Bolz and O'Bryant (1978) conducted a story were preschool children viewed an episode of Adam-12, a police drama. A teacher provided children in the intervention group with informational comments, such as "thieves and burglars may also be called robbers". The other group of children was given statements designed to comply with instruction, like "let's all sit down and watch quietly. The results indicated that formal instruction by a 'significant other' can facilitate learning. Application of this model to typical home viewing is probably difficult, because parents may not be competent or willing to use it. In schools this system may work well.

Previewing was used in a study by Neuman et al. (1989) to maximize story comprehension. They constructed a carefully-designed video advance organizer based on Ausubel's ideas (e.g. Ausubel 1968). It provides children with a brief overview of the basic plot structure of a televised story. Calvert et al. (1987) used one type of a preview, and analysed experimental inserts called 'preplays' to measure children's patterns of visual orientation to subsequent programme material. Those children who viewed visual preplays attended longer and performed better on segment sequencing tasks than those who viewed non-visual preplays. Previews in the study by Neuman et al. (1989), were based on studies in a similar field of reading research (e.g. Graves, Cooke, & Laberge 1983) that used a variation of Ausubel's advanced organizers. Graves and his associates created brief summaries that were read to students just before they read short stories. The aim of this procedure was to activate children's higher levels of cognitive processing by providing an organizational framework, which stimulates prior knowledge and prediction of story content. It has been demonstrated that such a preview can be used to facilitate learning among different aged students (Graves & Cooke 1980; Graves & Palmer 1981).

Results from two experiments in the study carried out by Neuman et al. (1989) suggest that the preview acted as a cueing device, drawing children's attention to certain aspects of stories, and can be of help in remembering central content of a story. Referring to Trabasso & Sperry (1985) and van den Broek & Trabasso (1986) Neuman et al. (1989) noted that previews that highlight causal reasoning may affect children's understanding of events that are not specifically stated but may be inferred from a televised narrative. In their own study the story was rather easy. Future studies could use stories more challenging to children. Using previews with more difficult stories might produce better gains for the experimental group compared with the control group. Also the long-term effects are still await further study. One interesting question connected with the long-term effects is: could previewing be utilized in teaching aspects of a story grammar?

One way of looking at television and video viewing has been the concept of *story schema,* which can be understood as a memory structure, which consists of clusters of knowledge about stories, and how they are typically structured. Story schema develops gradually as children hear and read stories and learn how events are typically sequenced and what are the probable causal relationships between story grammar elements. Eventually children develop a generalized story schema abstraction, a kind of prototype of a typical story. (Mandler & Johnson 1977.) By five years of age children have usually gained knowledge how stories are structured (Applebee 1977; Brown 1975), but it takes about two years more until they learn how to utilize this knowledge as an aid in processing complex stories (Brown & French 1976). Piaget (1926), who conducted the earliest studies of story schema development, claimed that the development of story schema is constrained until children reach concrete operation at about seven years of age. Before this, children are not able to put events in a correct temporal order, or - using Piaget's own word - seriate (Piaget 1969). These claims by Piaget are in conflict with the above-mentioned information (for a good review see Meadowcroft & Reeves 1985).

Story schemata are organized hierarchically, with the most important information at the top of the hierarchy. The basic mechanism influencing organization and memory is the process of instantiation. It occurs when people encode incoming information, matching information from a particular story with structures in the schema hierarchy. This process enables schemata to work as organizational frameworks, allowing individuals to understand stories with as low processing effort as possible (Schank & Abelson 1977). Story schema is also effective in producing expectations about the information that will appear later in the story. The more closely the structure of a given story matches the schema prototype and schema expectations, the more likely it is that stories will be interpreted correctly and recalled accurately, whereas mismatches may cause some delays and errors (e.g. Frederiksen 1975; Kintsch 1977; Mandler 1978; Stein & Glen 1979).

Meadowcroft and Reeves (1985) investigated children's attention to television and the impact of story schema on it. Attention has been primarily used as a predictor of learning (see e.g. Reeves, Thorson & Schlender 1986). Attention to television in the sense that one is looking at the television at the appropriate time, however, is not sufficient in facilitating comprehension. Young children may look at television, but still they often do not understand the programme they are watching (Anderson D. R., & Smith 1984). In their study Meadowcroft and Reeves (1985) noticed that the development of story schema was related to children's attention to television. Children with more developed story schema had better memory of central story content, were more efficient, and showed greater flexibility in capacity allocation strategies. Capacity allocation was found to be a function of both perceived task difficulty and the type of mental operations children perform while watching television stories. (Meadowcroft & Reeves 1985.) The same kind of basic conclusion has also been drawn by Salomon (1981), who noticed that 'top-down' processes were more often used by experienced viewers than by inexperienced viewers, who seem to use 'bottom-up' processes. Schema theory has been successfully applied also to mass media studies (Graber 1984; Wicks 1986a, 1986b). All these studies support the idea that schemata are widely used in interpretation of media. Schemata have also considerable effects on learning from different media forms.

Forman and Edwards (1982) conducted an interesting study concerning the use of *stopped-action video replay to heighten children's theory testing*. Their study is interesting also in the sense that it has the same domain (science learning) as the present study (see also section 4.1.1). They studied how to utilize immediate video replays with children studying the physical laws of balancing blocks on a fulcrum. The experimental design included the following four groups: 1) In the '*predict object*' group each child was asked to attempt to balance the blocks, one at a time, and this was videotaped. After each block, the child watched his or her action through the video replay. The action was stopped just at the moment the child placed the block on the fulcrum, and he was asked: "What is the block going to do?" The child's predictions were recorded on a data sheet. Then the child could see what actually happened by watching the rest of the episode from the tape. 2) The '*predict self*' group was provided with the same directions, except during the replay, action was stopped just before the child placed the block on the fulcrum. The child was asked to predict the placement. Predictions were recorded. After this the remainder of the episode was replayed. 3) The '*summarize video*' group had the same directions, but the replay was without stop action. The child was asked to tell what happened. Responses to the question were recorded. 4) In the '*no video*' group children tried to balance the block, and were asked to tell what happened.

No dramatic differences were found between the groups in analysis of variance. In further analysis the children were divided into two sub-groups, ego and theory group. The theory group consisted of children who could manage at least on some configuration of blocks indicating an aim to find a general rule. The ego group consisted of children who worked without paying any attention to general rules. As these sub-groups were included in the analysis, it was found that those children in the "predict self" group, who sought a general rule (theory sub-group), performed best. The "predict self" condition led even to diminished performance for the ego sub-group compared with other conditions the ego group received. Other studies have also indicated the importance of active thinking, and aim to find general rules that can then be tested (Jovick

1976; Rovet 1976). This aspect should be given serious attention in school teaching. (Forman & Edwards 1982.) Even though the perspective in the present study is quite different from the ones above, it seems clear that students' active learning processes involving an intention to seek theory are needed in *all* video-aided learning situations. Given this, it becomes a crucial question in instruction how these active learning processes can be facilitated. Natural curiosity is one approach.

The main concern particularly in teaching elementary science is how to maintain children's curiosity about how the world works (Hawkins 1983; Rowe 1978). When children are curious, they are willing to explore things more thoroughly. This 'explorative activity' may help them to learn analytic, critical, and creative skills to be applied to new phenomena they encounter. Motivating learning or discovery of scientific concepts is important. The school should also encourage children to apply systematic thinking to various situations where it is not usually applied. One important question is what becomes defined as a problem realm for students as they interact with authoritative sources. Certain kind of problem realms or practices are defined legitimate, whereas others are not. (Martin 1988.)

Martin (1988) analysed some classroom lessons on detecting problems that centred around a videotape to get an idea of how teachers treat 'everyday life' and 'scientific' in their teaching, and how that integration works in defining what a problem is and what a solution is at the new plateau of information from a student's point of view (see Engeström, 1987). Teachers were asked to organize a discussion about an episode of Mimi (a 13-episode video drama concerning scientists studying whales, Mimi was the name of the ship) during which the following questions would be addressed: 1) What problems did the "Mimi" crew have to solve? 2) What did the crew have to know in order to solve their problems? 3) What problems have you encountered in your experience that may be like the ones you saw in the show? The discussions were videotaped and transcribed. There were large variations between the teachers in how they incorporated systemacity in the discussion before and after viewing the video programme. By observing the student reactions to questions and comments of the teacher it was inferred that the way in which the teacher "treated the subject matter" and led the discussion had a strong influence on the process of learning. In particular, the way how teachers integrated the everyday life and scientific was important. (Martin 1988.) In an ideal situation the content and problems would be from students' own experiences and at the same time linked to existing curriculum. This is a demanding pedagogical goal, but worth trying.

Another interesting and promising way to utilize videos is provided by Sherwood et al. (1987). They used videos to provide students with macro contexts that illustrate how science information can be used to solve meaningful problems (see also section 4.1.1) Two experiments were conducted. The first experiment compared learning under information-only and information-plus-related-context conditions. The other experiment was conducted to find out, 1) if providing a strong contextual basis could integrate several seemingly disjointed sets of scientific information and increase student recall, and 2) if using information to solve problems in the video context could increase the spontaneous use of information in same kind of problem-solving tasks. Findings were promising, and suggest that this kind of use of video might be a good way to motivate and facilitate science learning.

Many studies discussed above show the important meaning of a larger context in designing and using educational video programmes in schools. This perspective is connected with the so-called Science-Technology-Society (STS) "movement". According to the STS approach it is very important to learn science not as an isolated field, but as integrated with technology and society (see e.g. STS Science education 1990 and "How to" explore science and technology 1991). Technology and society can be seen as a broad context, where science can be utilized in various ways. Science teaching in school should provide students with opportunities to realize how science can actually be applied in real life and – whenever possible and relevant – use examples, questions and problems related to real life situations. These perspectives were applied in designing the learning materials for the empirical phase of the present study: “Student Textbook” (see appendices S9 and S10) and one video programme version (see appendix S15) contained a section dealing with the application of gas laws and the kinetic theory of gases in real life companies. In addition, the “Student Workbook” (see appendices S13 and S14) included problems that have links to real life.

5 METHODOLOGY IN STUDYING LEARNING PROCESSES

The research approach selected for the present study was based on careful and thorough consideration after reading research literature and using the researcher’s experiences in learning, teaching, and of different learning materials including video programmes. The main underlying ideas on which the approach adopted in this study was based will be summarized in this chapter.

Adequately planned *experimental designs* may be useful in studying schemata and cognitive processes. Schema measurement using experimental approaches has proved to be successful; systematic manipulation of schemata provides information that helps in understanding the role of schemata and their effects (Cantor & Mischel 1977; Markus & Smith 1981). Experimental designs often have an important role also in the studies concerning the effects of video or television on learning, as was seen in sections 4.2, 4.3, and 4.4. Therefore, experimental design was used also in the present study:

1) One of the most important aspects was the attempt to relate the experimental design used in the study to the theoretical knowledge regarding students’ learning and learning materials, video programmes in particular. In this, the present study is different from most of the experimental studies conducted in the 70's and even 80's which often simply compared different modes of presentations without explicit theoretical considerations. These non-theoretical, experimental designs have been criticized by researchers, such as Bates (1979), who have pointed out the usefulness of non-experimental approaches and theoretically sound experimental designs.
2) A kind of "seminatural experimental design" was applied in this study where control over the content and structure of the learning materials used in different treatment groups was one important aim.

The advantage of laboratory studies is more control over the variables studied and more time devoted to a limited number of aspects. The approach in the present study includes an attempt to study effects of independent variables (structure and content of a video programme and the way the programmes are used) on learning outcomes in a controlled way in a real life environment, in senior high schools. Other important learning variables, such as motivational factors and learning strategies, are treated as intervening or explanatory background variables. The approach lacks control over many important aspects compared with strict - but otherwise limited - laboratory studies. The design and analysis of experiments was based on widely accepted (yet also criticized) considerations of Campbell and Stanley (1963) and Montgomery (1976). Apart from internal validity, a lot of attention was paid to external validity to assure that the results can be of help to schools. More discussion regarding the experimental design can be found in sections 7.3 and 7.7.

The "direct teaching of science concepts" applied in this study has been supported by a number of researchers. For instance, C. W. Anderson (1987) notes that various forms of exploratory activities, such as observation, hands-on activities and classroom discussions are useful in preparing students for conceptual change, but they are not enough in themselves to make the difference as indicated, for example, in a study by Smith and Anderson (1984). C. W. Anderson (1987, 86) points out that "therefore scientific concepts need to be explicitly introduced and taught to students." Also Hickey and Petrosino (1992) note that in a discovery-learning environment where a brief videotape was used to encourage problem-solving activities, explicit guidance was needed as well.

As described in more detail in chapter 7, the present study utilized both qualitative and quantitative data collection methods, some of which are similar to the ones used in schools for assessing learning. The following paragraphs review some alternative methods in studying schemata and learning processes. The methods used in this study will be discussed at the end of this section. Resnick (1985) identifies three methods that trace sequential steps in thinking: 1) recording patterns of reaction time for stimuli or tasks of different complexity, 2) tracking eye movements as subjects read texts or solve visually presented problems, 3) "think-aloud" protocols in which subjects solve problems while verbalizing what is going through their minds as they work.

Recording patterns of reaction time. This method gives the researcher a view of how demanding different kinds of tasks or stimuli are, how much time it takes to process them. For example, Meadowcroft and Reeves (1985) utilized this method in a study of children's attention to television. They referred to Kahneman (1973) who has stated that the amount of effort allocated depends on task difficulty, and if combined tasks require more attention than available from capacity, performance on one or more tasks suffers. The ground for this is in the assumption that the capacity for mental effort is limited (for classical studies see Broadbent 1958; Miller 1956). By using dual tasks, such as pressing a button as one hears a tone while watching TV, it is possible to get a measure for allocation of attention. The time between hearing a tone and pressing a button is assumed to vary with the primary task difficulty. The main idea in Meadowcroft's and Reeves's study was to find out if a more developed story schema makes it easier for a child to process information from a televised story. Thus, by recording the reaction times and by relating them to information about the "level" of children's story schema, it was possible to draw the necessary inferences. The learning objectives and the content of the learning materials in the present study were more complicated than in the studies described above. Therefore, recording patterns of reaction time was not used in this study.

Tracking eye movements. Our visual perception is based on eye movements and fixations between these movements. We receive visual information in small fragments that are related together in our brain. There is clear evidence that our eye movements differ as a function of the task or the aim. Based on this, it has been assumed that patterns of eye movements can be used as an index for cognitive strategies in reading, watching pictures, or visual displays (Fleming 1984; Klopfer 1983; Marschalek 1986; Mock 1976). There is reason to believe that eye movement tracking can contribute to television and video viewing studies. It may bring valuable information not available in any other way. However, it must be related to other measures of cognitive processes to be of benefit. In video viewing studies eye movement tracking may also be used as a control measure when, for example, a teacher or experimenter asks students to pay attention to certain important details presented on screen. Had eye movement tracking equipment been available, it would have been used in this study for analysing individual students while they were viewing the video programme versions used in this study.

Think-aloud protocols. In this method subjects solve problems while verbalizing what is going through their minds as they work. Protocol analysis, on the other hand, refers to an analysis method used in analysing think-aloud or interview protocols, to track structures and steps in cognitive processes. Think-aloud method and protocol analysis are used in many fields of research (Anderson M. A.1986; Ericsson & Simon 1984; Mosenthal, Tamor & Walmsley 1983; Neimark, Slotnick & Ulrich 1971; Radford 1974; Resnick 1985). Although useful on rather many occasions, the think-aloud method cannot be applied in the present study in a proper way. It would be very difficult, if not impossible, to watch a video programme while thinking aloud. However, protocol analysis might provide some useful ideas for analysing data received from an intensive case study of individual students.

By using any of the three above-mentioned methods, it is possible to record certain events through the whole process. These methods represent some kind of "direct measuring" of cognitive processes. Often more indirect methods for data gathering must be applied. One commonly used method is *free recall*, which could be divided into three categories: 1) free recall, 2) cued-free recall, and 3) stimulated free recall.

Free call (without any cues or other extras). In free recall subjects are asked to recall all they can, for example, concerning a topic they were studying. This is done either by telling (reports are normally recorded with a cassette player) or by writing. When subjects stop answering or have a long pause, they may be asked, for example, "is there something more you can recall?" An example of free recall could be a study where people hear a list of animals and flowers in a mixed order. After they have heard the list, they are asked to recall as many as they can (free recall). It is assumed that the way people recall the items reflects their association in an organized memory. Subjects with well-defined animal and flower schemata will cluster the animals in one part of the recall sequence and flowers in another. (e.g. Ostrom, Pryor & Simpson 1981.) Concept maps and essays (see also the end of this section) were used in the present study in a way which has some similarities with a free call situation (for more details see section 7.5).

Cued-free recall. In cued-free recall subjects are asked some questions, for example, concerning the content they were reading or watching. This is problematic because people may answer only because they do not want to give an impression that they do not know anything. A well-structured schema may not have been developed, and students may only have fragmented knowledge. There are some clustering methods that provide a systematic way to analyse the structure of individual items within a schema (Ostrom, Pryor & Simpson 1981; Roenker, Thompson & Brown 1971). The clustering indexes received from these analyses are designed to be used in situations where the number of individual items can be counted. (For a good review see Wicks 1986a.)

Stimulated recall is a widely used method, particularly in observational classroom studies and teacher training. The idea of stimulated recall is to provide a recording of a process (e.g. a teaching episode), which stimulates memory and is of help in recalling the mental events that were in a subject's mind during the process. Usually the researcher and the subject are watching the videotape together focussing on certain aspects of the process. (Calderhead 1981; Gabb 1984; Martin 1987; McConnell 1977; Tuckwell 1980a, 1980b.) With regard to the present study, had an eye movement equipment been available, stimulated recall would have been used as a method for gathering data on individual students' learning processes when they were watching the video programme versions.

Video recording events during learning processes has been used to provide a precise basis for observations. An obvious benefit of video recording is that a researcher can pick up even small details from the tape and focus on one aspect at a time by going through the tape several times. By using video recording it is possible to avoid the problems involved in narrative description: the high speed and simultaneity of relevant action (Erickson 1979). Video recording has, however, some constraints, such as the narrow angle of vision of a camera lens because of which some relevant events may be missed. Also the presence of a camera may distort the way people behave during a recording (Decker 1975). If possible it is good to help people get accustomed to video recording by taping them a number of times before the actual recording. The problem of the narrow angle of a camera lens may be avoided by using extra cameras and special video equipment (see Beattie & Bogle, 1982; Gardner, Clements & Rodriquez 1982). Originally, video recording was to be used in the present study to record the lessons where students studied gases. However, when it appeared that most of the teachers were hesitant about taping the lessons and many of them did not have video cameras available, the video recording was cancelled. This may have been a stroke of luck, because the data are quite extensive even without the video recordings.

Ross and Shuell (1990) constructed a *true-false item test* of knowledge and misconceptions about earthquakes for 4-6 grade students to determine whether it leads to the same conclusions as individual interviews. The 60 statements in the test consisted of items containing correct knowledge and statements including misconceptions earlier confronted in student interviews. It appeared that students often selected both correct items and items containing misconceptions to describe their knowledge about earthquakes. The test was least reliable for 4th graders. Based on the results Ross and Shuell noted the need for refinement of the test and pointed out the importance of using individual interviews as one source of information on misconceptions. Multiple choice questions can be used for the same purposes as the true-false item test described above. In the present study learning outcomes of senior high school students were studied by using a set of multiple choice questions (see appendix 6 and appendix S2).

One useful way of analysing the structure of knowledge people have is to use *concept maps*, as indicated by many researchers (see West & Fensham 1974; Novak 1976, 1980a, 1981; Stewart 1980; Novak, Gowin & Johansen 1983) Concept maps seem to be suitable for studying the changes taking place in people's schemata, since it can be seen as a kind of visual, written representation of a schema. It should not, however, be understood as a "direct" picture of a schema in one's head. Perhaps the major problem in using concept maps to represent people's schemata is that it may take some time before they get used to the method. The power of the method is in its dual nature: it can be used both as a data collection method and as a means to facilitate students' learning processes. Therefore, concept maps (accompanied by essays) were used as a data collection method during the empirical phase of the present study (see appendix 5). In addition, learning tasks in the form of the Task Papers (see appendix 7) were used for collecting data on students' learning (see also multiple choice question in the above paragraph). The use of multiple methods for collecting data on learning has to do with methodological triangulation, which is particularly useful when, for instance, a more holistic view of educational outcomes is sought or different methods of teaching are to be evaluated, as is the case in the present study (see Cohen & Manion 1989, 274-276; Denzin 1970; see also sections 7.5 and 7.7).

6 SUMMARY OF THE THEORETICAL FRAMEWORK

This chapter summarizes the main aspects of the theoretical framework and indicates briefly how they will be applied in the present study.

Learning processes (Chapter 2)

Schema construction is a key element in learning processes. Schema construction is used to describe the tendency of people to "chunk" units of information, propositions into larger units that are more general and abstract. This way it is possible to process a larger number of things simultaneously, and to use them as material for constructing new schemata. In the acquisition of knowledge, schemata will often be restructured when facing new information (e.g. new empirical observations or theoretical aspects) that will make one change the existing schemata to better link it to "the reality". The changes in schemata are of particular interest in science learning. Dweck and Henderson's (1989) theoretical considerations regarding students' perception of their intelligence and Biggs' (1987a, 1987b) theoretical views on students' approaches to learning were used in explaining students' learning outcomes regarding the behaviour of gases.

Chapter 2 included also a review of the means to influence learning processes. Since the objective of the present study is to test the effects of different versions of an educational video programme and the effects of learning tasks used prior to viewing the programme, all reviewed means are not equally important. The general notions presented in section 2.1. were used in planning the teacher manuals for the empirical phase. The purpose of these manuals was to provide a general, coherent starting point for the instruction given to the physics student groups participating the study.

The use of learning tasks is supported by the research on advance organizers. Also research in some other areas has shown the potential usefulness of learning tasks in facilitating learning. From a practical standpoint, learning tasks are easy to use in classroom situations where learning materials, such as textbooks and video programmes are used. It must be remembered that the objective of this research project was not to find means to guide learning processes in general, but to find ways to improve educational video programmes and the pedagogical methods in using them. This is why only relatively few of the possible means of influencing the learning processes were used during the empirical phase of this study.

Learning processes in school physics (Chapter 3)

Science learning studies and the theoretical thinking based on science learning studies have close connections to other studies and theories in the field of cognitive psychology. The basis for discussing these aspects in separate chapters was based on the division made between general and domain-specific information. Although the division is somewhat artificial, and many connections exist between them, it was considered important: In learning about a particular topic, there are always some aspects so closely connected with the content that understanding the process of learning and explaining the learning outcomes would be insufficient, if not impossible, without highlighting the domain-specific questions.

Attitudes towards school and school subjects have been treated both as predictors of learning outcomes (e.g. Kelly 1978; Napier and Riley 1985) and as dependent variables explained by the learning outcomes and other variables (e.g. Bloom 1976; Saari 1983). Generally, it seems that the relation between attitudes and learning outcomes should be seen as reciprocal. Since the instructional period in this project was short, the attitudes towards school and physics will be used mainly as predictors of learning outcomes. One aspect of attitudes, attitudes towards studying gases, will, however, be also used as a dependent variable.

The review of science learning studies, particularly the studies dealing with students' knowledge about the behaviour of gases and the kinetic theory of gases, raised many important questions and the review gave a basis for comparing the empirical results of the present study. Based on the results of previous studies it seems clear that the topic "the behaviour of gases and the gas laws", which was the topic used during the empirical phase, is not an easy topic even for senior high school students. The kinetic theory of gases, in particular, seems to be demanding for them. Theoretical aspects presented in chapter 3 were used in designing the learning materials ("Student Textbook" and the video programme versions dealing with the behaviour of gases) and the teacher manuals (used by participating teachers during the empirical phase). Part of the theoretical discussion in chapter 3 were used as a general interpretative framework and part of it was used in discussing specific empirical results of the present study.

Learning processes and video programmes (Chapter 4)

Earlier studies on educational television and video programmes have produced useful information for designing educational video programmes and they have generally shown that the type of audiovisual presentation form used in video programmes can efficiently facilitate learning, and may work better than other media, such as written presentations, or presentations including only audio components. The review of these studies presented in chapter 4 was used in designing and producing the video programme versions for the present study.

The studies of learning processes involved in television and video viewing indicate that it is very important that teachers and students, in particular, are actively involved in the learning processes. It seems that television and video programmes can facilitate students' use of schemata in learning, but some results show that video programmes, as such, may not be sufficient for achieving good learning outcomes. If students are actively searching for deeper understanding, for example, by trying to find the underlying principles related to the phenomena they are studying, they may be able to better use the potential support that an educational video programme can give them.

Key components used in designing the video programme and ways of using it during the empirical phase

Some studies of television and video viewing have shown the usefulness of *previews that summarize the main ideas of a television or video programme* (discussed in section 4.4; see e.g. Neuman, Burden, & Holden 1989; Calvert, Huston, and Wright 1987). Previewing was used in the study by Neuman et al (1989) to maximize story comprehension. They constructed a carefully-designed video advance organizer based on Ausubel's ideas (e.g. Ausubel 1968). It provides children with a brief overview of the basic plot structure of a televised story. Calvert et al. (1987) used a form of preview, and analysed experimental inserts called 'preplays' to measure children's patterns of visual orientation to subsequent programme material. The studies give a basis to assume that a preview section used in the beginning of an educational video programme aimed at teaching science concepts might help students. A preview section can help students get familiar with core ideas and with forms of presentation and thus help them follow the content more intensively during the learning processes. Based on the above, one interest in this study is to test if a preview section in the beginning of an instructional video programme helps students to pay more attention to the core information in the video programme dealing with the behaviour of gases.

Application section in a video programme (discussed in section 4.4). Sherwood et al. (1987) used videos to provide students with 'macro contexts' that illustrate how science information can be used to solve meaningful problems. The idea of showing the usefulness of scientific information emphasized by the Science-Technology-Society movement (see e.g. STS Science education 1990 and "How to" explore science and technology 1991) has close connections to the idea of using ‘macro context’. In this study, one of the three versions of an educational video programme used during the empirical phase has a section dealing with research and utilization of gases. This section contains interviews and video sequences from real life companies dealing with gases. The interviews and video sequences will describe how the companies use knowledge about gases and how technology is used to study gases.

Use of learning tasks prior to viewing a section of the video programme. (discussed in section 2.4) The use of learning tasks in instruction, and in learning materials can significantly facilitate learning (see e.g Kari 1987). An important aspect in using questions is to use an appropriate cognitive level (e.g. Biggs & Collis 1982; Leiwo et al. 1987a, 1987b; Merrill 1985). Cognitively demanding (but not too demanding) learning tasks may help in directing students’ attention to important aspects and make them better able to construct a schema. In this study, printed learning tasks consisting of questions dealing with core content were used prior to viewing certain sections of the video programme. It was presumed that the use of these learning tasks facilitates students’ learning in that they make them better able to control their learning process by directing their attention to central aspects of the video programme.

7 IMPLEMENTATION OF THE STUDY

The following research problems and hypotheses concern the Finnish senior high school students who will be described in more detail in section 7.2. Originally, both Finnish and Canadian students were supposed to be included in most of the analyses suggested in the problems and hypotheses. Because the Canadian data was not randomly obtained, contained some inconsistencies and missing information (see Puukari 1994 for details), and was rather small (n= 143), only the Finnish data will be used here. However, some comparisons with the results of the Canadian data will be made. Therefore, selected information on the Canadian data will be included in the following sections. Also the learning materials and data collections methods used in Canada and Finland will be appended.

7.1 Research problems and hypotheses

Some references to the data collection methods and data analyses used in the present study will be included in the following description for the sake of clarity and accuracy. The following sections contain a more detailed description of the data collection methods and data analyses.

1 How do teachers use videos in school according to students?

1.1 How often are videos used in different school subjects?

1.2 In what ways do physics teachers use videos in their instruction?

Comparisons between sub-groups: no comparisons.

Purpose: to get a general picture of how frequently and in what ways videos are used in senior high schools, in physics particularly.

Connection to the theoretical framework: Section 4.1.1

2 How do students perceive their intelligence?

Comparisons between sub-groups regarding a) theories about their intelligence and b) their confidence in their intelligence :

2.1 Females vs. males

2.2 Lower vs. higher socioeconomic groups

2.3 Weakly- vs. strongly goal-oriented students

2.4 Finnish vs. Canadian students

Other sub-problems:

2.5 Do students' theories about their intelligence and their confidence in their intelligence correlate with other variables?

Purpose: To describe students' perception of their intelligence and to use these variables in estimating their correlation with other variables. The information on the correlations will used in analyses related to explanation of students' learning outcomes.

Connection to the theoretical framework: Section 2.3.1

3 What approaches to learning do students apply in school?

Comparisons between sub-groups:

3.1 Females vs. males

3.2 Lower vs. higher socioeconomic groups

3.3 Weakly- vs. strongly goal-oriented students

3.4 Finnish vs. Canadian students

Other sub-problems:

3.5 Do students' approaches to learning correlate with other variables?

Purpose: To describe students' approaches to learning and to use these variables in estimating their correlation with other variables. The information on the correlations will be used in analyses related to explanation of students' learning outcomes.

Connection to the theoretical framework: Section 2.3.2

Hypotheses:

Hypothesis 1 (for problem 3.3): Strongly goal-oriented students make more use of a) the Deep Approach and b) the Achieving Approach and c) less use of the Surface Approach than weakly goal-oriented students. (for rationale see section 2.3.2)

4 What are students' attitudes towards school and physics?

Comparisons between sub-groups:

4.1 Females vs. males

4.2 Lower vs. higher socioeconomic groups

4.3 Weakly- vs. strongly goal-oriented students
(Comparisons to selected items of the IEA/SISS study will be included here)

4.4 Finnish vs. Canadian students

Comparisons between pretest and post-test scores:

4.5 Are there changes in attitudes towards studying gases between pretest and post-test?

Purpose: To describe students' attitudes towards school and physics. The information will be used in analyses related to explaining students' learning outcomes and their experiences of the minicourse dealing with the behaviour of gases.

Connection to the theoretical framework: Section 3.2

Hypotheses:

Hypothesis 2 (for problem 4.1): Females have more positive attitudes towards school than males do. (for rationale, see section 3.2)

Hypothesis 3: (for problem 4.3): Strongly goal-oriented students have more positive attitudes a) towards school and education, and b) towards physics than weakly goal-oriented students do. (for rationale, see section 3.2)

5 What knowledge do students have about the behaviour of gases and how does their knowledge develop during the minicourse?

5.1 What do students know about the behaviour of gases?
(included are descriptive results regarding the Multiple-Choice Questionnaire, the Task Papers, the Concept Maps + Essays)

Comparisons between sub-groups:

5.1.1 Females vs. males
5.1.2 Weakly- vs. strongly goal-oriented students
5.1.3 Finnish vs. Canadian students

(Comparisons with selected items of the IEA/SISS study will be included here)

5.2 How do the systematic variations in learning tasks and video programmes (in the experiments) and other variables (identified by statistical methods) explain students' learning outcomes regarding the knowledge of the behaviour of gases?

The main analyses (5.2) will be done using the following dependent variables:

1) The Multiple-Choice Questionnaire 1-2 total gain scores as a dependent variable. Separate further analyses for corresponding gain scores based on 1) items dealing with the gas laws, and 2) items dealing with the kinetic theory of gases will be presented if the variance models differ considerably from the variance model based on the Multiple-Choice Questionnaire 1-2 total gain scores (Pretest-post-test design used here)
2) The Task Papers 1-5 total sum scores as a dependent variable. Separate further analyses using the dependent variable based on 1) sum scores from the four Task Papers dealing with the gas laws and for 2) sum scores from one Task Paper dealing with the kinetic theory of gases will be presented if the variance models differ considerably from the variance model based on the Task Papers 1-5 total sum scores. (No pretest-post-test design here)
3) The Concept Map + Essay 1-2 total sum of gain scores as a dependent variable. Separate analyses using: a) sum gain scores based on the "Specific Structure and Coherence" of the Concept Map + Essay 1-2, b) sum gain scores based on the "Content" of the Concept Map + Essay 1-2 will be presented if the variance models differ considerably from the variance model based on the Concept Map + Essay 1-2 total sum of gain scores (Pretest-post-test design used here)

Purpose: To describe students' knowledge of the behaviour of gases and totest the effects of the video programmes, learning tasks and other variables on the learning outcomes and experiences of the minicourse dealing with the behaviour of gases.

Connection to the theoretical framework: Sections 3.3, 4.2, 4.3, and 4.4

Hypotheses: (for rationale, see sections 3.3, 4.2, 4.3, and 4.4)

Hypothesis 4 (for problem 5.2): Students viewing the video programme version including a preview section perform better than students who view no video programmes.

Hypothesis 5 (for problem 5.2): Students viewing the video programme version including an application section perform better than students who view no video programmes.

Hypothesis 6 (for problem 5.2): Students viewing the video programme version including only basic sections perform better than students who view no video programmes.

Hypothesis 7 (for problem 5.2): Students who are given learning tasks prior to viewing perform better than students who are not given learning tasks prior to viewing.

6 What experiences do students and teachers have of the minicourse dealing with the behaviour of gases?

6.1 What experiences of the minicourse do students have?

6.2 What experiences of the minicourse do teachers have?

6.3 What factors explain students' experiences (negative-positive) of the minicourse?

Purpose: To describe students' and teachers' experiences of the minicourse and to explain students' experiences by other variables. The information is used to better understand how this type of minicourse and applied learning materials could be further developed.

Connection to the theoretical framework: No specific sections, but connections exist to almost every section.

7.2 Subjects

General information on school systems in Finland and in Canada. The general structure of elementary and secondary education in Alberta, Canada and in Finland is approximately the same: elementary education consist of 6 grades starting at the age of 6 or 7, junior high school (called "ylä-aste" or "grades 6 to 9" in Finland) has 3 grades followed by 3 - 4 year-period in senior high school (called "lukio" in Finland) or 2-4 years in a vocational school. Senior high school includes grades 10 to 12 in Alberta, whereas in Finland the grades range from 1 to 3 respectively. A variety of programmes - vocational as well as academic - are offered to prepare students for the work place or to meet the entrance requirements of a college or university. It must be noted that in Finland currently most senior high schoosl follow a course-based plan where the graduation time from senior high school varies from about 2.5 years to 4 years. It is also worth noting that in some cases senior high schools and vocational schools both in Alberta and Finland offer joint programmes which give students an opportunity to graduate from high school and have a vocational education in a specific field. However, all the subjects in this research project were studying in a "traditional" academic programme. Senior high school students in Finland participate in a matriculation exam, a uniform national examination which is often taken into account when selecting new students for universities, polytechnics and vocational schools. In Canada, secondary school diplomas are granted to students who pass the compulsory and optional courses of their programmes. In some provinces, the ministry of education evaluates what students have learned by conducting uniform examinations. (Going to Canada to study 1992; General upper secondary education 2001.)

The subjects of the study were 358 year-one senior high school students from the province of Central Finland, Keski-Suomi, Finland; later the province of Central Finland was joined together with some other provinces to form a new province, called Westen Finland, Länsi-Suomi. The sampling method was a single-stage cluster sampling (see Liedes & Manninen 1975), the physics group being the cluster. At the time of sampling, autumn 1992, there were 28 senior high schools in the province of Central Finland containing 30 physics groups. The estimations of the number of students in the physics groups were obtained directly from the physics teachers, who keep files on their students. The figures described the sizes of the groups during the physics course preceding the minicourse on the behaviour of gases. Accurate figures were not available, since some students were planning to drop out in between the two physics courses.

The estimated student population in all the physics groups, excepting the one whose teacher did not wish to participate, was 595. Eight physics groups that would have probably had less than 10 students during the minicourse were excluded. This was to ensure that the physics groups to be selected would be typical with regard to the number of students. A very small number of students in the group would have changed the nature of the instruction process so that it more closely resembled that of small group teaching, which differs considerably from a "normal" classroom situation. After exclusion of these eight small physics groups (total number of students = 67) the number of the remaining physics groups was 22 and the size of the student population 528. From the 22 physics groups 16 groups were selected using simple random sampling (random number tables). The total number of students in those groups was 358 (67,8 % of the "group-size-limited" population and 60,2 % of the total available population). Given the size of the sample as compared with the number of clusters (physics groups) and with the size of the student population, the sample well represented the year-one senior high school physics students of the province of Central Finland. However, the deliberate bias towards larger student groups must be remembered.

A number of other sampling methods and more sophisticated options of cluster sampling were also considered during the literature review (Holopainen

& Konttinen 1984; Liedes & Manninen 1975; Pahkinen & Lehtonen 1989). However, keeping in mind the rather small size of the student population and the practical aspects in organizing the experimental stage in a school context, the chosen sampling method seemed to be the most reasonable and easiest one to carry out.

Selected results will be compared with the Canadian results based on data collected from 143 senior high school grade 1 students in Canada. *Please note that, if not otherwise specifically indicated, all information hereafter refers to the Finnish data*.

There were 123 *females* and 235 *males* among the students. The greater number of males is due to the fact that generally more males than females select physics as part of their senior high school programme . The *age distribution* was as follows: 15 years (4), 16 years (308), 17 years (39), 18 years (1), and 19 years (6) (6 missing cases).

Most students were *planning to include science subjects as part of their further education* (184), but a large number of students had not yet decided (154). A number of students were not planning to include science subjects as part of their further education (12) and three students indicated they were not going to continue education after senior high school at all.

Some information on students' school performances was also obtained regarding course grades in Physics, Mathematics, Finnish and Chemistry. It must be noted that Chemistry is an optional subject, and only a few students have selected it. The following table is a summary of mean grades in these subjects. Note that in the Finnish grading system numbers from 4 to 10 are used; 4 represents "poor" and 10 "excellent".

TABLE 5 Students' course grades in four subjects

Subject	**n**	**Course grades**							
		below 5.50	**5.50-6.49**	**6.50-7.49**	**7.50-8.49**	**8.50-9.49**	**9.50-10.00**	**M**	**SD**
Physics	352	12	28	85	102	92	33	7.80	1.20
Math	351	21	53	70	102	72	33	7.57	1.34
Finnish	352	3	18	89	124	103	15	7.90	0.95
Chemistry[1]	44	1	6	17	9	5	6	7.66	1.31

1) note that categories for Chemistry are from 5 to 10

7.3 Experimental design

The study is largely based on experiments. The ideas adopted from Campbell & Stanley (1963) and Montgomery (1976) were utilized in planning the following experimental design. The theoretical reasons for using these particular video programmes and instruction versions were noted earlier. More comments on the theoretical ideas behind the design will follow a brief presentation of the design.

Video programme versions:

V_1 = a preview section + basic sections
V_2 = basic sections + an application section
V_3 = basic sections only
V_4 = no video programme

Instruction versions:

I_1 = learning tasks are given to the students prior to viewing each of the following five video programme sections: Boyle's law, Charles' law, the third gas law, General gas law, and the kinetic theory of gases.
I_2 = The above mentioned video programme sections are shown without specific directions prior to viewing.

Treatment groups:

By combining the video programme and instruction versions we have the following treatment groups A - H:

Instructional versions	**Video versions**			
	preview and basic sections	basic sections and application section	basic sections	no video
learning tasks prior to viewing	A ($n_{F1} = 23$; $n_{F2} = 25$) ($n_C = 0$)	B ($n_{F1} = 28$; $n_{F2} = 21$) ($n_C = 15$)	C ($n_{F1} = 11$; $n_{F2} = 25$) ($n_C = 26$)	D ($n_{F1} = 37$; $n_{F2} = 22$) ($n_C = 29$)
no directions prior to viewing	E ($n_{F1} = 24$; $n_{F2} = 12$) ($n_C = 22$)	F ($n_{F1} = 23$; $n_{F2} = 20$) ($n_C = 19$)	G ($n_{F1} = 21$; $n_{F2} = 23$) ($n_C = 19$)	H ($n_{F1} = 22$; $n_{F2} = 19$) ($n_C = 13$)

n_{F1} and n_{F2} = number of Finnish students in physics groups 1 and 2 respectively, two groups per each treatment group. n_C = number of Canadian students, one physics group per each treatment group.

In Finland, the 16 physics groups to participate in the study, were randomly selected from the senior high schools of the province of Central Finland. At the time there were 28 senior high school in the province of Central Finland, 8 of which had such small physics groups (10 or fewer students) that the schools were not included in the selection to ensure a greater number of students in treatment groups (see also section 7.2). One teacher representing one physics group refused to participate. Then from the available physics groups (n = 22) in the remaining schools, 16 physics groups were randomly selected. These 16 groups were then randomly selected for the treatment groups, two groups per each treatment group. In Canada, all the schools were selected by the school systems and only one physics group per treatment group was available. Therefore, only the selection for the treatment groups was randomized. Note that all the random selections were based on simple random sampling using random number tables.

Experimental design:

Pretest	Treatment	Post-test	Follow-up
0_1	X_A	0_2	0_3
0_1	X_B	0_2	0_3
0_1	X_C	0_2	0_3
0_1	X_D	0_2	0_3
0_1	X_E	0_2	0_3
0_1	X_F	0_2	0_3
0_1	X_G	0_2	0_3
1	X_H	0_2	0

With regard to controlling the experimental design, the following aspects should be noted. The students in all the treatment groups from A to H were given the following materials (for more information on the materials see section 7.4):

1) The Student Textbook "The Behaviour of Gases and the Gas Laws - Textbook" for the Canadian students (Appendix S9) and "Kaasujen käyttäytyminen ja kaasulait - Opetusteksti" for the Finnish students (Appendix S10);
2) The "Student Workbook" titled "The Behaviour Of Gases And The Gas Laws - Workbook" for the Canadian students (Appendix S13) and "Kaasujen käyttäytymi-nen ja kaasulait - Tehtäväkokoelma" for the Finnish students (Appendix S14);
3) The Task Papers 1-5 consisting of physics problems related to the gas laws and behaviour of gases (Appendix 7). In addition to these materials, treatment groups from A to C and E to G received one of the three versions of a Video Programme (see the manuscript of the video programme versions in appendix S15).

In addition, each participating teacher was given a face-to-face introduction to the materials and to the way they were expected to teach during the research process. These sessions took from 1 to 2 hours depending on the timetable of the teacher. During these training sessions teachers were given a Teacher's Manual which explained the principles to be followed during the teaching periods related to the behaviour of gases and the gas laws (Appendix S22 contains the English versions and Appendix S23 the Finnish versions). The manual also contained specific directions for each treatment group regarding the use of the Video Programme and provided instructions on how to use Video Assignment Papers (learning tasks) before viewing each of the five selected sections of the video programme. It also provided detailed descriptions of when and how to use Lesson Assignment Papers (learning tasks), similar to Video Assignment Papers, before giving an instructional session on each of the same topics as in the selected video programme. Furthermore, the use of data collection methods was explained. Given the complexity of the empirical phase, it is possible - even probable - that the participating teachers have interpreted the guidelines in the Teacher's Manual in different ways. It can be assumed that these different interpretations have caused some variation in the results. For example, the instructions regarding the use of Concept Maps + Essays as data collection methods may have been interpreted in different ways. Also the experiences that the teachers and the students have had of using concept maps may have caused some differences in the results.

One small but important detail is that the "Student Textbook" dealing with gases contains the same type of illustrations or presentation forms in describing the gas laws (particularly Boyle's Law and Charles' Law) as the video programme, with the exception that animation is used in presenting the same aspects in the video programme. On the other hand, the video programme contained sections of the same text used in the "Student Textbook", read by the narrator.

The purpose of all these steps was to guarantee that as many factors as possible would be the same for each treatment group to ensure that the effects of the systematic variations (different versions of the video programme and the use of learning tasks prior to viewing a section of the video programme) could be detected. Problems in the implementation of the experiments will be discussed later.

7.4 Materials and pilot studies used for designing the materials

The most important material in this study is the video programme that was used as complementary learning material in the experiments. The idea was to see whether a video programme used along side more traditional learning materials ("Student Textbook" and "Student Workbook") can further facilitate learning about gases. The video programme and its systematic variations were designed to meet high standards

1) technically,
2) visually, and
3) pedagogically.

However, there were a number of problems that limited the possibilities to meet these standards especially in the animation sections of the video programme. These problems will be discussed in more detail later.

Three different versions of the video programme were used in the experiments. Each version included so-called basic sections that included an introduction to the topic "the behaviour of gases and the gas laws", information about the gas laws and about the kinetic theory of gases. Each teacher using a video programme was given a list of the video programme sections (see Appendix S24 for the English version and Appendix S25 for the Finnish version). Appendix S16 contains a permission to use excerpts from a videotape showing a PVT shell in action. The excerpts were used in a video section dealing with changes in the state of a gas. The three versions of the video programme were:

1) *Programme including a preview section and basic sections* was used to see whetherit helped students to pay attention to the core information. The idea of the preview section was based on earlier studies that have used abstracts and preview sections as advanced organizers in books and in television programmes (Ausubel 1968; Graves, Cooke & Laberge 1983; Neuman, Burden & Holden 1989).
2) *including basic sections and an application section* was used to provide students with information on how the knowledge of gases can be used in real life situations in companies dealing with gases. The idea was adopted from Sherwood, Kinzer, Bransford & Franks (1987), who used video-based macro contexts in their study of science instruction. However, in this study the application section simply described the utilization of the theoretical information, it was not designed to provide a context from which students would have inferred some scientific principles.
3) *Programme including only the basic sections.*

The steps in the design of the video programme and its versions are reported to offer information for scriptwriters and other people involved in design or production of video and television programmes of a similar type.

Two other learning materials were used in the experiments: The "Student Textbook" (see appendices S9 and S10) and the "Student Workbook" (see appendices S13 and S14), which was designed to be used with the textbook. Design of the English version of the "Student Textbook" and the "Student Workbook" was based on discussions with several researchers and professionals. A number of books on physics and chemistry were used as sources (Boorse & Motz 1966; Daintith 1990; Erätuuli et al.1986; Giancoli 1985; Kurki-Suonio, Kervinen & Korpela 1982; Murphy et al.1986; Newman 1963; Nikkola, Viljanmaa & Virtanen 1990; Taffel 1986; Webber, Billings & Hill 1970). The "Student Textbook" was designed according to the principles listed below. The idea was to provide the same textual basis for each experimental group in order to see the effects of different video versions and instructional versions more clearly. The gas related topics from the physics curricula of Alberta (Appendix S5) and the province of Central Finland as represented by the communal curriculum of Jyväskylä (Appendix S6) functioned as a starting point for the design of all the materials.

Later the researcher found two learning packages, Natural Gas Energy Educational Kit (1982) developed by the American Gas Association and Fishman's (1985) package, both containing a range of problems and assignments that could have been incorporated in the learning materials used in the present study. Fishman's (1985) package included problems that were particularly mathematically oriented.

The planning of the text and the video programme started with the following ideas and principles as a basis: (most of these were drawn from the theoretical discussion presented in sections 2.2, 2.4, 3.1, 3.3, and 4.

1) Physics content was drawn from school physics books and other physics materials.
2) A concept map was formed to identify the central concepts and the relations between them.
3) A proper presentation order for the content was chosen.
4) Metatext was added to help students in concentrating on essential information and in seeing the relations between different concepts.
5) The points where pictures or photographs could be used to illustrate principles and processes were selected.
6) Applications related to real-life situations and their relations to the theoretical information were identified. The selection of applications was based on interviews conducted in companies that apply Gas Laws in their daily work.
   a) Some applications were presented in the beginning of the learning text as an introduction into the topic to motivate the students.
   b) Other applications were presented in one section of the text (after the basic theoretical section) to provide students with understanding of how the Gas Laws can be applied in "real life" for the benefit of people.
7) a) Avoiding difficult words or expressions that make the text too difficult and using more readily comprehensible words and expressions without losing accuracy. Scientific terminology will be used where necessary for learning purposes.
   b) Avoiding disconnections between different parts of the text by using additional information or metatext where necessary to link different parts of the text.
8) To bridge the gap between students' possible alternate conceptions and scientific views, it may be of use to follow the order according to which scientific knowledge has developed over the centuries (see section 3.3.3). Therefore, the gas laws were presented in the order they were discovered.
9) Giving context information which helps students to form an expectation of the type of incoming information and to process the information in the intended way using a) *appropriate titles* for the text to be learned and b) *incorporation of students' existing schemata into the instructional process* so that the materials are close to their experience and knowledge (see section 2.2). Accordingly, the titles were carefully considered and the topics dealing with

gases were presented starting from basic aspects that should already be familiar to the students from their earlier studies and experiences.

In addition to these design principles used in developing the "Student Textbook" and the video programme versions, three pilot studies were conducted in spring 1991 to provide information specifically for developing the textbook. The *first pilot study* was based on a task for students in teacher training in the secondary education department at the University of Alberta. Students were asked to brainstorm ideas in small groups to present the gas laws (one of the core content areas) in a clear and illustrative way. The groups produced some ideas that were later used in creating text, pictures, and graphs about the gas laws.

The *second pilot study* was conducted to provide information for writing a section describing research and utilization of gases. The purpose of this section in the text and in the video programme is to show students the usefulness and meaningfulness of the gas laws and other information regarding the behaviour of gases. This second pilot study was conducted by using three interviews based on a questionnaire (see appendix S7). Three companies dealing with gases were involved in this study: a gas company, a chemical company and a research company studying natural gas and oil samples. These interviews produced a good basis for writing the section and gave a realistic view of actual situations where the information about the gases is used in these types of company.

The *third pilot* study was carried out in senior high schools. The fifth draft version of the "Student Textbook" was given to physics teachers in three senior high schools. The teachers distributed the text papers to those students who agreed to go through the text according the instructions provided with the text (See appendix S8). The basic idea was to have students read the text and mark every point of the text, where they had difficulties - even slight ones - to understand the text. Approximately 20 students gave the requested feedback information. The feedback was used in improving the text so that the text would facilitate the reading/learning process. Besides the feedback provided by the students, several people representing different fields of expertise provided their feedback and suggestions for refining the text. Even after all these steps, some inaccurate expressions or errors were found in the English text afterwards. The errors are listed in appendix S11. Also the translated Finnish version included some errors. A letter listing the noted errors was sent to the participating teachers in Finland (Appendix S12).

When the text was considered good enough by the researcher, it was used as a basis for the narration of the video programme. Some parts of the text were used for narration as such, some were modified to better meet the requirements of the video programme, where close coordination between the narration and the picture is important. Some sections of the narration were specifically designed for the narration. The picture sequences of the video programme were usually created based on the narration and on some occasions they were designed independently before the narration was written for those sequences.

7.5 Data collection methods

The following data collection methods were used in classrooms during the experiments. The methods are presented in the order they were used during the research process. The cover pages of the data collection methods had certain colours indicating the phase of the process when they were expected to be used; the colours are noted in the following description. The first three questionnaires were completed by the participating students during one session before the experiments started. The cover pages of these three questionnaires were light green. The idea behind using several data collection methods lies in methodological triangulation (Cohen & Manion 1989, 274-275; see also section 7.7)

1) The Learning Questionnaire (appendix 1 contains the Finnish version of the original measures) was based on Dweck & Henderson (1989). The selected three short measures developed by Dweck and her colleagues were included in this questionnaire to provide information on students' conceptions about their intellectual abilities and learning potential. *Target group*: All students.

2) The Learning Process Questionnaire (LPQ) (appendix 2 contains the Finnish version of the original LPQ questionnaire) was directly adopted from Biggs' (1987a) publication where he presented the items of the Learning Process Questionnaire. It was used to measure the students' approaches (general learning strategies) to learning. *Target group*: All students.

3) The General Questionnaire - English version (Appendix 3) and Finnish version (Appendix S1) - was created by the researcher to collect information about students' background, relation to school and science learning, physics in particular. Selected items from the latest IEA/SISS study conducted in 1984 (see Connelly, Crocker, & Kass 1989) were also used in this questionnaire for the sake of comparison with the international data (The permission to use the IEA/SISS test items is in appendix 4). *Target group*: All students.

The next two methods were used at the very beginning of the experiment (1) before any learning materials were delivered to students and they were used again at the end (2) of the experiment. The cover pages of these two papers were light red.

4) The Concept Map + Essay 1 (2 and 3) - English version including the Finnish translation in brackets (Appendix 5). Students were asked to list all the concepts they knew related to gases and to form a concept map. The teacher first explained what the concept map is and showed how it can be made by creating a sample concept map with students. The teachers were asked to take the sample concept maps for their students from other than topics dealing with gases. Furthermore, neither of the two concept maps presented in every Teacher's Manual were about gases. The idea behind these procedures was that the students would not start memorizing and copying their own concept maps (during data collection) directly from the sample concept maps, but rather develop their own concept maps that better reflect their personal understanding of gases. Scores for the Concept Map + Essay 1 and 2 were given according to the guidelines presented in appendix 13. A total of 40 cases were excluded because either the Concept Map + Essay 1 or Concept Map + Essay 2 were missing or left unfilled. Furthermore, 23 cases were excluded (from 3 different schools) because either the Concept Map + Essay 1 or 2 was apparently not completed with serious intention. In practice those responses containing only bad language or humourous comments with no relevance to the topic were excluded. Also those few cases in which the Concept Map + Essay made during the post-test was clearly much worse compared to the one made during the pretest and to other learning measures during the post-test, were excluded. Inclusion of these cases would have distorted the data. *Target group*: All students.

5) The Multiple-Choice Questionnaire 1 (and 2) - English version (Appendix 6) and Finnish version (Appendix S2) - provided another way to collect information on students' knowledge concerning the behaviour of gases and the gas laws . *Target group*: All students.

6) The Task Papers - English version including the Finnish translation in brackets (Appendix 7) - were designed to provide information about how students solve problems dealing with the the behaviour of gases and the gas laws. These papers gave an opportunity to follow the progress students were making during the experimental periods. The five different Task Papers were completed by students, each after a certain instructional section (such as Boyle's law) was finished. The colour of all the Task Papers was white. *Target group*: All students.

The following four measures were used at the end of the experiments; The cover pages of these four papers were light blue. *7) The Concept Map + Essay 2* (see the description above). *Target group*: All students. *8) The Multiple-Choice Questionnaire 2* (see the description above) *Target group*: All students.

9) The Experience Questionnaire - English version (Appendix 8) and Finnish version (Appendix S3) - provided information on the experiences students had of the minicourse "The Behaviour of Gases and the Gas Laws" and of the materials used during instruction. *Target group*: All students.

10) The Teachers' Experience Questionnaire - English version (Appendix 9) and Finnish version (Appendix S4) - was used to measure teachers' experiences of the minicourse "The behaviour of gases and the gas laws". Part of the items were identical with the items in the corresponding students' questionnaire. *Target group*: All participating physics teachers.

The following method was to be used for follow-up four weeks after the end of the minicourse: *11) The Concept Map + Essay 3* (see the description above). *Target group*: All students. Many of the students did not complete these papers with serious intention or had too little time to do it properly or returned them unfilled. For these reasons Concept Map + Essay 3 will not be used in analyses.

*Instructional support material*s

The following two methods were used for instructional purposes as part of the experimental design. The idea was to produce systematic variation in *how* the video sections or teachers' instruction regarding the selected five topics (Boyle's law, Charles' law, the third gas law, General gas law, and the kinetic theory of gases) were integrated into the lessons in order to see the effects on the learning outcomes. The colour of all these papers was white.

1) The Video Assignment Papers - English version (Appendix S26) and Finnish version (Appendix S27) - were used prior to viewing each of the video sections described above to give students an assignment for viewing. The purpose of using these prior-to-viewing tasks was to see whether they help students to concentrate on the core information prompted in the assignments. *Target group*: treatment groups A, B, and C.

2) The Lesson Assignment Papers - English version (Appendix S28) and Finnish version (Appendix S29) - were used prior to instruction (given by the teacher) on each of the above mentioned topics. The purpose of using these prior-to-studying tasks was to see whether they helped students to concentrate on the core information prompted in the assignments. *Target group*: treatment group D.

The original plan was to test also a number of individuals in a laboratory setting using a video-taped stimulated recall together with eye-movement tracking equipment. However, since the equipment was not available and the amount of data was already challenging, the plan was cancelled.

7.6 Procedures

In Finland, the principals of all the senior high schools in the province of Central Finland (total of 24 schools) were first contacted by letter, which included an information package, (appendix S19) and then by phone. After the rectors gave their permission, all the physics teachers were contacted by phone and were sent an information package regarding the research project (see appendix S19). Later on a similar type of information package was prepared for students and their parents (see appendix S21). In Canada, after the school systems informed the researcher which schools would be available for the research project, the principals and the physics teachers were contacted by phone. An information package on the project was mailed to the principals before the phone contact and an identical information package was given to the physics teachers during the first face-to-face meeting (the information package is in appendix S18). A corresponding information package for the students and their parents was given to the students by their physics teachers (see the package in appendix S20).

Training the teachers. The researcher visited all the participating senior high school physics teachers in their schools and had individual face-to-face training sessions with them. The sessions took from one to two hours depending on the teacher. During the sessions, all the materials and data collection methods were presented to the teachers and they were instructed how and when to use the methods and how to teach the topic. Each teacher was given his or her own written manual including all the information needed to carry out the minicourse. Contact information was provided for the teachers in case they had any questions or concerns regarding the research project. Four of the sixteen Finnish teachers and three of the eight Canadian teachers used this opportunity and called the researcher to confirm whether they had understood some directions correctly.

Teachers from each treatment group were given their own Teacher's Manual with a letter of the alphabet indicating the treatment group. Most text sections in the Teacher's Manual were the same in all versions of the manuals. These common features included, for example, some basic rules or principles according to which the teachers were asked to teach. However, the detailed planning of the lessons was to be decided by each teacher. Appendix S22 contains one complete teacher's manual (manual A - English version) and the pages that differ in other manuals (B to H) are placed at those points where the differences appear. The corresponding teacher's manual in Finnish is in appendix S23. Sample concept maps in the appendix section of the Teacher's Manual were from Pefirsson & Denner (1989). The idea of giving the training and the manuals was to have control over the instructional processes in order to better detect the effects of the video programmes and the instructional interventions (video and lesson assignments). At the same time the aim was to let learning happen in a "normal way", that is, in physics groups taught by their own physics teachers. The researcher also reminded the teachers to tell their students that the Multiple-Choice Questionnaire 2, and the Concept Map + Essay 2 would be used for academic evaluation purposes as part of their normal physics courses even if this would not be the case. This was to make sure that all students would take the test seriously.

Instruction given by the researcher could have improved the control over the experimental design with regard to its internal validity, but would have reduced its ecological validity (for more discussion on validity see section 7.7). In addition to giving proper guidelines for carrying out the experiment, the training was carried out to motivate and activate teachers. Knowing that special attention may cause extraordinary motivation plus other effects (Hawthorne effect) that are not comparable with normal circumstances, the results will probably represent the kind of effects that could be achieved with teachers who have attended in-service training dealing with the use of videos in schools. A somewhat longer period of training might have been more effective and could have produced even better control of intervening variables. However, considering that teachers have quite a heavy workload during the school terms, a brief, intensive training was considered to work best.

Experiments in classrooms. Students from typical senior high schools participated in experiments conducted in students' own classrooms, to provide a basis for good external validity and ecological validity. Experiments took place during physics lessons, and they were supposed to be integrated with school work, as if they were normal parts of it. This aspect was discussed during the training of teachers. Also the viewing of the video programme was integrated into the lessons, but now in a systematic way to study the effects of different versions of the video programme and instruction. The whole minicourse took about 4-5 physics lessons depending on the length of the lessons, approximately 240 minutes in total, apart from the initial data collection before the experimental stage.

In Finland, the data collection started in some schools in November 1992 and ended in the last schools in March 1993. In Canada, the dates were November 1991 and April 1992 respectively. The viewing of the video programme and the data gathering were designed to be an integral part of physics instruction so that they would disturb lessons as little as possible. The following table illustrates the main elements of instruction and data collection immediately before and during the experimental phase.

TABLE 6 The main elements of instruction and data collection during the experimental phase in each treatment group in chronological order. Abbreviations used: prev = preview section, bsec = basic sections, app = application section

THE TREATMENT GROUPS							
Learning tasks				**No learning tasks**			
Video versions				**Video versions**			
prev+bsec	**bsec+app**	**bsec**	**no video**	**prev+bsec**	**bsec+app**	**bsec**	**no video**
A	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Training sessions for the teachers before the minicourse: Individual training sessions for all the teachers in all the treatment groups during which the content of the Teacher's manual were discussed in detail. In addition to general guidelines, each manual contained specific directions on how to carry out the experimental stage in each treatment group. The manuals and all the related materials were given to the teachers during the training session.							
Data collection methods used before the experimental stage, in the order they were used:							
Learning Questionnaire							
Learning Process Questionnaire							
General Questionnaire							
At the beginning of the experimental stage: Teachers give a brief, general introduction on the minicourse							
Data collection methods used at the beginning of the experiment, in the order they were used:							
Concept Map + Essay 1							
Multiple-Choice Questionnaire 1							
("Student Textbook" and "Student Workbook" distributed to the students)							
Introduction to the topic "The behaviour of gases and the gas laws" begins.							
Sub-topic: Boyle's law							
Video Assignment paper 1			Lesson Assignment Paper 1	No specific directions given before the instruction			
Viewing of the video section: "Boyle's law"			Instruction by the teacher about Boyle's law	Viewing of the video section: "Boyle's law"			Instruction by the teacher about Boyle's law
							(continues)

(table 6 continued)			
Task Paper 1			
Sub-topic: Charles' law (or Gay-Lussac's law)			
Video assignment paper 2	Lesson Assign-ment Paper 2	No specific directions given before the instruction	
Viewing of the video section: "Charles' law"	Instruction by the teacher about Charles' law	Viewing of the video section: "Charles' law"	Instruction by the teacher about Charles' law
Task Paper 2			
Sub-topic: The third Gas law (or Gay-Lussac's law)			
Video assignment paper 3	Lesson Assign-ment Paper 3	No specific directions given before the instruction	
Viewing of the video section: "The third Gas law"	Instruction by the teacher about the third Gas law	Viewing of the video section: "The third Gas law"	Instruction by the teacher about The third Gas law
Task Paper 3			
Sub-topic: The Combined gas law			
Video assignment paper 4	Lesson assign-ment paper 4	No specific directions given before the instruction	
Viewing of the video section: "The Combined gas law"	Instruction by the teacher about the Combined gas law	Viewing of the video section: "The Combined gas law"	Instruction by the teacher about the Combined gas law
Task Paper 4			
Sub-topic: The Kinetic Theory of Matter			
Video assignment paper 5	Lesson assign-ment paper 5	No specific directions given before the instruction	
Viewing of the video section: "the kinetic theory of matter"	Instruction by the teacher on the kinetic theory of mat-ter	Viewing of the video section: "the kinetic theory of matter"	Instruction by the teacher on the kinetic theory of mat-ter
Task paper 5			
Other instruction about gases			
Data collection methods used right at the end of the experimental stage, in the order they were used:			
Concept Map + Essay 2			
Multiple-Choice Questionnaire 2			
Experience Questionnaire (student and teacher versions)			
Data collection method used approximately four weeks after the experimental stage:			
Concept Map + Essay 3 (this was not used in analyses, because of missing and distorted data)			

7.7 Validity and reliability

The validity and reliability of the study will be discussed mainly from two different perspectives: the validity related to the experimental design (internal and external validity) and the validity and reliability of the data collection methods. The external validity of the sample (see Valkonen 1978, 77-79) from the province Central Finland, can be considered as quite good (for more details about the sampling see section 7.2).

7.7.1 Internal validity of the experimental design

With regard to experimental designs, one of the most important things is internal validity, which is "the validity with which statements can be made about whether there is a causal relationship from one variable to another in the form in which the variables were manipulated or measured" (Cook & Campbell, 1979, 38). Forty years ago already Campbell and Stanley (1963) wrote about a systematic way to evaluate the internal validity of an experimental design.

The design used in this study can be regarded as an extension of non-equivalent control group design, which typically consists of school classes. This means that classes rather than individuals were randomly assigned to the treatment groups. The design in this study should be able to give relatively good control over the following sources of (internal) invalidity: History, maturation, testing, instrumentation, selection, and mortality (Campbell & Stanley, 1963, 40).

A careful plan was carried out to ensure that at least the main factors in instruction would be as similar in all the treatment groups as possible to make it possible to detect the effects of the systematic variations (different versions of the video programmes, and the use of learning tasks). Especially the teacher's manuals handed out to every teacher, the individual 1-2 hours training sessions for the teachers, and the learning materials (the same for all students) given to the students gave control over intervening factors. It should also be noted that the "Student Textbook" and the video programme sections were based on the same material. The "Student Textbook" had similar types of diagrams and pictures as used in corresponding sections of the video programme. The most significant difference in the visual elements of these two learning materials was that the video sections included animated movement, thus giving extra information about the processes. Therefore the effects of the video sections on the learning outcomes can be more accurately determined. However, given the length of the minicourse and the natural school settings where the study was carried out, it was impossible to control all the factors that affect learning.

There were some problems in carrying the experimental design that must be considered in interpreting the results. The main concerns were as follows:

1) Expectations about testing were different from the intended - at least in one class in treatment group H. The teacher of this group did not remember to tell the students that the Multiple-Choice Questionnaire 2, and the Concept

Map + Essay 2 would be used for academic evaluation purposes as part of their normal physics courses.
2) The proposed amount of time used for data collection at different stages of the experimental phase varied in some groups.
3) The treatment groups having learning tasks (Video assignments or Lesson assignments) prior to video viewing/instruction had more paperwork than the groups without these tasks.
4) Loss of respondents (between pretest and post-test)

These problems are discussed here to estimate their effects on the internal validity of the experimental design.

1) *Expectations about testing*. The original idea was that all the teachers tell their students that their learning will be evaluated at the end of the minicourse for grading purposes, not only for research purposes. This was to guarantee that students take the minicourse seriously in a way that would be similar to any other physics courses they take in school. One of the teachers said afterwards she did not tell her physics group that they would be evaluated for grading purposes. This has probably resulted in weaker motivation for the group to try their best. The results of this one group in treatment group H (control group with no video) will be critically noted when interpreting the learning outcomes. As to the means to avoid this type of problems the teacher's manual gave specific directions in "(5) Measuring learning outcomes" about informing the students that their learning would be evaluated especially based on their understanding as expressed in their Concept Maps + Essays. This aspect was clearly emphasized also verbally during the individual training sessions for the teachers.

2) Due to the relatively *strict time limits* given for the experimental stage, many teachers felt they had too little time to cover the topics of the minicourse, which caused some teachers to exceed the time limit (240 minutes). The total time differences spent on the experimental stage among the treatment groups varied from about 5 to 20 minutes according to verbal reports by the teachers. Even though the time differences are not longer than these, they may have caused some differences in learning outcomes, which must be remembered in evaluating the results.

3) The experience questionnaires suggest that the students were apparently disturbed by *the amount of paperwork* they had to do during the experimental stage. Since the treatment groups A, B, C, and D (the groups that had learning tasks prior to instruction) had more paperwork (Video assignments or lesson assignments) than the rest of the groups (groups that had no learning tasks prior to instruction), it can be assumed that the performance of the learning task groups might have been even slightly better with less paperwork. Therefore, it seems probable that the positive effects of learning tasks (see section 8.5.2) were rather underestimated than overestimated.

4) *The mortality* (between pretest and post-test) was considerable. Given the nature of the experimental design used, the design should be able to give rather good control over the mortality effect (see Campbell & Stanley, 1963, 40).

With regard to the use of Concept Maps + Essays as part of the data collection, there may have been some differences between the treatment groups in how familiar they were in drawing/writing them. This particular aspect, however, was not controlled in this study.

Summa summarum, the internal validity of the experimental design can be considered quite satisfactory. There must, however, be some caution in interpreting the results regarding the effects of different factors on learning the behaviour of gases.

7.7.2 External validity of the experimental design

External validity in an experimental study refers to "the approximate validity with which conclusions are drawn about the generalizability of a causal relationship to and across populations of persons, settings, and times" (Cook & Campbell, 1979, 39). As explained earlier in sections 7.3, 7.4. and 7.6., raising the external validity was one of the main objectives in this study: the content of the video was drawn from actual physics curriculum, and the way the video programme was used is rather typical of a school context, excepting the amount of paperwork (see section 7.7.1 and 7.7.4 for more information on the effects of paperwork). In many earlier studies the comparison of videos to other materials, such as radio programmes, written materials, or traditional lectures, has been artificial in the sense that the topics were not always part of a normal school curriculum and they were often some isolated topics without a broader context around them, the length of the treatment was often short, and the situations in which the videos were used were not similar to the situations in school settings.

In this study the idea was to start from an actual curriculum: the minicourse during which the videos were used, was based on the senior high school physics curriculum of Alberta and on a similar curriculum of Jyväskylä, Finland. Actual senior high school physics textbooks and some additional articles and interviews were used as sources for writing the “Student Textbook” used during the experimental stage. All this together with students’ own physics teachers and classrooms, provided a meaningful context in which the videos were used for illustrating the behaviour of gases.

The students in this study had to do considerably more paperwork and their time budget was stricter than normally. In practice this means that in normal school situations the learning effects of using video programmes would probably be more positive. However, there is a very important aspect that has to be considered: None of the treatment groups carried out any laboratory experiments. Had the students been doing experiments, the learning results might have been different. The idea of using a video programme is not to reject laboratory work when the facilities are available, but rather to use video programmes when laboratory experiments cannot be carried out. Video programmes can also be used as complementary materials during lessons including laboratory activities, because the programmes can include animation sections illustrating processes and aspects which cannot be simulated in laboratory settings. An example of such processes are the aspects of the kinetic theory of gases presented in the video programme used in the present study.

Considering all the factors as a whole, the external validity can be seen as rather good. Nevertheless, the limitations described above should be noted.

7.7.3 Validity of the data collection methods

The validity of a data collection method refers to its ability to measure what it is meant to be measuring (e.g. Eskola 1974, 85; Kerlinger 1986, 417). In this study a number of different data collection methods were used, some for the purposes of providing multiple perspectives, and some for different purposes.

The Learning Questionnaire consisted of three measures of students' perception of their intelligence (Theories of Intelligence, Goal Preference, and Confidence in Intelligence) by Dweck and Henderson (1989). Previous studies reported in Dweck and Henderson (1989) have provided information suggesting the validity is good. Theories of Intelligence and Confidence in Intelligence correlated rather weakly with some other aggregate variables (see table 25). The correlations, however, were logical in terms of the interpretations (excepting one), so in this respect the Learning Questionnaire seems to work fairly well.

The Learning Process Questionnaire (LPQ) by Biggs (1987a) designed to measure students' approaches to learning (consisting of sub-scales of motives and strategies) has been used in rather many studies. Biggs (1987a, 27) states, after referring to some studies using LPQ, that "these patterns are quite consistent with the theory underpinning the LPQ and illustrate the fact that scale scores relate to student performance in consistent and predictable ways". It seems, however, that one of the main scales, the Surface Approach, is not as good as the other two, the Deep Approach and the Achieving Approach. This was seen also in the results of a factor analysis (appendices 15 and 16) used for checking whether the factor loadings were the same as suggested in the original factor structure: high loadings for the items belonging to a particular scale, such as the deep motive, or the deep strategy.

The General Questionnaire consisted of scales measuring students' attitudes towards school and physics and their thoughts about school. This questionnaire included quite many attitude items adopted directly from questionnaires used in the IEA/SISS study in Canada and in many other countries. The scales proved to be quite consistent internally (see reliability) and their inter-correlations and correlations to other variables (particularly knowledge on gases) were predominantly logical and easily interpretable (see section 8.4.3). This gives reason to believe that the validity is good.

The Task Papers 1 - 5 were used both as learning materials and for following up how students learn the gas laws and aspects of the kinetic theory of gases. The tasks were typical physics problems including a need to apply proper equations and make calculations, excepting the Task Paper 5, which was a qualitative task requiring description of certain key aspects of the kinetic theory in writing. Some of the tasks were adopted from the physics books used as sources for writing the "Student Textbook". All the tasks were clearly focussed on topics they were designed to measure. Generally, the validity of the Task Papers can be considered quite good.

The Concept Map + Essay 1 and 2 were used to estimate students' knowledge of the behaviour of gases from the perspective of the structure of knowledge and relations between different propositions. These measures provide information on the learning outcomes on a more qualitative basis compared with the more quantitatively oriented Multiple-Choice Questionnaire described below. Concept Maps + Essays also better reflect students' active learning in that they allow the measurement of learning in a "free recall" situation, while the Multiple-Choice Questionnaire items prompt the students with the elements to which they respond.

Although the validity of a concept map and an essay as such is usually good when determining students' active learning, there were two aspects that must be kept in mind. First, the use of concept maps may not have been familiar to all the students: the use of the concept map technique itself may have required their attention, thus leading to deteriorated performance. It would have been useful to include a control question about this aspect in the General Questionnaire. Secondly, the strict timetable and rather extensive paperwork during the experimental stage were probably too demanding for most of the students. As a result of the time factor and the workload, it seems evident that all of them were not able to do their very best in making the second Concept Map + Essay during the post-test (see more in section 8.6.1). All this has probably led to systematically decreased learning results. Furthermore, possible differences in teachers' interpretations regarding the guidelines of using the Concept Maps + Essays and differences in teachers' and students' experiences of using concept maps may have caused some variation in the results (see also section 7.3). Finally, it must be noted that many of the concept maps produced by the students can be regarded as mind maps in which the links between the concepts are not specified by indicating the nature of the link using words or symbols. However, in this study it was the combination of the concept map and the essay that determined the final score for each aspect of this method (see appendix 13 for details). Therefore, most of those concept maps resembling mind maps, can in a sense be regarded as "true" concept maps together with the information presented in the related essay.

The Multiple-Choice Questionnaire 1 and 2 were also used to estimate students' knowledge of the behaviour of gases. The fourteen items were selected to provide a good coverage of the main aspects regarding the gas laws and the kinetic theory of gases supplemented with some other general aspects of the behaviour of gases. The number of items dealing with the gas laws was deliberately greater compared with items measuring other aspects. This is because the gas laws were the main topic of the whole minicourse. The Multiple-Choice Questionnaire can be considered to have good validity in measuring the amount of factual information regarding the behaviour of gases.

The Experience Questionnaire consisted of items measuring students' experiences of the minicourse dealing with the behaviour of gases. There were also five identical items used for measuring students attitudes towards studying gases that were already used in the General Questionnaire. As with the General Questionnaire, the internal consistency (see reliability) and the correlations of these scales support the conclusion that the validity is good.

As can be seen from the feedback of the participating students regarding the minicourse on the behaviour of gases, the rather extensive number of data collection methods and learning assignment papers caused many students an overload of paperwork. This overload may have caused some distortion in the validity: Instead of measuring purely physics learning in "regular" situations, the results may also reflect students' responses under "frustrating" situations. However, given the experimental design used in this study, these problems should not be very harmful with regard to the overall picture of physics learning studied here.

7.7.4 Reliability of the data collection methods

Check-Question reliability. Some questionnaires in this research project had check questions to control the consistency of students' answers. The correlation coefficients of each pair of questions are presented questionnaire by questionnaire. Data regarding the General Questionnaire in table 7 suggest the reliability based on check-questions was quite reasonable. Keeping in mind that the check questions were not (deliberately) completely identical with the original ones, the reliability can be considered satisfactory (correlations mostly around .60 and .70).

TABLE 7 Reliability of the General Questionnaire based on check-question correlations

Variable	Check-question	r	
		Finland	Canada
... to fill up time (26)	... just to give something to do (34)	.52	.61
I like school (36)	I generally dislike my schoolwork (49)	-.65	-.49
I like school (36)	School is not very enjoyable (59)	-.74	-.71
I generally dislike my schoolwork (49)	School is not very enjoyable (59)	.72	.47
Physics is an interesting subject for me (38)	The physics taught at school is interesting (60)	.66	.66
Physics is an interesting subject for me (38)	Physics is an enjoyable school subject (50)	.61	.74
I already know fairly well how gases behave (69)	I know very little about gases and their behaviour (72)	.54	-.72

Factor analysis was used in reducing the number of variables regarding students' attitudes and thoughts about school and physics (the General Questionnaire) and in increasing the reliability. Factor extraction was based on principal component analysis, which forms linear combinations of observed variables. Before entering the variables for factor analysis the variables with "technical correlations" were excluded; that is, check questions were left out. None of the attempts produced a satisfactory factor solution for interpretation. Therefore, the results of the factor analysis were used only as a supplementary means to select single variables for creating aggregated variables. To limit the size of an already extensive appendices section, the output of these factor analyses will not be included. Logical analysis of the content of the variables connected with reliability analyses (alpha) provided the extra information needed to decide the final scales. The alpha coefficients provide information on the internal consistency of a scale consisting of variables using a uniform ordinal scale (see e.g. Valkonen 1978). The reliability results of the final scales are given in table 8.

Generally the alpha coefficients of these scales were rather good (around .80) or satisfactory (around .50 and .60), excepting the scale “Visuality in physics” with an alpha of only 0.51. Some of these scales were used in a number of further analyses (for more see chapter 8).

TABLE 8 Internal consistency of scales in the General Questionnaire

Scale[2]	**Alpha coefficient**	
	Finland	**Canada**
Ways to use videos in physics (g25,g27 to g33, g35)	.84	.88
Visuality in physics (g37, g41, g44, g64)	.51	.66
Connections of science to real life (g42, g43, g45, g52, g53)	.62	.74
Difficulties in physics (g40, g54, g56, g58, g63, g67)	.67	.68
Relation to physics (g38, g39, g46, g50, g60)	.78	.71
Relation to school and education (g36, g57, g59[2], g61[2], g62)	.77	.79
Relation to studying gases (g68, g70, g71[2])	.76	.75
Prior knowledge of gases (g69, g72[2])	.70	.84

1) Note that the numbers in brackets refer to the variables in appendix 10.
2) the original direction of coding reversed.

There were five questionnaire items used both during pretest and post-test. This gave an opportunity to check *test-retest reliability* by computing the correlations between the corresponding variables (table 9). Correlations were rather low considering the close resemblance of each pair of the variables. However, one must remember that real changes in attitudes and estimations may have happened during the experimental stage that can explain the low correlations.

Note that there were two pairs of variables that measure students' estimations of their prior knowledge of gases and their behaviour. One explanation for the considerably low correlations (.50) between these variables may be the simple fact that it is not an easy task to estimate one's prior knowledge. Thus, this may also reflect uncertainty in students' metacognitive abilities needed in self-evaluation of prior knowledge. Further analyses regarding the changes in these variables during the instructional period can be found in chapter 8.

TABLE 9 Test-Retest reliability of some questions in the General Questionnaire* and in the Experience Questionnaire (Note the difference in tense/content)

Test (question in the General Questionnaire)	**Retest (question in the Experience Questionnaire)**	**r**	
		Finland	**Canada**
I find gases and their behaviour as an interesting topic to learn about (g68)	I found gases and their behaviour as an interesting topic to learn about (exp1)	.34	.42
I already know fairly well how gases behave (g69)	I already knew fairly well the things we were taught (exp2)	.37	.50
I think it is useful to know more about gases and their behaviour (g70)	I think it was useful to learn more about gases and their behaviour (exp3)	.35	.27
Studying gases and their behaviour does not make sense to me (g71)	Studying gases and their behaviour did not make sense to me (exp4)	.29	.25
I know very little about gases and their behaviour (g72)	I knew very little about gases and their behaviour before this course (exp5)	.34	.50

* Note that the letter-number combinations in brackets refer to the variable list in appendix 10.

Table 10 shows the check question correlations of the *Experience Questionnaire*. The two correlations indicate a moderate consistency in students' answers given the fact that there are some differences between the original variables and the check questions.

TABLE 10 Reliability of the Experience Questionnaire based on check question correlations[1]

Variable	**Check-question**	**r**	
		Finland	Canada
I already knew fairly well the things we were taught (exp2)	I knew very little about gases and their behaviour before this course (exp5)	-.60	-.50
I feel confident that I understand the things we studied in the course (exp7)	I had big difficulties in understanding the things taught in the course (exp8)	-.71	-.47

1) Note that the letter-number combinations in brackets refer to the variable list in appendix 10.

Internal consistency of the scales in the Experience Questionnaire is not quite as good as it was in the scales of the General Questionnaire. However, it is good enough for the type of group comparisons used in this study (see alpha coefficients in table 11).

TABLE 11 Internal consistency of scales in the Experience Questionnaire

Scale[1]	Alpha coefficient	
	Finland	Canada
Relation to the course in general (exp1,exp3, exp12)	.64	.71
Prior knowledge of gases estimated after the course (exp2, exp5)	.73	.66
Experiences of the video programme (exp15, exp16, exp20, exp21[2])	.78	.81
Experiences of the written materials (exp10, exp11, exp13, exp14, exp17[2], exp19)	.72	.68
Experiences of understanding (exp7, exp8[2])	.83	.63

1) Note that the letter-number combinations in brackets refer to the variable list in appendix 10.
2) The original direction of coding changed.

In Dweck and Henderson's (1989) measures of theories of intelligence used in the present study there were two scales for which it was possible to compute alpha-coefficients. Both scales, Entity vs. Incremental Intelligence and Confidence in Intelligence seemed to be quite reliable in terms of their internal consistency (see table 12).

TABLE 12 Internal consistency (alpha) of two scales in the Learning Questionnaire[1]

Scale[2]	Alpha coefficient	
	Finland	Canada
Entity - Incremental intelligence (L1, L2, L3)	.86	.87
Confidence in Intelligence (L8, L9, L10, L11)[2]	.81	.75

1) Note that the letter-number combinations in brackets refer to the variable list in appendix 10.
2) Items were first coded to the same direction.

Biggs' (1987a) Learning Process Questionnaire was an instrument used for gathering information on students' learning processes, the way they study and learn. The alpha coefficients in the present study and in the Canadian data (Puukari 1994) were by and large the same as in Biggs' original norm sample (see table 13). Internal consistency can be considered satisfactory or reasonably good (coefficients from .60 to .80) except the Surface sub-scales.

A factor analysis (Principal components) using a Varimax rotation was used for checking whether the LPQ-items had high loadings on the factors to which they would be expected to belong according to the six sub-scales of LPQ. The number of factors was set to six according to the six sub-scales. The loadings showed that the factor structure obtained in this analysis was rather far from the expected factor structure (see appendix 15 for the inter-correlation matrix and appendix 16 for the rotated factor matrix). The common variance - communality - values of the items varied from .177 to .602. In a factor analysis the variance can be divided into three components: common variance, unique variance and error variance (see e.g. Sänkiaho 1974). Reliability is a combination of the common and unique variance, the latter of which is not known. Therefore, the communality value can be interpreted as a minimum level of reliability. Given the alpha coefficients and communality values, the reliability of LPQ-scales, as a whole, can be regarded as satisfactory.

TABLE 13 Internal consistency (alpha) of the Learning Process Questionnaire (LPQ) scales (the number of cases slightly varies from scale to scale)

Scale	**alpha coefficient**		
	Finland	**Canada**	**Biggs***
Surface Approach SA (all items from the two sub-scales)	.63	.60	.60
- sub-scale: Surface Motive SM (1, 7, 13, 19, 25, 31)	.45	.43	.45
- sub-scale: Surface Strategy SS (4, 10, 16, 22, 28, 34)	.57	.49	.55
Deep Approach DA (all items from the two sub-scales)	.74	.77	.73
- sub-scale: Deep Motive DM (2, 8, 14, 20, 26, 32)	.60	.66	.54
- sub-scale: Deep Strategy DS (5, 11, 17, 23, 29, 35)	.63	.68	.65
Achieving Approach AA (all items from the two sub-scales)	.74	.84	.78
- sub-scale: Achieving Motive AM (3, 9, 15, 21, 27, 33)	.59	.72	.67
- sub-scale: Achieving Strategy AS (6, 12, 18, 24, 30, 36)	.70	.80	.78
Deep-Achieving Approach DAA (all items from DA and AA)	.80	.87	-

* Year 11 students in a norm sample reported in Biggs (1987a,b)

Parallel Coder Reliability. *The Task Papers 1-5*. The criteria for scoring the Task Papers can be seen in appendix 12. Parallel coder reliability checking was not used here, because the criteria were very detailed, the responses of the students followed the same, quite clearly defined, basic lines, and all papers containing responses that were somehow difficult to interpret were thoroughly discussed with an expert in physics until unanimous agreement on the scoring was reached. Two experienced senior high school physics teachers were consulted by the researcher during this process.

Criteria for classification and scoring the *Concept Map + Essays (1 and 2)* are in appendix 13. Given the open nature of this data collection method, it was not possible to develop very detailed coding criteria, and the concept maps and essays produced by the participating students were not as clearly defined as their responses to the Task Papers. Therefore, a parallel coder reliability checking was made using a small, random sample of students responses. The sample had to be small, because it took a lot of time to get familiar with the coding criteria in order to score the responses. The same two physics teachers who discussed the unclear Task Papers with the researcher participated in parallel coding. Before this the researcher carried out the coding twice by himself. During the parallel coding process a number of inconsistences and incomplete criteria were observed. After thorough discussions the necessary changes and additions were made to the coding criteria and the scoring for the sample responses were completed by the parallel coders and the researcher. The final results of this coding process are in table 14. As seen in the table the parallel coder reliability can be considered very good. Using the finalized coding criteria the researcher - once again - coded all Concept Maps + Essays to ensure that the final scores follow the coding criteria as systematically as possible.

Methodological triangulation refers to a procedure where two or more methods of data collection are used in the same study (Cohen & Manion 1989, 274-275; Denzin 1970). In this study the Multiple-Choice Questionnaire 1-2, the Task Papers 1-5, and the Concept Maps + Essays 1-2 were all used for measuring students learning about gases. It is expected that the results obtained by these three methods correlate with each other - even though there are differences in perspectives and emphases. For calculating the correlations between the three methods, aggregated variables (or scales) were used: single points from the Multiple-Choice Questionnaires 1-2 were summed, as well as the points of the single Task Papers 1-5. Single scales of Concept Maps + Essays 1-2, Overall Structure (OS), Specific Structure and Coherence (SSC) and Content (C) were summed. Note that the Task Papers were not used as part of the pretest - post-test -design, and therefore the correlation of the Task Paper scores is calculated only between the Multiple-Choice Questionnaire 2 scores and the Concept Map + Essay 2 scores.

Given the fact that all the measures in table 15 clearly deal with behaviour of gases, the reason for rather low correlations probably lies in the fact that these measures require different cognitive skills, and not that they do not focus on the same content. From the perspective of methodological triangulation it is better to use these different measures even though the correlations are not high. From the point of view of learning it is interesting to see how the correlation between the Multiple-Choice Questionnaire and the Concept Map + Essay had increased during the pre- and post-test, which probably can be explained mostly by instruction.

TABLE 14 Parallel coder reliability of the Concept Map + Essay 1-2 scoring

Explanation of abbreviations: R = scores given by the researcher; A = scores given by the parallel coder A; B = scores given by the parallel coder B; r = correlation between the Researcher and parallel coder scores. OS = Overall structure; SSC = Specific Structure and Coherence; C = Content. For a detailed description on OS, SSC and C see appendix 13.

Concept Map + Essays 1							Concept Map + Essays 2						
	OS		SSC		C			OS		SSC		C	
case	R	A	R	A	R	A	case	R	B	R	B	R	B
169	2	2	8	7	10	11	158	4	4	12	13	32	32
192	2	2	3	3	14	12	196	4	4	8	8	29	31
194	2	2	7	9	14	17	199	2	2	6	9	14	15
215	2	2	6	6	11	11	215	4	4	15	15	34	35
227	2	2	9	11	20	20	227	2	2	11	12	17	18
241	4	4	6	7	18	18	241	2	2	6	5	14	16
361	2	2	2	2	8	8	246	2	2	9	9	18	18
380	2	2	10	10	13	14	272	4	4	9	9	20	20
400	2	2	6	7	20	19	301	2	2	10	8	23	26
423	2	2	7	7	7	7	312	4	4	12	17	29	28
430	2	2	2	2	5	5	317	2	2	7	7	20	20
431	2	2	11	12	13	13	376	2	2	12	12	33	35
459	2	2	8	10	15	12	378	2	2	9	10	24	24
466	2	2	6	5	10	10	439	2	2	5	5	7	7
490	2	2	4	5	6	5	444	2	2	4	4	8	7
r	1.00		.95		.96			1.00		.90		.99	

TABLE 15 Correlations between the summed scores of three data collection methods (The Multiple-Choice Questionnaires 1-2, the Task Papers 1-5, and the Concept Maps + Essays 1-2)

Data collection methods	**n**	**r**	**p**
Multiple-Choice Questionnaire 1 - Concept Map + Essay 1	243	.16	.01
Multiple-Choice Questionnaire 2 - Concept Map + Essay 2	240	.32	.000
Task Papers 1-5 - Multiple-Choice Questionnaire 2	279	.42	.000
Task Papers 1-5 - Concept Map + Essay 2	205	.38	.000

7.8 Data analyses and statistical methods used

Quantification of qualitative data and other preparations for data analyses

Even though most of the items included in the data collection methods were structured, containing a set of answering choices, there were also open questions and tasks. One method, the Concept Map + Essay (1-2), was specifically designed for obtaining qualitative information on students' learning about gases. Also the Task Papers (1-5) were designed for collecting data on students' learning about gases using an open format. Given the sample size (n = 358) it would have been too much work to go into very detailed, purely qualitative analyses, where, for instance, students' errors would have been studied. However, the collected qualitative data was carefully studied from various perspectives suggested by research literature and intuition, and systems to quantify the data into numeric scales were developed. The following provides an overview of the quantification processes. When these scales are discussed in the sections dealing with the results, readers are referred to the present section to see how the scales were constructed.

Socioeconomic status (SES) of the students, which was used as a background variable in some analyses, was obtained as follows. First the occupations of students' mothers and fathers were classified into four categories (1 - 4) according to ISCO-88 (1990) and education into seven categories (1 - 7) according to ISCED (1974). Coding rules used in some special cases, which are not included in the above two manuals, are in appendix 11. The values of these four variables were added together and the aggregated values were divided into the following four categories with value categories marked in the first brackets and frequencies for the Finnish data in the second brackets: low SES (4-8) (25), lower middle SES (9-13) (52), upper middle SES (14-18) (74), and high SES (47). The number of missing cases was large, 160: Many students either chose not to answer or did not remember the occupational titles or education of their parents. Given the large number of missing cases, the results of the analyses involving socioeconomic status must be critically interpreted and taken only as tentative. *Students' hobbies and activities*: Meriläinen (1989) was used as a basis for the classification of students' sports hobbies; other main categories were developed by the researcher after consulting a number of people.

The Concept Map + Essay (1-2). Since the main idea of using this method was to combine the benefits of a concept map and an essay to produce information both on the factual information and the structure of the information, both aspects were considered in developing a system to quantify the data obtained. After extensive consideration of various choices based on research literature presented in chapters 2 and 3 and on consultations with senior high school physics teachers, a set of three scales was developed by the researcher: 1) Overall Structure (OS), 2) Specific Structure and Coherence (SSC), and 3) Content (C). The third of these scales, Content, represents the amount of factual information found in from the essays and in the concept maps, while the other two scales are more - yet not totally - based on the concept maps. Note that only papers with both the concept map and the essay in both pretest and post-test phases properly filled in were included in the final analyses. After these strict criteria there were 243 concept maps available for data analyses (115 missing). Detailed information on the scoring rules of these three scales can be found in appendix13.

The Task Papers (1-5). All the Task Papers contained physics problems or questions dealing with the core topics of the video programme used in this study. Systematic scoring rules were developed for quantifying the level of students' performance on these tasks. Scoring these types of tasks is a demanding process. A number of senior high school physics teachers provided the researcher with the professional assistance needed in analyzing the many details which were hard to interpret. The model answers and their scoring are included in appendix 7. Due to the complexity of the data, a large number of exceptions and special cases had to be considered: the specific coding rules are in appendix 12. Furthermore, coding rules were also needed for some structured items in the General Questionnaire and in the Experience Questionnaire (see appendix 14).

One important grouping variable in a number of comparisons was students' *goal-orientation*, which had two values: 1) weakly goal-oriented and 2) strongly goal-oriented. This variable was based on a background question presented in the General Questionnaire (see appendix 3). The question "Do you expect to include any science subjects as part of your further education?" had four response options: 1) I expect to include science subjects, 2) I do not expect to include science subjects, 3) I do not expect to continue my education after leaving high school, and 4) I have not yet decided. Students who chose the first option were defined as strongly goal-oriented and student who chose any other option were defined as weakly goal-oriented. Even though this type of simple and straightforward grouping variable can be critiqued as being too simplistic and unreliable, it seemed to work well in all the analyses it was used.

The main data analysis methods used

Content analyses. There were a number of open questions in the General questionnaire and in the Experience questionnaire. The answers to these questions were analysed using content analysis. First, the researcher quickly read through all the answers and, based on the observations, a preliminary list of rather detailed content categories was created. Then the answers were read again, and each individual aspect in each response was marked into one of the existing content categories; during the classification process new content categories were created if needed. Finally, all the content categories and the respective frequencies were collected into tables. Concurrently some categories containing only a few cases were joined into new, broader categories. Since the categories used in tables were generally clearly and easily interpretable and the information included in these tables was "complementary" rather than "core information", no systematic evaluations regarding the reliability of the classification were made.

Statistical analyses were computed by the researcher using the SPSS for Windows 9.0 and 10.0 Software Packages. The following publications were used in planning the use of statistical methods: Malin and Pahkinen (1990), Valkonen (1978), Hand and Taylor (1987), Montgomery (1976), Winer (1971), SPSS (1992,a,b,c), Sänkiaho (1974), and Manninen (1976). The main statistical methods used in the study were:

1) Descriptive results:
- percentage distributions
- means (M)
- standard deviations (SD).

2) Comparisons between different sub-groups of the sample:
- t-tests (comparisons of two groups, for example, females and males)
- One-way ANOVA (comparisons of multiple groups, such as socioeconomic groups)

3) Testing the effects of the video programme versions and other factors:
- The explore option in SPSS (includes a number of graphs and parameters) was used to test the assumptions of analyses of variances
- General full-factorial ANOVA (2x4) with covariates and simple contrasts
- McNemar tests for investigating changes in individual items of the Multiple-Choice Questionnaire

4) Learning effects (pretest - post-test comparisons) inside each treatment group:
- pair-wise t-tests

5) Explaining students' experiences of the minicourse:
- Step-wise regression analysis

6) Reliability of the data collection methods
- Cronbach's Alpha
- Pearson correlation
- Factor analysis (Principal Component)

7) Testing the structure of the Learning Process Questionnaire (LPQ):
- Factor analysis (Principal component analysis with Varimax rotation)

8) Relations between some aggregated variables:
- Pearson correlations
- Cross-tabulations

With regard to testing the effects of the video programme versions and other factors the general full-factorial ANOVA (2x4) with covariates and simple contrasts was used. Gain scores (post-test score minus pretest score) were used in these covariance analyses as dependant variables (see section 8.5.2). When learning has been measured, the gain scores indicate the “learning effect”, they show how much (or how little) has been learned between pretest and post-test. It should be noted that the use of gain scores has been critiqued as it may be unreliable. Another option is to use the pretest and post-test scores as a repeated factor. This option was tested, but it seemed that the gain score -based analyses produced results that were more clearly interpretable. Therefore, the gain score option was used as a basis for the analyses.

8 RESULTS

The results will be presented in sections which follow the order of the research problems, except for the first section which contains general descriptive information on the subjects. All results are based on the Finnish data, if not otherwise indicated. Note that in tables and figures the complete name (letter/s + number) of a variable is given in brackets after the verbal label of the variable. The names of all the variables together with their answering scales/choices are in appendix 10. A label 'AGGREGATE' at the bottom of a table refers to an aggregate variable. The values of the aggregate variables were calculated by adding up the values of the single variables in a table for each case, and the sum of each case was then divided by the number of the single variables. For presenting distributions of the aggregate variables the original values of these variables were classified as follows: 1.00 - 1.49 = 1, 1.50 - 2.49 = 2, 2.50 - 3.49 = 3, 3.50 - 4.49 = 4, 4.50-5.00 = 5. Note that the means and standard deviations of the aggregate variables were calculated from the original values of the aggregate variable, not from the categorized values. Also note that in all tables means and standard deviations are rounded to one decimal, test values (such as t and F) are rounded to two decimals and probabilities (p) referring to statistical significance include three decimals. All the roundings are based on values obtained from output files of SPSS for Windows 9.0 and 10.0 versions. The following abbreviations will be used in all tables: n = number of subjects, f = frequency, % = percentage, M = mean, SD = standard deviation, p = probability/statistical significance, r = (Pearson) correlation, R = multiple correlation, n.s. = non significant.

8.1 School and leisure time activities of the students

This section provides a brief overview of students' school performance and of how much time they spent on different activities during their school and leisure time. This section also includes information on students' main hobbies as they have described them in their responses to an open-ended question. The purpose of this section is to give the reader a better understanding of the target group. Some of the variables presented here will also be used in other analyses discussed in later sections.

TABLE 16 Frequencies of students' school and leisure time activities

Activity Hours a week spent on ...	Occurrence (number of hours)						n
	never (1)	up to 2 (2)	3-5 (3)	6-10 (4)	11-20 (5)	>20 (6)	
all homework (g9)	1	40	121	148	37	5	352
science homework (g10)	3	136	163	44	6[1]		352
watching TV (g12)	9	21	84	122	94	23	353
watching videos (g13)	109	189	50	3	2	1	354

1) the last answering category for this question was "more than 10 hours"

Table 16 shows that the majority of the students spent from 3 to 10 hours a week on all their homework, and up to 5 hours a week on science homework. Many students seem to spent more time on watching TV than on their homework, but video viewing is considerably less frequent among them. The results follow the same general tendency seen also in the Canadian data (see Puukari 1994, 87).

Table 17 indicates that not many Finnish students worked during the school term, excepting a small number of individuals. In Canada working was considerably more common.

TABLE 17 Students' working hours per week during a school term in Finland and in Canada

hours/week	0	1-5	6-10	11-15	16-20	21-25	26-30	>30	n
Finland (f%)	89	8	2		1				347
Canada (f%)	55	2	7	12	15	3	3	3	139

The General Questionnaire had one open-ended question regarding students' main hobbies and other activities. The original idea was to use also the information on how many hours per week students spend on each hobby/activity. However, many students left this information out and many of those who answered did not specify which hobbies the hours referred to. Therefore, only the information regarding the type of hobbies/activities will be used here. All the hobbies were classified according to the categories presented in appendix 17. The percentages in the appendix were calculated from the total number of each of the two student samples (Finnish/Canadian). There were 18 missing cases in the Finnish and 13 in the Canadian student samples. Meriläinen (1989) was used as a basis for classification of students' sports hobbies; other main

categories were developed by the researcher after consulting a number of people. Table 18 shows the frequencies of main categories
of students' hobbies and activities. Note that an individual student may have mentioned more than one hobby belonging to the same category.

TABLE 18 Frequencies for main categories of Finnish (n= 358) and Canadian students' (n=143) hobbies and other activities based on open-ended questions

Main category of hobbies and other activities	Finland (f)	Canada (f)
Full or part-time work (sh1)		4
Radio, television, and video viewing/listening (sh2)	12	10
Collecting (sh3)	3	10
Reading, languages, and writing (sh4)	701	20
Social life (sh5)	15	35
Sports and recreation (sh6)	2712	946
Art hobbies (sh7)	1123	36
Technical hobbies and handicraft (sh8)	814	25
Community work and social issues (sh9)	335	14
Other hobbies and activities	32	13

The great majority of the students mentioned at least one form of sports or recreation as one of their main hobbies. Art hobbies, social life, technical hobbies and handicraft and also reading, languages and writing were rather popular main activities among the students. It should be noted that students decided themselves the activities they considered to be their main hobbies. Thus, many students may, for example, listen to radio or watch television quite a lot, although they do not regard it as their "hobby". The frequencies of the detailed categories of hobbies are in appendix 17.

8.2 Using videos in senior high school

This section deals with use of videos in senior high schools as perceived by students. First there will be an overview concerning the relative frequency of video usage in different subjects followed by a closer look at the ways videos are used in physics.

As seen in table 19 biology, geography, Finnish, and religion, in particular, seemed to be the subjects where videos were most frequently used. This is understandable since these are subjects for which there are relatively many video programmes available. The main purpose of these questions was to see how physics relates to other subjects with regard to how frequently videos are used.

TABLE 19 Use of videos in different subjects in senior high school according to students' answers (Percentage distributions)

Subject (n)	never (1)	some-times (2)	rather often (3)	often (4)	very often (5)	M	SD
Physics (352)	68	31	1			1.3	0.5
Chemistry [1] (286)	68	32				1.3	0.5
Finnish (354)	40	47	11	2		1.8	0.7
Mathematics (349)	98	2				1.0	0.1
Biology [1] (315)	42	33	18	4	3	1.9	1.0
Foreign languages (351)	54	39	6	1		1.5	0.6
Religion [1] (346)	7	42	31	13	7	2.7	1.0
Geography [1] (330)	45	33	13	6	3	1.9	1.1
Psychology [1] (144)	64	21	8	5	2	1.6	1.0
History and social science [2]	1					1.0	0.0

1) Some students do not have courses in this subject as part of their senior high school study programme; 2) Only one student replied to this; many physics students do not have courses in this subject as part of their senior high school study programme

Although the way of evaluating video use cannot be considered a very reliable one (some deviation among answers within each physics student group existed), a general conclusion can be made that videos are used rather rarely in physics (see table 20). This may have slightly affected the learning results in this study as the treatment groups using the video programme have not got used to using videos as part of their physics instruction (possible Hawthorne effect).

The most common ways to use videos in physics instruction were: showing how theory applies to practice, introducing new concepts, summarizing the content studied, and providing a basis for discussion. Comparison of the aggregate video use variable (last in table 20) to the corresponding variable in table 19 shows that both provide approximately the same picture: videos were quite rarely used. The correlation between the two variables was quite strong (Spearman's rho 0.82), indicating that students' ratings are rather consistent. There were, however, some differences between the treatment groups in how often videos were used in their physics instruction. These differences may have had some effect on the results obtained in other analyses comparing the treatment groups, but these effects are probably quite small since the actual differences (in means) between the treatment groups were not so large, though some statistically significant differences were detected (see appendix 18).

TABLE 20 How videos are used in physics in senior high school according to students' answers (n=346)[1]; Percentage distributions

Video use	never (1)	some-times (2)	rather often (3)	often (4)	very often (5)	M	SD
Summarizing the content studied (g25)	86	12	5	15		1.2	0.5
Filling up time (g26)	87	11	2			1.2	0.4
Tasks used when viewing videos (g27)	89	9	1	1		1.1	0.4
Videotaped feedback about performance in laboratory (g28)	98	2				1.0	0.1
Providing a basis for discussion (g29)	84	14	2			1.2	0.5
Giving instructions for working (e.g. in lab.) (g30)	95	3	1	1		1.1	0.4
Introducing new concepts (g31)	75	20	3	2		1.3	0.7
Giving video cameras for gathering information (g32)	99	1				1.0	0.1
Making a video programme (g33)	99		1			1.0	0.2
Showing how theory applies to practice (g35)	77	19	2	2		1.3	0.7
AGGREGATE[2] (GVIDUSE)	92	8				1.1	0.3

1) The number of cases varied from 343 to 346 depending on the variable; As a rule - with one exception - the figures were rounded to the nearest whole number; if only one case was involved the percentage figure was marked as zero (empty cell). 2) Classification of values from 1 to 5: 1 (1-1.49), 2 (1.50-2.49), 3 (2.50-3.49), 4 (3.50-4.49), and 5 (4.50-5.00)

8.3 Affective and cognitive factors in students' learning

8.3.1 Students' perception of their intelligence

Dweck and Henderson (1989) developed measures to study peoples' implicit beliefs or as they call them 'theories about intelligence'. The results of three measures used in the present study are shown in the following tables. Table 21 shows the majority (45 %) of the students can be classified as incremental theorists, who see their intelligence as something that can be developed. 40 % of the students were entity theorists sharing the idea that intelligence is something given, more static and unchangeable. Uncertain, or the in-between group included 15% of the students.

Students were also supposed to put a check by the kind of problems they would like to work on. The idea was to choose only one problem type so that it would have been possible to determine whether they prefer a performance goal or a learning goal. However, quite many students chose more than one problem type. Therefore, table 22 contains two columns for percentages: the first column includes all students who responded and the second column the students who chose just one alternative. Based on the second percentage column, the great majority of the students preferred learning goals, about one seventh of the students preferred challenging performance goals, and the rest of the students preferred easy performance goals over the other goals.

TABLE 21 Students' (n=353) conceptions of their intellectual abilities: Entity vs. Incremental Intelligence. Percentage distributions

Variable	strongly agree (1)	agree (2)	sort of agree (3)	sort of disagree (4)	disagree (5)	strongly disagree (6)	M	SD
You have a certain amount of intelligence and you really can't do much to change it (L1)	2 (2)	13 (5)	19 (19)	26 (17)	34 (36)	6 (21)	3.9 (4.4)	1.2 (1.3)
Your intelligence is something about you that you can't change very much (L2)	4 (3)	18 (8)	24 (13)	23 (18)	28 (40)	3 (19)	3.6 (4.4)	1.3 (1.3)
You can learn new things, but you can't really change your basic intelligence (L3)	7 (3)	33 (14)	21 (18)	26 (19)	11 (34)	2 (12)	3.1 (4.0)	1.2 (1.4)
AGGREGATE: Entity vs. Incremental Intelligence (SLENTITY)	(mean: 1.0-3.0) Entity theorist 40 (21)		(mean: 3.1-3.9) Uncertain 15 (10)		(mean: 4.0-6.0) Incremen.theor. 45 (69)		3.5 (4.3)	1.1 (1.2)

TABLE 22 Students' goal preferences - the third column contains the students that chose only one problem type giving an opportunity to use goal-choice classifications

Type of problem	**% (n=356)[1]**	**% (n=238)**
Problems that aren't too hard, so I don't get many wrong (L4)	10	11[2]
Problems that are fairly easy so I'll do well (L6)	20	5[2]
Problems that are hard enough to show that I'm smart (L7)	30	15[3]
Problems that I'll learn something from, even if they're so hard that I'll get a lot wrong (L5)	72	69[4]

1) Note that the sum is not 100, because a number of students chose more that one type of problem; 2) Easy performance goal; 3) Challenging performance goal; 4) Learning goal

Table 23 shows that a vast majority of the students were confident about their intelligence and only few of them seemed to have really low confidence in their intelligence.

Table 24 indicates the number of students classified into the different groups of Henderson and Dweck's model. Before this classification the variables were recoded in the following way: For the 'Entity vs. Incremental Intelligence -variable' the in-between group was coded as missing, for the Goal preference -variable all the performance goal choices were combined as one group, and for the 'Confidence in Intelligence - aggregate variable' categories 1-3 (see table 23) were combined into 'low confidence' group and categories 4-6 were combined into 'high confidence' group. After the cross-tabulations only five students were left in the 'Entity - performance goal - low confidence' group, and 23 students in the 'Entity - performance goal - high confidence' group, while 75 students were in the 'Incremental - learning goal - high/low confidence' group. Since the sample size was rather small even before the cross-tabulations, the number of cases in the above listed "final" groups was too small for any further analyses: Five students in the group of helplessness type of learning behaviour was not enough for comparisons.

TABLE 23 Students' (n= 353) confidence in their intelligence (Percentage distributions)

Statement A	**very true for me (1)**	**true for me (2)**	**a little true for me (3)**	**a little true for me (4)**	**true for me (5)**	**very true for me (6)**	**Statement B (M/SD)**
I wonder if I'm intelligent (L8)[1]	1	3	15	42	34	5	I usually think I'm intelligent. (4.2 / 0.9)
I'm not sure I'm smart enough to be successful (L9)		5	17	26	41	11	I'm pretty sure I'm smart enough to be successful. (4.4 / 1.1)
When I get new material, I often think I may not be able to learn it (L10)		3	11	31	48	6	When I get new material, I'm usually sure I will be able to learn it (4.4 / 0.9)
I'm not very confident about my intellectual ability (L11)		4	16	31	42	7	I feel pretty confident about my intellectual ability. (4.3 / 1.0)
AGGREGATE[2] LOW confidence (SLCONFI)			10	38	45	7	AGGREGATE HIGH confiden. (4.3 / 0.8)

1) n = 352; 2) n = 350, classification of values: 1 (1.00-1.49), 2 (1.50-2.49), 3 (2.50-3.49), 4 (3.50-4.49), 5 (4.50-5.49), 6 (5.50-6.00)

TABLE 24 The number of students classified into the groups of Henderson's & Dweck's model

Type of theory	Goal preference[1]	Confidence in Intelligence	Behaviour pattern
Entity theory 140	Performance goal 43	high 23	Mastery-orientation
		low 5	Helplessness
Incremental theory 161	Learning goal 117	high or low 75	Mastery-orientation

1) includes only those students who selected one goal preference

Comparisons

Since more elaborated comparative analyses were not possible, some basic aspects were analysed using simple methods: t-tests, F-tests, and correlation coefficients. No significant differences were found between females and males (appendix 19), socioeconomic groups (appendix 20), or between weakly and strongly goal-oriented students (appendix 21) in 'Entity vs. incremental intelligence'. Males were somewhat more 'Confident in their intelligence' than females, higher middle SES group more confident than lower middle SES group and strongly goal-oriented students more confident than weakly goal-oriented students (see the same appendices respectively). There were no significant differences between Canadian and Finnish students in their 'Confidence in their intelligence', but the Canadians tended more towards incremental understanding of intelligence than the Finns (appendix 22). With regard to goal-orientation, there were 60 females and 124 males who were strongly goal-oriented (planning to include science subjects as part of their future education) and 62 females and 107 males who were weakly goal-oriented (no science subjects/not yet decided/not continue education).

Correlation with other variables

The raw scores of Entity vs. Incremental intelligence -aggregate variable were used in computing correlations with other aggregate variables. It appeared that practically all the correlations were very small and statistically non-significant. 'Confidence in Intelligence' correlated more strongly with other aggregate variables, which is probably partly due to the larger distribution of this variable. Based on the correlations in table 25 we can say that students'confidence in their intelligence correlates positively with the pre- and post-test Multiple-Choice Questionnaire scores and also with the total score of all the five Task Papers and with 'Visuality in physics', where high scores indicate that visual presentation forms are seen as an important part of physics learning. Confidence in Intelligence correlated negatively with students' (positive) experiences of the video programme. One possible explanation could be that students who were more confident in their intelligence did not feel they needed the help of a video programme and thus their experiences of the video programme were less positive. This and other aspects regarding the video programme and learning outcomes will be studied in more detail later in this dissertation.

TABLE 25 Correlations between Confidence in Intelligence and other aggregate variables. (Includes only correlations of minimum .20)

Aggregate variables[1]	**n**	**r**	**p**
LPQ Surface Motive (LPQSM)	347	-.29	.000
LPQ Deep Motive (LPQDM)	344	.21	.000
LPQ Achieving Motive (LPQAM)	345	.20	.000
LPQ Surface Strategy (LPQSS)	345	-.26	.000
LPQ Deep Strategy (LPQDS)	344	.21	.000
LPQ Surface Approach (LPQSA)	345	-.33	.000
LPQ Deep Approach (LPQDA)	341	.24	.000
LPQ Deep-Achieving Approach (LPQDAA)	339	.22	.000
Visuality in physics (GVISINPH)	337	.22	.000
Difficulties in Physics (GDIFINPH)	339	-.38	.000
Relation to Physics (GRELTOPH)	341	.38	.000
Relation to School and Education (GRELSCHO)	344	.28	.000
Experiences of the Video Programme (EEXPVH)	234[2]	-.21	.001
Estimation of prior knowledge about gases (pretest) (GPRIKNOW)	347	.21	.000
Estimation of prior knowledge about gases (post-test) (EPRIKNOW)	323	.22	.000
Multiple-Choice Questionnaire 1 score (pretest) (MULTI1)	340	.37	.000
Multiple-Choice Questionnaire 2 score (post-test) (MULTI2)	329	.24	.000
Task Papers 1 - 5 total score (SUMTASKP)	283[2]	.20	.001

1) The aggregate variables in this table will be presented in detail in the following sections, and a brief description of each aggregate variable can be found in appendix 10; 2) Four physics student groups did not use the video programme and four physics student groups did not use the Task Papers

Students with lower confidence in their intelligence tend to rely more on the Surface Approach, whereas students with better confidence in their intelligence are more inclined to rely on the Deep Approach and the Deep-Achieving Approach in their learning (for more on these approaches see the next sub-section). Easily understandable is also the fact that students who are more confident in their intelligence experience less difficulties in physics, and have more positive attitudes towards physics and towards school and education. Furthermore, students who are more confident in their intelligence tend to estimate their prior knowledge as better than less confident students do. Confidence in intelligence also correlated positively with scores obtained in the Multiple-Choice Questionnaire. Finally, it must be noted that, although statistically significant, all these correlations are quite small with regard to 'explained variance'.

8.3.2 Students' approaches to learning

Before going on to the results dealing with students' approaches to learning, it should be noted that the conclusions on whether a student has a surface motive, achieving strategy etc. are based on the scores of each whole scale, not on individual items. Therefore, the distributions of the aggregate values give a better picture of each scale. It must also be noted that the scores of the aggregate values were (after analysing the raw data) classified into five value categories used with the individual items. However, the distributions of the aggregate values do not, as such, give a correct understanding of the number of students who can be considered as having a motive or a strategy. The purpose of this classification was to enable the presentation of the aggregate values in a concise way.

The tables containing the distributions, means and standard deviations of the six sub-scales of Biggs' (1987a) Learning Process Questionnaire (LPQ) are in appendix 23. Table 26 shows the distributions, means and standard deviations of the learning approaches. Generally, the distributions of all three learning approaches indicate that there are very few low and high scores. The Deep Approach and the Achieving Approach to learning are slightly more usual than the Surface Approach.

TABLE 26 LPQ-Learning Approaches: Percentage distributions of the aggregate values

Learning Approach[1]	**never true (1)**	**proba-bly not true (2)**	**some-times true (3)**	**usually true (4)**	**always true (5)**	**M**	**SD**
Surface Approach (SA) n = 349		22	66	12		34.4	5.5
Deep Approach (DA) n = 344		10	64	25	1	37.1	5.5
Achieving Approach (AA) n = 349	2	25	56	17		34.7	6.1
Deep-Achieving Approach (DAA) n = 342	1	11	72	16		71.7	9.7

1) Classification of values (1-5) for SA, DA and AA: 1 (12-20), 2 (21-30), 3 (31-40), 4 (41-50), 5 (51-60); for DAA: 1 (24-40), 2 (41-60), 3 (61-80), 4 (81-100), 5 (101-120)

The raw scores of the scales were also classified according to the decile scaled scores given in the norm tables of LPQ (Biggs, 1987a, 32-33) to see how the students in the present study differ from the reference population (see table 27).

This classification was done separately for males and females. Had the students distributions of scores on different scales been identical to the norm distributions provided by Biggs (1987a, 32, 33) the percentage in each cell in table 27 would have been 10. By comparing the percentages to this figure, we can see that the Finnish students obtained somewhat lower scores on the Surface Approach scale than the Australian norm population. Since there may be differences between Finnish and Australian student populations, it is better to be cautious in the comparisons. Supposing the norm results in Finland were the same as in Australia, we could say that the students in this study tend to make less use of the Surface Approach than average. The differences between the Finnish students and the Australian norm population were not as clearly interpretable with regard to the Deep Approach and the Achieving Approach, but it seems the Finnish students obtained somewhat more frequently middle scores than the norm population.

TABLE 27 Percentage distributions of the decile scaled scores for males and females (Percentages and n of females in brackets)

Scale/n	Decile scaled scores									
	1	2	3	4	5	6	7	8	9	10
SM 230 (121)	13.9 (19.8)	19.1 (10.7)	20.4 (20.7)	14.8 (15.7)	9.6 (8.3)	10.4 (9.1)	3.0 (5.8)	2.2 (5.0)	3.0 (5.0)	3.5 (-)
SS 229 (120)	9.6 (16.7)	17.9 (9.2)	17.5 (13.3)	15.7 (10.0)	9.2 (25.8)	7.9 (8.3)	6.1 (5.0)	7.4 (8.3)	6.6 (3.3)	2.2 (-)
SA 229 (120)	17.5 (20.0)	20.5 (12.5)	14.8 (24.2)	10.9 (6.7)	3.5 (10.0)	11.8 (5.8)	10.0 (15.0)	7.0 (4.2)	3.1 (0.8)	0.9 (0.8)
DM 230 (118)	4.8 (1.7)	3.9 (5.9)	10.4 (10.2)	13.0 (16.1)	10.4 (12.7)	12.2 (19.5)	11.3 (11.0)	19.6 (9.3)	7.4 (8.5)	7.0 (5.1)
DS 228 (119)	1.8 (5.9)	6.1 (10.1)	6.6 (4.2)	6.6 (13.4)	9.6 (12.6)	16.2 (17.6)	14.9 (10.1)	20.6 (9.2)	10.5 (11.8)	7.0 (5.0)
DA 228 (116)	2.6 (4.3)	5.7 (6.0)	7.5 (11.2)	17.5 (12.1)	6.1 (20.7)	16.2 (8.6)	6.1 (10.3)	12.3 (9.5)	17.5 (12.9)	8.3 (4.3)
AM 228 (121)	9.6 (1.7)	12.3 (5.8)	22.8 (16.5)	18.9 (25.6)	8.3 (11.6)	7.5 (7.4)	7.9 (8.3)	4.4 (8.3)	7.0 (10.7)	1.3 (4.1)
AS 230 (121)	8.3 (3.3)	9.1 (7.4)	10.9 (17.4)	9.6 (11.6)	20.4 (12.4)	8.7 (27.3)	10.4 (5.0)	11.7 (9.9)	7.8 (5.8)	3.0 (-)
AA 228 (121)	8.8 (3.3)	18.4 (9.1)	8.8 (17.4)	14.5 (13.2)	11.4 (17.4)	14.5 (14.9)	9.2 (9.9)	8.3 (5.0)	4.8 (9.1)	1.3 (0.8)
DAA 226 (116)	4.9 (2.6)	9.7 (6.9)	10.6 (17.2)	20.4 (14.7)	8.8 (12.9)	12.4 (10.3)	10.2 (19.8)	10.2 (4.3)	8.0 (8.6)	4.9 (2.6)

The cross-tabulations and correlations presented in table 28 indicate that the students who scored high on the Surface Approach got lower scores on the Deep Approach (r= -.31). The Surface Approach and the Deep Approach did not correlate (.04). Students who obtained high scores on the Deep Approach got high scores on the Achieving Approach as well (.40). As Biggs (1987a) stated, the Deep Approach and the Achieving Approach are often present together, whereas the Deep Approach and the Surface Approach represent qualitatively different approaches. The correlations indicated the type of relations as expected, thus supporting the theoretical considerations regarding the scales of LPQ.

Comparisons

Based on appendix 19, we see that there were a one or two statistically significant differences between male and female students: the Surface Strategy was slightly stronger among male students, whereas females relied more on the Achieving Strategy than males. No significant differences were detected between the four socioeconomic groups in any of the Learning Process Questionnaire scales (appendix 20).

TABLE 28 Cross-tabulation of Surface- and Deep Approach classified values, and correlations between the approaches based on raw scores (n = 342)

Surface Approach	**Deep Approach**				
	12-20	**21 - 30**	**31 - 40**	**41 - 50**	**51-50**
12-20				1	
21 - 30		2	40	32	2
31 - 40		23	154	46	
41 - 50	1	8	25	7	1
51-50					

SA-DA r = -.31 ($p < .001$)
SA-AA r = .04 (n.s.)
DA-AA r = .40 ($p < .001$)

Comparisons between strongly- and weakly goal-oriented students (see appendix 21) showed that the students with strong goals (planning to include science subjects as part of their future education) were using the Deep Approach (*supports hypothesis 1a*) and the Achieving Approach (*supports hypothesis 1b*) more than students with weak goals (not planning to use science/ not decided/ not continuing education). The strongly goal-oriented students used the Surface Approach less than the weakly goal-oriented students (*supports hypothesis 1c*), though the difference here was not as big as with the above two approaches. Based on mean differences (see appendix 22) Finnish students used the Surface Approach somewhat less than Canadian students. The Canadian students were more strongly achievement-oriented than the Finnish students; the same trend was also seen in Deep-Achieving approach.

8.4 Students' attitudes towards school and physics

This section begins by presenting distributions, means and standard deviations of variables dealing with students' attitudes towards and thoughts about school and physics. These results are for the whole Finnish sample. After this, results concerning differences between some sub-groups of the sample and between Finnish and Canadian students will be given. Note that the aggregate variables presented in this section were computed as follows: the values of individual variables were added up and the sum was divided by the number of variables for each case. Accordingly the categories from 1 to 5 are: 1 (1-1.49), 2 (1.50-2.49), 3 (2.50-3.49), 4 (3.50-4.49), and 5 (4.50-5.00)

8.4.1 Description of students' attitudes

Table 29 contains basic information about students' attitudes towards and thoughts about school and physics. Several items used in this study were adopted the from IEA/SISS study conducted in several countries. This made it possible to compare the results of this study to the ones obtained in the IEA/SISS study. The results of the present study were compared with the Finnish IEA/SISS results (see Laurén 1987, 1990; Leimu & Laurén 1987b). Since the rating scale used in the IEA/SISS study was in reverse order compared with the one used in the present study, the means obtained from the IEA/SISS study were transferred before the comparisons. The number of students in the Finnish IEA/SISS study concerning physics was 833. The comparisons will be presented below in the tables when applicable.

A large number of the students had positive attitudes towards school and education, and the majority of them found school challenging. The number of students selecting the "uncertain" option was quite high. A quarter of the students agreed that they were bored most of the time in school or that school is not very enjoyable. The "boredom variable" correlated significantly ($p < .001$) with other attitude variables: g36 (-.58), g57 (-.28), g59 (.69), and g62 (-.32) all the correlations being "logical". Perhaps a certain amount of boredom related to school is considered as "natural" by many students.

There was only one significant difference in attitude variables between the the students of the Finnish IEA/SISS study and the students of the present study: Students of the IEA/SISS study wanted to have more education than the students in this study (as based on mean differences of variable g57 in table 29).

As expected, given that the students had freely chosen physics, a vast majority of them had positive attitudes towards physics and were confident that by doing their best they could understand physics well (table 30). Compared with the Finnish IEA/SISS results, the students had significantly ($p < .001$) more positive attitudes based on means.

TABLE 29 Students' (n = 352) relation to school and education (Percentage distributions)

Variable	strongly disagree (1)	dis-agree (2)	un-certain (3)	agree (4)	strongly agree (5)	M	SD
I like school (g36)	4	11	43	40	2	3.3	0.8
I want as much education as I can get (g57)[1]	3	14	41	34	8	3.3	0.9
School is not very enjoyable (g59)[1]*	5	38	31	22	4	2.8	0.9
I am bored most of the time in school (g61)[2] *	3	37	34	22	4	2.9	0.9
I find school challenging (g62)[3]		7	18	63	12	3.8	0.8
AGGREGATE[2, 4] (GRELSCHO)		4	40	54	2	3.5	0.6

1) n = 354; 2) n = 352; 3) n = 353; 4) Classification of values from 1 to 5: 1 (1-1.49), 2 (1.50-2.49), 3 (2.50-3.49), 4 (3.50-4.49), and 5 (4.50-5.00); M and SD are based on raw values; * The direction of the scale was reversed for the aggregate variable; Comparisons with the Finnish IEA/SISS results:
variable g57 (n= 354) M= 3.31 SD= 0.81 IEA/SISS: (n= 3581) M= 4.14 SD= 0.77 t= -19.26 p< .001
variable g59 (n= 354) M= 2.82 SD= 0.95 IEA/SISS: (n= 3600) M= 2.83 SD= 1.15 t= -0.16 p= n.s.
variable g61 (n= 352) M= 2.87 SD= 0.94 IEA/SISS: (n= 3593) M= 2.82 SD= 1.12 t= 0.81 p= n.s.
variable g62 (n= 353) M= 3.78 SD= 0.76 IEA/SISS: (n= 3602) M= 3.74 SD= 0.93 t= 0.78 p= n.s.

For a large number of students physics is quite a challenging subject (table 31): About 3/4 of the students considered physics to be a difficult subject and about a fifth of them agreed that there are too many facts to learn in physics. Half the students often worried they were not able to learn physics well enough and more than a quarter of them found physics difficult when it involves calculations. Only a small minority of the student had difficulties in relating physics to the real world or saw handling apparatus in physics as difficult.

There were some differences in means between the students in question and the IEA/SISS students (table 31): The students in this study found physics a little more difficult subject than the IEA/SISS students ($p < .001$), whereas the IEA/SISS students found physics considerably more difficult than the students of the present study when it involves calculations ($p < .001$) and they also felt more strongly than the students in this study that there are too many facts to learn in physics ($p < .001$).

TABLE 30 Students' (n= 352) relation to physics (Percentage distributions)

Variable	strongly disagree (1)	disagree (2)	un-certain (3)	agree (4)	strongly agree (5)	M	SD
Physics is an interesting subject for me (g38)[1]	2	7	30	49	12	3.6	0.9
I find physics challenging (g39)	1	4	13	60	22	4.0	0.8
I am confident that if I try to do my best I can understand physics well (g46)	1	1	19	60	19	4.0	0.7
Physics is an enjoyable school subject (g50)	6	20	49	21	4	3.0	0.9
The physics taught at school is interesting (g60)[2]		10	33	50	7	3.5	0.8
AGGREGATE[3] (GRELTOPH)		2	30	63	5	3.6	0.5

1) n = 350; 2) n = 351; 3) Classification of values from 1 to 5: 1 (1-1.49), 2 (1.50-2.49), 3 (2.50-3.49), 4 (3.50-4.49), and 5 (4.50-5.00), M and SD are based on raw values;
Comparisons with the Finnish IEA/SISS results:
variable g50 (n= 352) M= 2.96 SD= 0.91 IEA/SISS: (n= 3555) M= 2.55 SD= 1.19 t= 6.28 $p < .001$
variable g60 (n= 351) M= 3.52 SD= 0.79 IEA/SISS: (n= 3543) M= 2.73 SD= 1.15 t= 12.59 $p < .001$

TABLE 31 Students' (n = 350) difficulties in physics (Percentage distributions)

Variable	strongly disagree (1)	disagree (2)	un-certain (3)	agree (4)	strongly agree (5)	M	SD
Physics is a difficult subject (g40)	2	5	21	47	25	3.9	0.9
There are too many facts to learn in physics (g54)[1]	3	37	43	14	3	2.8	0.8
Physics is difficult when it involves calculations (g56)[2]	12	32	25	24	7	2.8	1.1
Physics is difficult when it involves handling apparatus (g58)	8	41	45	5	1	2.5	0.8
I have difficulties in relating physics to real world (g63)[2]	8	51	33	7	1	2.4	0.8
I often worry that I am not able to learn physics well enough (g67)3	4	21	24	42	9	3.3	1.0
AGGREGATE[4] (GDIFINPH)		15	64	21		3.0	0.6

1) n =351; 2) n = 352; 3) n = 353; 4) n = 344, classification of values from 1 to 5: 1 (1-1.49), 2 (1.50-2.49), 3 (2.50-3.49), 4 (3.50-4.49), and 5 (4.50-5.00), M and SD are based on raw values;
Comparisons with the Finnish IEA/SISS results:
variable g40 (n= 350) M= 3.90 SD= 0.89 IEA/SISS: (n= 3545) M= 3.61 SD= 1.09 t= 4.82 p < .001
variable g54 (n= 351) M= 2.80 SD= 0.84 IEA/SISS: (n= 3515) M= 3.04 SD= 1.01 t= -4.31 p < .001
variable g56 (n= 352) M= 2.84 SD= 1.14 IEA/SISS: (n= 3541) M= 3.43 SD= 1.21 t= -8.77 p < .001
variable g58 (n= 350) M= 2.51 SD= 0.76 IEA/SISS: (n= 3523) M= 2.59 SD= 0.98 t= -1.48 p = n.s.

Table 32 indicates that well above half the students considered science and physics to have connections to everyday life and quite many also regarded science as a potential route to develop one's career. Only about 10% of the students disagreed with these aspects. The differences compared with the IEA/SISS study (table 32) were all statistically significant (p < .001), though not very remarkable in terms of the actual difference in means, except for the importance of knowing science in order to get a good job: More students in this study indicated this importance than in the IEA/SISS study. One explanation for this could be the fact that schools and school administration have started to pay more attention to science-technology-society connections, which raises career questions as one important part of science education (see e.g. STS Science education 1990; How to explore science and technology 1991). Also some associations and networks have been established to promote closer relations between schools and society during the recent years. All these aspects may have helped the students recognize the importance of science in getting a good job. In most other individual items the students of the present study felt more positively about the connection of science to real life than the IEA/SISS students. However the IEA/SISS students agreed more strongly than the students in this study that science is useful for solving the problems of everyday life.

TABLE 32 Students' (n = 352) views about the connection of science to real life (Percentage distributions)

Variable	strongly disagree (1)	disagree (2)	un-certain (3)	agree (4)	strongly agree (5)	M	SD
Science is useful for solving the problems of everyday life (g42)[1]	1	4	30	51	14	3.7	0.8
It is important to know science in order to get a good job (g43)	1	10	39	41	9	3.5	0.8
In my future career I would like to use the science I learned at school (g45)	1	4	25	49	21	3.9	0.8
Physics is relevant to every-day life (g52)[1]	1	7	33	51	8	3.6	0.8
Science is a very good field for creative people to enter (g53)	1	9	47	36	7	3.4	0.8
AGGREGATE[2] (GSCIREAL)		2	47	48	3	3.5	0.5

1) n = 350; 2) Categories from 1 to 5 are: 1 (1-1.49), 2 (1.50-2.49), 3 (2.50-3.49), 4 (3.50-4.49), 5 (4.50-5.00), M and SD are based on raw values; Comparisons with the Finnish IEA/SISS results:
variable g42 (n= 350) M= 3.74 SD= 0.78 IEA/SISS: (n= 3605) M= 4.14 SD= 0.77 t= -9.27 p < .001
variable g43 (n= 352) M= 3.47 SD= 0.84 IEA/SISS: (n= 3593) M= 2.49 SD= 1.02 t= 17.45 p < .001
variable g45 (n= 352) M= 3.86 SD= 0.82 IEA/SISS: (n= 3589) M= 3.55 SD= 1.05 t= 5.38 p < .001
variable g52 (n= 350) M= 3.57 SD= 0.78 IEA/SISS: (n= 3505) M= 3.16 SD= 1.07 t= 6.99 p < .001
variable g53 (n= 352) M= 3.39 SD= 0.80 IEA/SISS: (n= 3585) M= 3.04 SD= 1.16 t= 5.53 p < .001

TABLE 33 Students' (n = 351) attitudes towards studying gases (Percentage distributions)

Variable	strongly disagree (1)	disagree (2)	un-certain (3)	agree (4)	strongly agree (5)	M	SD
I find gases and their behav-iour as an interesting topic to learn about (g68)	2	9	59	27	3	3.2	0.7
I think it is useful to know more about gases and their behaviour (g70)	1	8	31	54	6	3.5	0.8
Studying gases and their be-haviour does not make sense to me (g71)[1]	10	51	32	6	1	2.4	0.8
AGGREGATE[2] (SMRELG1)		7	41	48	4	3.5	0.6

1) n = 351, the direction of the scale was reversed for the aggregate variable; 2) n = 350, classification of values from 1 to 5: 1 (1-1.49), 2 (1.50-2.49), 3 (2.50-3.49), 4 (3.50-4.49), and 5 (4.50-5.00), M and SD are based on raw values

As can be seen from table 33, more than half the students thought it was useful to know more about gases and their behaviour and a about third of them found gases and their behaviour an interesting topic to learn about. Many students were uncertain of these statements, but only relatively few of them disagreed. Only 7% of the students agreed that studying gases and their behaviour does not make sense to them.

TABLE 34 Percentage distributions of some General Questionnaire variables not included in previous scales (n = 351)

Variable	strongly disagree (1)	dis-agree (2)	un-certain (3)	agree (4)	strongly agree (5)	M	SD
I want to learn more about the world we live in (g47)		2	15	56	27	4.1	0.7
While I am solving physics problems I try to form a clear idea about the components in the problem before trying any equations (g48)[1]		7	30	50	13	3.7	0.8
I try to solve physics problems by searching for the equations (g66)[2]	1	8	19	61	11	3.7	0.8
If properly taught, almost all students could learn physics (g51)	3	14	29	45	9	3.4	1.0
I read just the text in physics books without paying attention to pictures and drawings (g55)[2]	31	56	8	4	1	1.9	0.8
Studying physics without knowing how the information is used in real life does not make sense to me (g65)	3	13	49	29	6	3.2	0.9
I am relieved this is the last item (g73)[2]	4	19	34	36	7	3.2	1.0

1) n = 350; 2) n = 352; Comparisons with the Finnish IEA/SISS results:
variable g47 (n= 351) M= 4.08 SD= 0.70 IEA/SISS: (n= 3576) M= 4.16 SD= 0.72 t= -1.99 $p < .05$
variable g51 (n= 351) M= 3.42 SD= 0.95 IEA/SISS: (n= 3563) M= 3.18 SD= 1.20 t= 3.64 $p < .001$

Table 34 shows that more than 4/5 of the students wanted to learn more about the world we live in (no suprise here) and more than half of them thought that, if properly taught, almost all students could learn physics. About 7/8 of the students implied they do not read physics books without paying attention to pictures and drawings. About 1/3 of the students felt that without knowing how physics information is used in real life there is no sense in studying physics; the number of students selecting the "uncertain" option was high (49%). Almost 2/3 of the students stated that while solving physics problems they try to form a clear idea about the components in the problem before trying any equations. Approximately same type of distribution was obtained for the variable "I try to solve physics problems by searching for the equations". The original idea was that these two variables concerning the way to solve physics problems, would have reflected opposite ways of problem-solving, but apparently the content of the latter variable was not interpreted the way it was meant to be understood. Perhaps adding the word "directly" before "searching for the equations" would have helped students to see the item more clearly as an opposite to the preceding item. Another problem with this type of items is, of course, that people may answer the way they believe would be more desirable, not necessarily according to their action in real life. Compared with the IEA/SISS students, the students in this study agreed more strongly that, if properly taught, almost all students could learn physics ($p < .001$).

8.4.2 Differences between sub-groups of students

The differences between sub-groups of students include comparison between males and females (see appendix 19), socioeconomic groups (appendix 20), weakly and strongly goal-oriented students (appendix 21) and Finnish and Canadian students (appendix 22). Comparisons are based on aggregate variables. Gender differences in some individual items will also be noted.

Females had somewhat more positive attitudes towards school and education compared with males (*supports hypothesis* 2). This corresponds to the results obtained in previous studies (see e.g. Kelly 1981; Kass 1989). Contrary to previous studies females did not differ from males concerning attitudes towards science and physics. However, it is important to note that the females in Kelly's and Kass' studies were from a large national sample representing all females, whereas the females in the present study were from one province representing only those females who have taken physics as part of their senior high school programme. This probably explains why there were no significant differences between the two sexes in attitudes towards science and physics: naturally students who have voluntarily chosen physics usually have positive attitudes towards it. During the post-test males estimated their prior knowledge about gases more positively than females. Females experienced slightly more difficulties in physics than males, which was more clearly seen in two individual variables: females ($M= 3.6$; $SD= 0.9$) worried considerably more than males ($M= 3.2$; $SD=1.1$) that they were not able to learn physics ($p = .001$) and they ($M= 2.7$; $SD= 0.7$) also felt more than males ($M= 2.4$; $SD= 0.8$) that physics is difficult when it involves handling apparatus ($p= .001$). For more differences between females and males in aggregate variables see appendix 19. No significant differences were found between the four socioeconomic groups (see appendix 20).

Strongly goal-oriented students (who were planning to include science subjects as part of their future education) saw visuality in physics as more important than weakly goal-oriented students (not planning to include science subjects or having not yet decided or not planning to continue their education). Strongly goal-oriented students had clearly more positive attitudes towards school and education (*supports hypothesis 3a*), towards physics (*supports hypothesis 3b*) and towards studying gases than the weakly goal-oriented. Here, among the individual variables, the most striking difference was that the strongly goal-oriented students (M= 3.9; SD= 0.8) considered physics to be a more interesting subject than the weakly goal-oriented students did (M= 3.3; SD= 0.9) (p= .000). In addition, the strongly goal-oriented experienced fewer difficulties in physics than the weakly goal-oriented and they recognized the connection of science to real life more clearly than the weakly goal-oriented. This latter difference is quite obvious since the aggregate variable consisted of items dealing with the meaning of science in terms of career development and applicability to the real world: these aspects are naturally more important to students who are planning to include science subjects as part of their future education.

The Canadian students had a slightly more positive relation to physics than the Finnish students and they experienced slightly fewer difficulties in physics than the Finns. Furthermore, the Canadian students recognized the connection of science to real life a bit more clearly than the Finnish students and they also estimated their prior knowledge about gases to be better during the pretest and especially during the post-test. For details and other comparisons between Canadian and Finnish students see appendix 22.

8.4.3 Changes in students' attitudes towards studying gases

From table 35 we can seen the pretest post-test changes of three attitude items regarding the studying of gases. All attitudes had changed in a more positive direction, two of the changes being statistically significant ($p < .001$). There were significant differences between the treatment groups in attitude changes in one of the three attitude items (table 36). The Dunnet t-test showed that the significant differences were in groups A and D as compared with control group H: in these two groups students' attitude (gases were seen as an interesting topic to learn about) had changed in a more positive direction than in the control group, where this attitude had slightly changed in a negative direction. Appendix 25 contains comparisons of the attitude changes by treatment group using t-tests. In the majority of treatment groups the attitudes had changed in a more positive direction with some changes being statistically significant. However, the changes were relatively small and the comparisons revealed no considerable systematic differences between the treatment groups.

TABLE 35 T-tests for students' changes in attitudes[1] towards studying gases between pretest and post-test (n = 324)

Attitude item[1]	r	Pretest		Post-test		t-test	
		M	SD	M	SD	t-value	p
I find (pretest; "found" in post-test) gases and their behaviour as an interesting topic to learn about (g68-exp1)	.34[2]	3.2	0.7	3.4	.94	-3.59	.000
I think it is (pretest; "was" in post-test) useful to know more about gases and their behaviour (g70-exp3)	.35[2]	3.5	0.8	3.6	0.8	-1.88	.061
Studying gases and their behaviour does (pretest; "did" in post-test) not make sense to me (g71-exp4)	.29[2]	2.4	0.8	2.1	0.9	4.82	.000

1) Scale: 1 strongly disagree, 2 disagree, 3 uncertain, 4 agree, 5 strongly agree; 2) $p < .001$

TABLE 36 One-way analysis of variance: Comparison between the treatment groups regarding post-test - pretest mean differences in attitudes towards studying gases (n= 324)

Attitude item	Attitude change means in treatment groups[1]								F-test	
	A	B	C	D	E	F	G	H	F-ratio	p
I find gases and their behaviour as an interesting topic to learn about (g68-exp1)[2]	.45	.11	.13	.45	.37	.19	-.12	-.16	2.68	.010[3]
I think it is useful to know more about gases and their behaviour (g70-exp3)[2]	.15	-.07	.22	.10	.34	.11	.00	-.06	0.94	.476
Studying gases and their behaviour does not make sense to me (g71-exp4)[2]	.41	.16	.00	.35	.57	.39	.10	.03	1.76	.095

1) A: preview + tasks/b.sec.+ applic.sec.; B: tasks/b.sec.+ applic.sec.; C: tasks/b.sec.only; D: tasks/no video; E: no tasks/prev.+b.sec.; F: no tasks/b.sec.+applic.sec.; G: no tasks/b.sec.only; H: no tasks/no video; 2) No significant differences between variances; 3) Post-hoc tests - significant differences according to Dunnett t-tests (group H as a control group) exist between groups A-H (p= .021) and D-H (p=.017)

Correlations of selected aggregate attitude variables with other aggregate variables

The abbreviation of each aggregate variable will be indicated after the label as well as the questionnaire from which it comes. Note that only statistically significant correlations ($p < .001$) above .30 will be presented:

Relation to school and education (General Questionnaire aggregate variable consisting of variables indicating students' attitudes towards school and education) correlated with:

- Mean of course grades in Finnish	.34
- Surface Approach (LPQSA Learning Process Questionnaire scale)	-.34
- Deep Approach (LPQDA Learning Process Questionnaire scale)	.50
- Achieving Approach (LPQAA Learning Process Questionnaire scale)	.44
- Relation to physics (GRELSCHO from the General Questionnaire)	.52
- Attitudes towards studying gases-pretest (SMRELG1 from the General Questionnaire)	.36
- Attitudes towards studying gases-post-test (SMRELG2 from the General Questionnaire)	.39

Relation to physics (GRELTOPH General Questionnaire aggregate variable consisting of variables indicating students' attitudes toward physics) correlated with:

- Mean of course grades in Physics	.36
- Surface Approach (LPQSA Learning Process Questionnaire scale)	-.33
- Deep Approach (LPQDA Learning Process Questionnaire scale)	.51
- Difficulties in Physics (GDIFINPH from the General Questionnaire)	-.44
- Attitudes towards studying gases-pretest (SMRELG1 from the General Questionnaire)	.41
- Attitudes towards studying gases-post-test (SMRELG2 from the General Questionnaire)	.43

Difficulties in physics (GDIFINPH General Questionnaire aggregate variable consisting of variables indicating difficulties students experience in physics) correlated with:

- Mean of course grades in Physics	-.35
- Surface Approach (LPQSA Learning Process Questionnaire scale)	.43

The above correlations are quite clearly interpretable. The more positive attitudes students had towards school and education, the less they used the Surface Approach and the more they used the Deep Approach and the Achieving Approach when studying. Positive attitudes towards school and education also correlated positively with attitudes towards studying gases (both pre- and post-test measurement) and with mean of course grades in Finnish. Students' positive attitudes towards studying physics correlated positively with their mean course grades in Physics, with using the Deep Approach and also with attitudes towards studying gases (both pre- and post-test measurement). Understandable negative correlation was found between positive physics attitudes and use of the Surface Approach. Positive physics attitudes correlated negatively also with difficulties experienced in physics, which correlated negatively with mean course grades in physics and positively with the Surface Approach. Perhaps the most interesting result here, was that students' use of learning approaches (the Surface, the Deep and the Achieving) were quite clearly and logically connected with their attitudes and the Surface Approach also with experienced difficulties in physics.

The assumptions of variance analysis are: the data are gathered using a random sampling method, for each cell there is a normal distribution, and all of the cell variances are the same. The data were gathered using random sampling. However, it must be noted that cluster sampling was used and therefore individual students were not randomly assigned to the treatment groups, but groups of students (see section 7.2). There were no statistically significant differences between the cell variances according to Levene's test of homogeneity of variances (p= .122).

The results (see table 37) suggest that the effects of the four covariates,"Relation to studying gases - pretest", "Experiences of the written materials", "Relation to physics", and the Deep-Achieving Approach were statistically significant. There were no significant effects attributable to the two factors or their interaction. The size of the squared multiple correlation (R^2= .47) indicated quite a large explained total variance. Squared partial Eta values indicate that proportionally compared the greatest effect can be attributed to "Experiences of the written materials". This suggests that students whose experiences of the written materials were positive correspondingly found studying gases a positive activity. Also the other three covariates had a positive correlation with "Relation to studying gases - post-test". However, in the covariance model their proportional effects were not so large. The observed power at the .05 level varied from .64 to 1.00 suggesting a good power for rejecting the null hypothesis regarding the effects of the covariates. The assumption regarding the normal distribution was checked by studying the distribution of residuals produced by the above covariance model. The normal distribution assumption was met: the residuals were normally distributed according to the Kolmogorov-Smirnow test (p= .200); the same conclusion was obvious when based on a histogram and a Normal Q-Q plot, as well (see section 8 in appendix 26).

TABLE 37 Covariance analysis: "Relation to studying gases - post-test" (dependent), video groups and task groups as factors, "Relation to studying gases - pretest", "Experiences of the written materials", "Relation to physics", and "the Deep-Achieving Approach" as covariates (n= 290)

Task group	Video group attitude means (standard deviations)				Combined group mean
	preview + basic sections (1)	basic sections + application section (2)	basic sections (3)	no video (4)	
tasks (A)	11.1 (2.1)	10.8 (2.1)	10.9 (2.0)	11.6 (2.0)	11.1 (2.1)
no tasks (B)	11.7 (1.4)	11.3 (2.5)	9.8 (2.6)	10.3 (1.5)	10.7 (2.2)
Combined group mean	11.3 (1.9)	11.0 (2.3)	10.3 (2.4)	11.1 (1.9)	10.9 (2.2)

Levene's Test of Equality of Error variances: F = 1.65 df1 = 7 df2 = 282 p = .122

Tests of Between-Subject Effects:

Source of Variation	Type III SS	DF	MS	F	p	Partial Eta Sqr.	Observed Power using alpha .05
Corrected Model	633.6	11	57.6	22.71	.000	.47	1.0
Intercept	5.7	1	5.7	2.23	.136	.01	.32
Relation to studying gases during pretest (smrelg1)	66.1	1	66.1	26.07	.000	.09	.99
Experiences of the written materials (eexpwri)	192.3	1	192.1	75.81	.000	.21	1.0
Relation to Physics (greltoph)	22.1	1	22.1	8.7	.003	.03	.84
The Deep-Achieving Approach (LPQDAA)	13.6	1	13.6	5.37	.021	.02	.64
Video group	7.1	3	2.4	0.93	.427	.01	.25
Task group	0.07	1	0.07	0.03	.866	.00	.05
Video group * task group	0.5	3	0.2	0.07	.976	.00	.06
Error	705.2	278	2.54				
Total	360340	290		(R^2 = .47)			

Statistically Significant Parameter Estimates of the Covariance Model:

Covariates/factors	r with dependent	B	Std Err.	t-value	p	Partial Eta Sqr.	Observed power using alpha .05
Relation to studying gases during pretest (smrelg1)	.42 ***	0.3	0.06	5.11	.000	.09	.99
Experiences of the written materials (eexpwri)	.58 ***	1.5	0.18	8.71	.000	.21	1.0
Relation to Physics (greltoph)	.43 ***	0.7	0.23	2.95	.003	.03	.84
The Deep-Achieving Approach (LPQDAA)	.41 ***	0.03	0.01	2.32	.021	.02	.64

Statistically significant contrasts: No statistically significant contrasts in this variance model

*** $p < .001$

8.5 Students' knowledge and learning about gases

This section deals with students' knowledge about gases based on the results of the Multiple-Choice Questionnaires 1 - 2, the Task Papers 1 - 5 and Concept Maps + Essays 1 - 2. A number of comparisons between sub-groups of the students will be presented as well as results of analyses explaining the learning outcomes.

8.5.1 Description of students' knowledge

Quantitative perspectives on students' knowledge

Before describing students' knowledge and learning outcomes regarding the behaviour of gases, students' relation to visuality in physics and their estimations of their prior knowledge about gases will be presented briefly. Table 38 shows that most students stated they use pictures and drawings in physics books to understand physics better and feel that visual presentations have made it easier for them to understand physics. About 1/3 of the students indicated they use visual images of physics concepts in studying topics and 1/5 of them felt that science programmes on television and videocassettes have helped them to understand physics better.

About 1/7 of the students felt they already knew fairly well how gases behave (see table 39). This was before the instruction on the behaviour of gases and the gas laws began. Later we see how students' estimations of their prior knowledge correlated with the learning effects and with similar estimations after the instruction was over.

Table 40 presents the proportion of correct answers item by item for pretest and post-test including Finnish and Canadian students. First the results of the Finnish students will be discussed. Generally, the number of correct answers increased between the two measurements, whereas the number of correct guesses decreased indicating that after the instruction students were more confident in their answers. There were, however, considerable differences in the percentage of correct answers between the items: in pretest from 4 % to 62 % and in post-test from 13 % to 81 %. In most items the percentage of correct answers had clearly increased. This trend is also seen in table 41, where the frequencies of higher scores is greater in post-test than in pretest.

Despite the progress, responses to many items were still wrong in the post-test indicating that the behaviour of gases is a difficult topic for many senior high school students. In this respect the results of the present study correspond with a number of previous studies (Brook, Briggs, & Driver 1984; Connelly, Crocker, & Kass 1989; Laurén 1987, 1990; Novick and Nussbaum 1981; Nussbaum and Novick 1982; Rozier and Viennot 1991). Comparison of individual items dealing with gas laws and kinetic theory of gases show that with one exception students' performance was worse on the kinetic theory items, which again follows the trend noted in the studies listed above.

TABLE 38 Students' relation to visuality in physics (Percentage distributions)

Variable	strongly disagree (1)	disagree (2)	un-certain (3)	agree (4)	strongly agree (5)	M	SD
I use visual images of physics concepts in order to understand the topics I am studying (g37) (n = 345)	3	13	48	33	3	3.2	0.8
Science programmes in television and in videocassettes have helped me understand physics better (g41) (n =349)	10	22	48	17	3	2.8	0.9
I use pictures and drawings in physics textbooks to form a better understanding of the topic I am studying (g44) (n = 352)	1	10	39	41	9	3.5	0.8
Visual presentations make it easier for me to understand physics (g64) (n = 353)	1	1	38	52	12	3.7	0.7
AGGREGATE[1] (n = 342)		3	48	48	1	3.4	0.5

1) Categories from 1 to 5 are: 1 (1-1.49), 2 (1.50-2.49), 3 (2.50-3.49), 4 (3.50-4.49), and 5 (4.50-5.00); M and SD are based on raw values

TABLE 39 Students' (n = 352) estimation of their prior knowledge about gases before instruction (Percentage distributions)

Variable	strongly disagree (1)	disagree (2)	un-certain (3)	agree (4)	strongly agree (5)	M	SD
I already know fairly well how gases behave (g69)	7	49	29	14	1	2.5	0.9
I know very little about gases and their behaviour. (g72)[1]	4	19	34	36	7	3.2	1
AGGREGATE[2]	15	53	23	8	1	2.6	0.8

1) The direction of the scale was reversed for the aggregate variable; 2) Categories from 1 to 5 are: 1 (1-1.49), 2 (1.50-2.49), 3 (2.50-3.49), 4 (3.50-4.49), and 5 (4.50-5.00); M and SD are based on raw values

Given the theoretical maximum total score 42 (1 point for a correct guess and 3 points for a "normal" correct answer per item), students' knowledge about the behaviour of gases, particularly in post-test, could have been much better. The average total gain score was 11.8 and 12.5 with negative gain scores eliminated, which means that on average the students increased their results by approximately four correct items, the highest increase being almost 11 correct items (see table 41). There were altogether 20 negative gain scores ranging from -1 to -13 (for frequences of negative gain scores see table 41).

Comparisons

Comparisons with the Finnish IEA/SISS results. Finnish students' performances on items 1-3 in table 40 were clearly better on item 1, approximately the same on item 2 and somewhat worse on item 3 as compared to the Finnish IEA/SISS results (table 40).

Comparisons between male and female students revealed statistically significant differences in total scores on the Multiple-Choice Questionnaire 1 (pretest) and 2 (post-test): males were somewhat better than females (see appendix 19). There were also statistically significant differences in some individual items (table 42). Males were better than females on six items in pretest and on three items in post-test. The differences were not particularly considerable, except for variable M8 (in pretest), which dealt with a mercury barometer. However, by post-test the difference on this item had decreased, though the difference was still statistically significant. Generally, the differences were considerably smaller than in some previous studies (Kass 1989; Kelly 1978).

There were no statistically significant differences in the total scores of the Multiple-Choice Questionnaire 1 or 2 between the four socioeconomic (SES) groups (see appendix 20). There were, however, two statistically significant differences in two single items. Means in MM6 were: low (0.91), lower middle (1.9), upper middle (2.0) and high SES group (2.18); F-ratio 4.36, p=.005, post-hoc comparisons according to the Dunnett t-test indicated statistically significant differences between the low SES and the other three SES groups - significance values ranging from .019 to .001. Means in MM14 were low (0.8), lower middle (0.7), upper middle (0.9) and high SES group (1.4); F-ratio 2.66, p=.049, post-hoc comparisons according to the Dunnett T3-test (for unequal variances) indicated significant difference between lower middle and high SES groups - the significance being .050.

Strongly goal-oriented students were statistically significantly better than the weakly goal-oriented students in the total scores of the Multiple-Choice Questionnaire 2 (post-test) (see appendix 21). Comparisons in single items showed some statistically significant differences, strongly goal-oriented students having higher average scores than weakly goal-oriented (table 43). The most considerable difference was in variable MM8 dealing with a mercury barometer.

Comparisons between Finnish and Canadian students (table 40) showed that pretest performances varied depending on the item, whereas in post-test the Finnish students outperformed the Canadian students, except on three items in which Canadians were slightly better. Differences between the Finnish and the Canadian students were also seen in comparing the single Multiple-Choice Questionnaire items mean values (see appendix 24). The Finnish students had higher average scores on most of the items: the most striking difference was in variable M11 (pretest) and especially on MM11 (post-test) dealing with the concept of mole. The reason may be that the concept of mole had been introduced earlier and more thoroughly in Finland than in Canada. The Canadians performed better on four items, particularly on variable M13 dealing with the behaviour of molecules of a gas when it is heated.

TABLE 40 Students' pretest (the Multiple-Choice Questionnaire-1) and post-test (the Multiple-Choice Questionnaire-2) results. Percentages of correct answers

Item[1]	Pretest Finland (Canada) n= 348 (n= 134)			Post-test Finland (Canada) n= 334 (n= 107)		
	correct guess	correct answer	correct total	correct total	correct answer	correct guess
When a small volume of water is boiled, a large volume of steam is produced. Why? (1)	18(10)	62(54)	80(64) 52[2]	87(70)	81(67)	6(3)
An iron container is weighed after the air in it has been pumped out (evacuated). Then it is filled with hydrogen gas and weighed again. What is the weight of the container full of hydrogen compared to the weight of the evacuated container? (2)	13(10)	20(33)	33(43) 29[2]	41(52)	28(48)	13(4)
A jar of oxygen gas and a jar of hydrogen gas are at the same temperature. Which of the following physical quantities has the same value for the molecules of both gases? (3) K	7(16)	6(10)	13(26) 19[2]	57(44)	42(31)	15(13)
The gas laws are valid for real gases, except (4) G	10(10)	4(3)	14(13)	72(52)	68(50)	4(2)
When pressure is constant the volume of a gas (5) G	39(30)	30(17)	69(47)	81(66)	74(55)	7(11)
When temperature is constant the volume of a gas (6) G	17(10)	25(19)	42(29)	62(37)	58(36)	4(1)
When volume is kept constant the pressure of a gas (7) G	28(26)	22(24)	50(50)	59(68)	50(60)	9(8)
In a simple mercury barometer (see the figure) the mercury in the tube - whose bottom end is open - stays above the level of mercury in the dish. What makes this possible? (8)	19(14)	32(16)	51(30)	80(61)	68(51)	12(10)
Which of the following statements is not part of or cannot be derived from the Kinetic Theory of Gases? (9) K	9(15)	5(4)	14(19)	20(27)	13(15)	7(12)
Which of the following statements is not true?: At the zero point of Kelvin Scale ... (10) K	13(8)	21(19)	34(27)	64(50)	58(47)	6(3)
A mole ... (11)	13(6)	29(7)	42(13)	78(38)	66(32)	12(6)
Which statement is not true about pressure? Pressure of a gas... (12)	21(10)	18(20)	39(30)	70(39)	61(35)	9(4)
When a gas is heated, its molecules (13) K	23(8)	45(67)	68(75)	80(76)	74(69)	6(7)
Which of the following statements is wrong? When the temperature of a gas decreases, the molecules of the gas (14) K	15(10)	14(20)	29(30)	34(30)	30(26)	4(4)

1)The numbers in brackets refer to the original questionnaires, variable names accordingly are M1(pretest), MM2(post-test); M2, MM2; etc.; 2) G indicates that the item deals with gas laws, 3) K indicates that the item deals with kinetic theory of gases 2) Finnish IEA/SISS results from Laurén 1987, 1990; Leimu & Laurén 1987b.

TABLE 41 Students' pretest- (the Multiple-Choice Questionnaire-1), post-test (the Multiple-Choice Questionnaire-2) total scores and total gain scores. Percentage distributions

Type of score	Points								
	0-4	5-9	10-14	15-19	20-24	25-29	30 >	M	SD
Pretest[1]	11	28	23	23	10	3	2	12.5	6.8
Post-test[2]	2	5	5	15	23	18	32	24.2	8.3
Gain[3]	14	21	21	22	18			11.8	7.8
Gain-positive[4]	15	22	22	23	18			12.5	7.2

1) n =348, highest single value was 33; 2) n = 334, highest single value was 42; 3) n = 325, Post-test scores minus pretest scores, negative scores (n= 14, 4%), frequences in brackets: -1 (1), -2 (4), -3 (4), -4 (1), -6 (1), -8 (2), -13 (1), last category was "20 or more", the highest single value was 32; 4) negative scores eliminated, n =311; last category was "20 or more", the highest single value was 32.

TABLE 42 T-tests for gender differences in students' pretest (the Multiple-Choice Questionnaire 1) and post-test (the Multiple-Choice Questionnaire 2) results

Item	female		male		t-test	
	M	SD	M	SD	t-value	p
(M1)[1] When a small volume of water is boiled, a large...	1.8	1.3	2.1	1.3	-2.05	.041
(M2)[1] An iron container is weighed after the air in it ...	0.5	1.0	0.8	1.3	-2.43	.016
(M6)[1] When temperature is constant the volume of ...	0.7	1.1	1.1	1.3	-2.86	.010
(M8)[1] In a simple mercury barometer the mercury ...	0.6	1.0	1.5	1.4	-6.93	.000
(M10)[1] Which of the following statements is not true?: ..	0.6	1.0	0.9	1.3	-2.35	.019
(M14)[1] Which of the following statements is wrong? : ...	0.4	0.8	0.7	1.2	-2.56	.011
(MM3)[2] A jar of oxygen gas and a jar of hydrogen gas...	1.2	1.4	1.5	1.4	-2.29	.023
(MM8)[2] In a simple mercury barometer the mercury ...	1.9	1.3	2.3	1.2	-2.76	.010
(MM13)[2] When a gas is heated, its molecules ...	2.0	1.4	2.4	1.2	-2.64	.010

1) Pretest: female n= 123, male n= 225; 2) Post-test: female n= 116, male n= 218;
3) t-test for unequal variances was used

TABLE 43 T-tests for differences between weakly- and strongly goal-oriented students on some Multiple-Choice Questionnaire single items

Item	Weak goal		Strong goal		t-test	
	M	SD	M	SD	t-value	p
(M1)[1] When a small volume of water is boiled ...	1.8	1.3	2.2	1.2	-2.54	.011
(M8)[1] In a simple mercury barometer the mercury ...	1.0	1.3	1.3	1.3	-2.31	.022
(11)[1] A mole ...	0.8	1.2	1.1	1.4	-2.34	.020
(MM1)[2] When a small volume of water is boiled ...	2.3	1.2	2.6	0.9	-2.39	.018
(MM3)[2] A jar of oxygen gas and a jar of hydrogen ...	1.2	1.4	1.6	1.4	-2.81	.010
(MM8)[2] In a simple mercury barometer the mercury..	1.9	1.4	2.4	1.1	-3.31	.000

1) Pretest: strong goal n= 161, weak goal n= 182; 2) Post-test: strong goal n= 155, weak goal n= 177; 3) t-test for unequal variances was used

All the treatment groups including the control groups D and H had made good progress from pretest to post-test according to the means of the Multiple-Choice Questionnaire total scores, differences between the pretest and post-test being statistically significant at $p < .001$ (see table 44). The differences between the treatment groups are discussed in more detail based on the results of variance analyses presented later.

TABLE 44 T-tests for learning effects (the Multiple-Choice Questionnaire 1 pretest and the Multiple-Choice Questionnaire 2 post-test total score comparisons) in treatment groups

Treatment Group	n	r	Pretest total score		Post-test total score		t-test	
			M	SD	M	SD	t-value	p
A: tasks/preview section + basic sections	43	0.34	13.8	7.1	29.7	6.8	-13.10	.000
B: tasks/basic sections + application section	45	0.39	9.7	5.6	24.8	7.5	-13.70	.000
C: tasks/basic sections	32	0.62	13.8	6.2	24.9	7.4	-10.40	.000
D: tasks/no video	57	0.43	12.7	5.3	24.5	6.4	-14.00	.000
E: no tasks/preview section + basic sections	35	0.63	11.0	6.9	20.5	7.0	-9.42	.000
F: no tasks/basic sections +application sec.	40	0.37	11.9	5.4	20.4	10.8	-5.37	.000
G: no tasks/basics sections	40	0.60	16.5	8.1	26.2	8.3	-8.34	.000
H: no tasks/no video	33	0.51	9.7	6.6	21.3	9.2	-8.19	.000

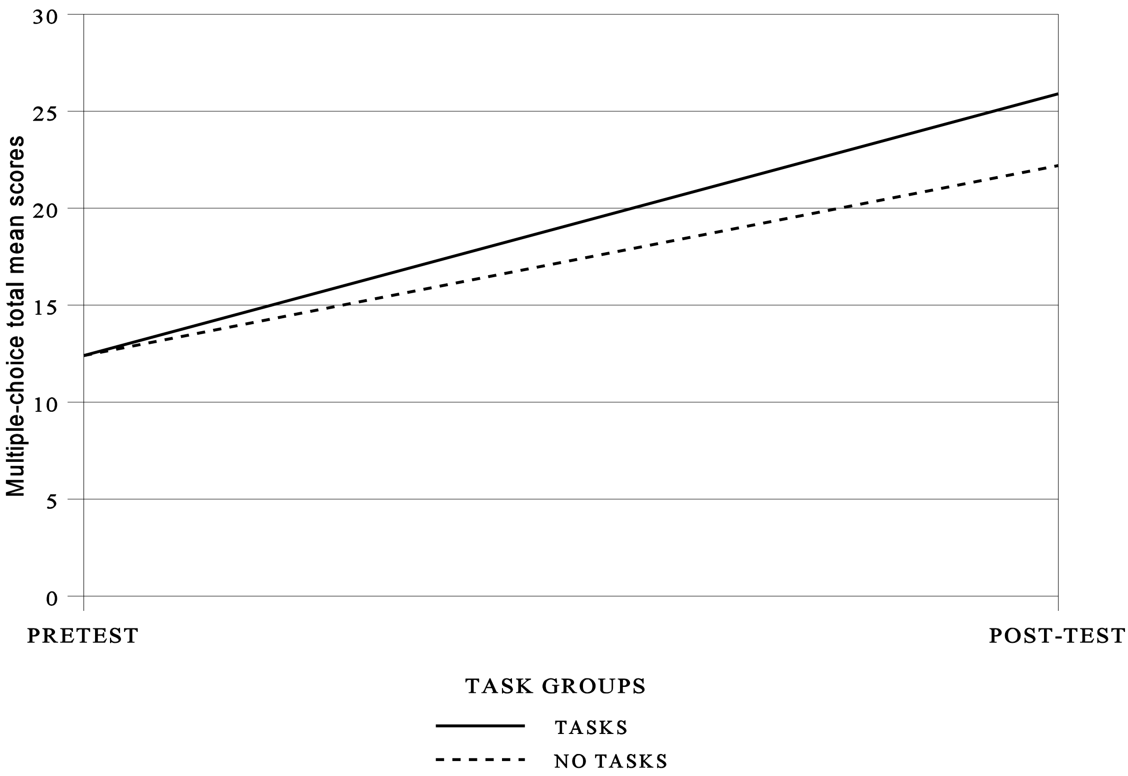


FIGURE 5 Pretest-post-test Multiple-Choice Questionnaire total mean scores in tasks and no tasks groups: Tasks prior to instruction (video viewing or traditional teaching) (n= 177) and no tasks prior to instruction (video viewing or traditional teaching) (n= 148). Differences in means: Pretest: tasks (M= 12.4; SD= 6.2) vs. no tasks (M= 12.4; SD= 7.2) p= .994; Post-test: tasks (M= 25.9; SD= 7.25) vs. no tasks (M= 22.2; SD= 9.2) p= .000 (t-test for nonequal variances used here).

Figure 5 shows the learning progress in those treatment groups using learning tasks prior to instruction which consisted either of viewing a section from the video programme (in the experimental groups), or of "traditional" instruction (in the control groups). Both task and no task groups increased their learning. There were no statistically significant differences between the two sets of groups in means in the pretest, but in the post-test the groups using tasks were significantly (p= .000) better than the groups using no tasks (*supports hypothesis 7*).

Figure 6 shows that, based on the Multiple-Choice Questionnaire total mean scores, students in the different video groups all increased their learning. There were statistically significant differences in the pretest: the video groups using only basic sections were significantly better than the video groups using basic sections + an application section (p= .000) and they were also better than the groups using no video (p= .005). There were no statistically significant differences between the video groups in the post-test. More detailed analyses regarding the learning effects will be discussed in section 8.5.2.

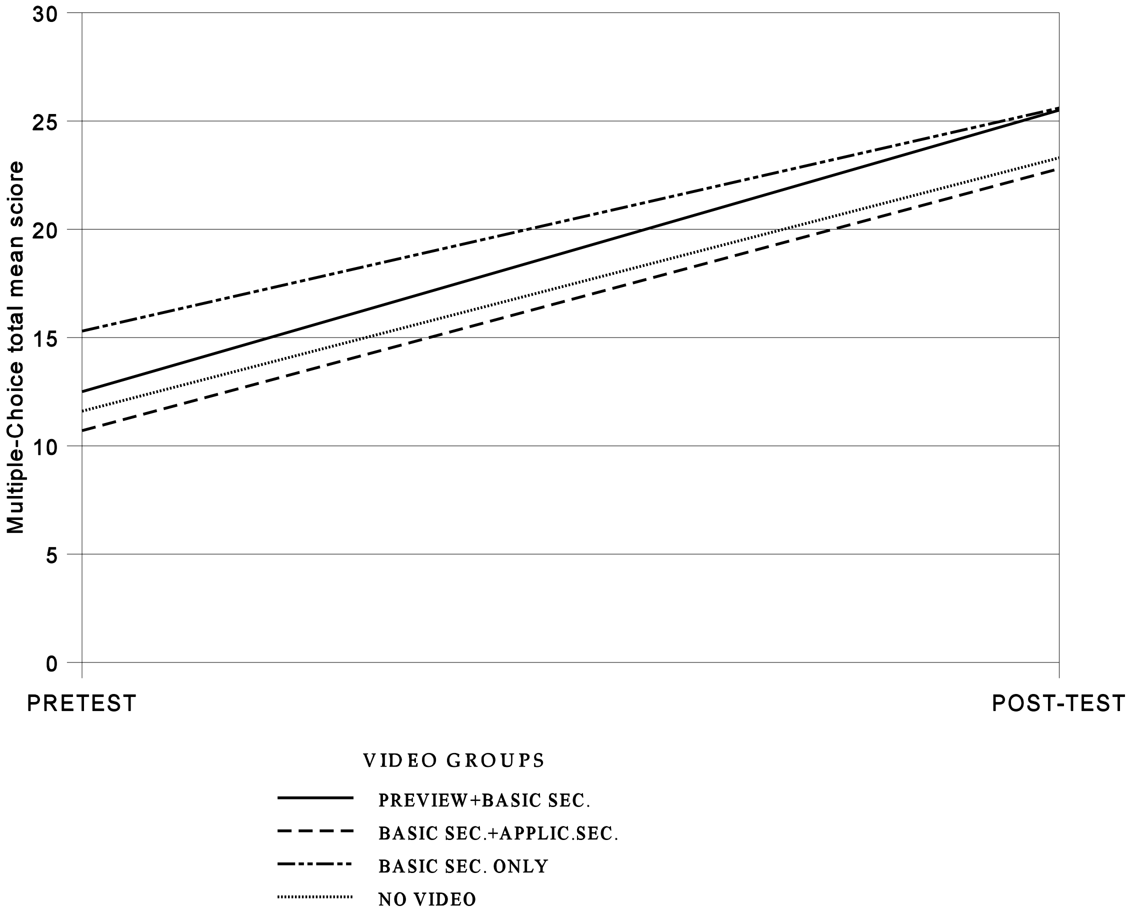


FIGURE 6 Pretest-post-test Multiple-Choice Questionnaire total mean scores in three video groups: Preview section + basic sections (n= 78; Pretest: M= 12.5; SD= 7.1 Post-test: M= 25.5; SD= 8.3), basic sections + application section (n= 85; Pretest: M= 10.7; SD= 5.6 Post-test: 22.8; SD= 9.4), basic sections (n= 72; Pretest: M= 15.3; SD= 7.4 Post-test: 25.6; SD= 7.9), and no video (n= 90; Pretest: M= 11.6; SD= 5.9; Post-test: M= 23.3; SD= 7.7). Pretest comparisons of means between the video groups: F= 7.16; p= .000; Significant differences based on post-hoc comparisons using Dunnett T 3: basic sections + application section vs. basic sections only (p= .000); basic sections only vs. no video (p= .005). Post-test comparisons of means between the video groups: F= 2.53; p= .057.

Qualitative perspectives on students' knowledge

The Task Papers 1-5 and Concept Maps + Essays 1-2 were used for collecting qualitative data on students' knowledge of gases. The Task Papers included typical physics problems (see appendix 7) and Concept Maps + Essays included a task to form a concept map and an essay based on the concept map (see appendix 5). Since the sample was rather large (n = 358) the information obtained from the qualitative data collection methods was quantified using scales specifically developed for this study (see section 7.8 and appendices 12 and 13).

TABLE 45 Students' performances on the Task Papers 1-5. Percentage distribution

Task Paper	n	Scores							M	SD
		0	1	2	3	4	5	6		
1 - task 1	348	6	3	4	2	10	5	71	5	1.8
1 - task 2	348	21	5	6	4	2	4	58	4	2.5
2 - task 1	336	2	0	1	18	3	2	74	5.2	1.4
2 - task 2	336	25	4	4	9	13	22	23	3.4	2.3
3 - task 1	341	4	2	1	12	4	6	71	5.1	1.7
3 - task 2	341	13	10	7	26	22	9	13	3.1	1.8
4 - task 1	335	13	3	4	3	9	5	63	4.6	2.2
4 - task 2	335	23	8	13	5	1	1	49	3.5	2.6
5 - task 1	326	17	16	19	18	12	3	15	2.6	2
5 - task 2	327	25	20	20	8	6	13	8	2.2	2

Table 45 shows that students' performances on each Task Paper's first task were better than on the second task; also the distribution in the second tasks was greater than in the first tasks (except for the Task Paper 5). This is understandable since the second tasks were designed to be more difficult than the first ones: The first tasks in the Task Papers 1-4 required a rather straightforward use of a proper equation whereas the second tasks required more application of knowledge. The performances were clearly better in the Task Papers 1-4 dealing with the gas laws than in the Task Paper 5 dealing with the kinetic theory of gases. Difficulties in understanding the particulate nature of gases have been noted in several previous studies as well (e.g. Brook, Briggs & Driver 1984; Novick & Nussbaum 1978, 1981).

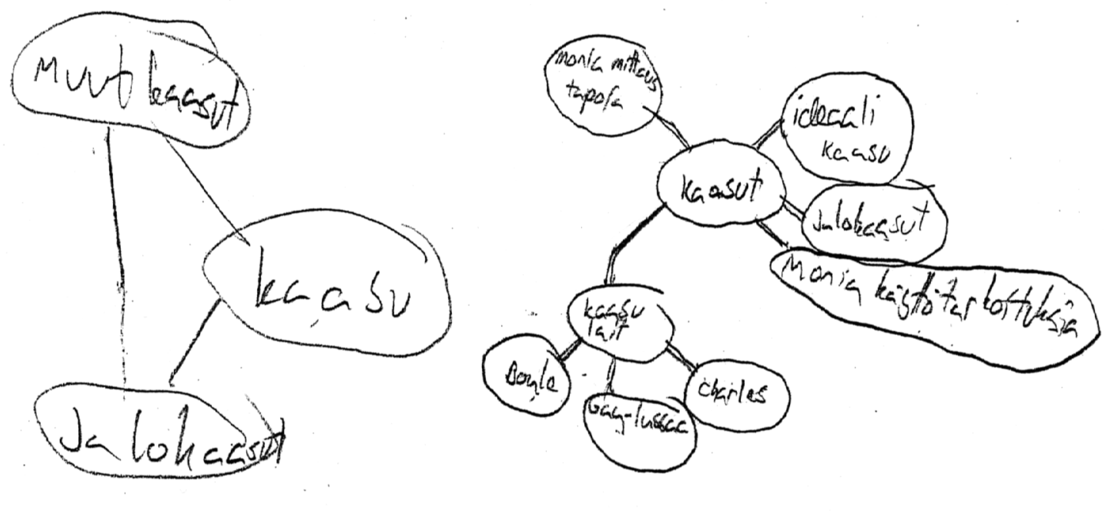
Results of the Concept Maps + Essays 1-2 will be presented in the following tables. Table 46 shows the basic distributions of the three scales used in analysing students' performances. In all three scales there was a clear improvement from pretest to post-test measurement. Also the distributions increased noticeably - in two scales the increase was more than double.

TABLE 46 Students' (n= 243) performances on Concept Maps + Essays 1-2. Percentage distributions. Abbreviations: OS= Overall Structure; SSC= Specific Structure and Coherence; C = Content

Data info	Pretest: Concept Map + Essay 1			Post-test: Concept Map + Essay 2		
	OS	SSC	C	OS	SSC	C
M	2	4.5	9.2	2.7	9	19.9
SD	0.1	2.2	4.4	1.1	4.3	10.3
Distributions:						
2	99.6			66		
4	0.4			33		
8	-			1		
1		6	-		-	-
2		7	4		-	-
3		25	2		6	-
4		20	7		7	1
5		14	7		9	-
6		11	11		10	2
7		7	10		10	3
8		2	12		9	3
9		3	4		11	3
10		4	10		10	5
11		1	7		5	3
12		-	5		8	4
13 - 16			13		11	19
17 - 20			7		3	16
21 - 24			1		1	12
25 - 28						7
29 - 32						9
33 - 36					-0.4	7
37 - 40						4
50 - 69						2

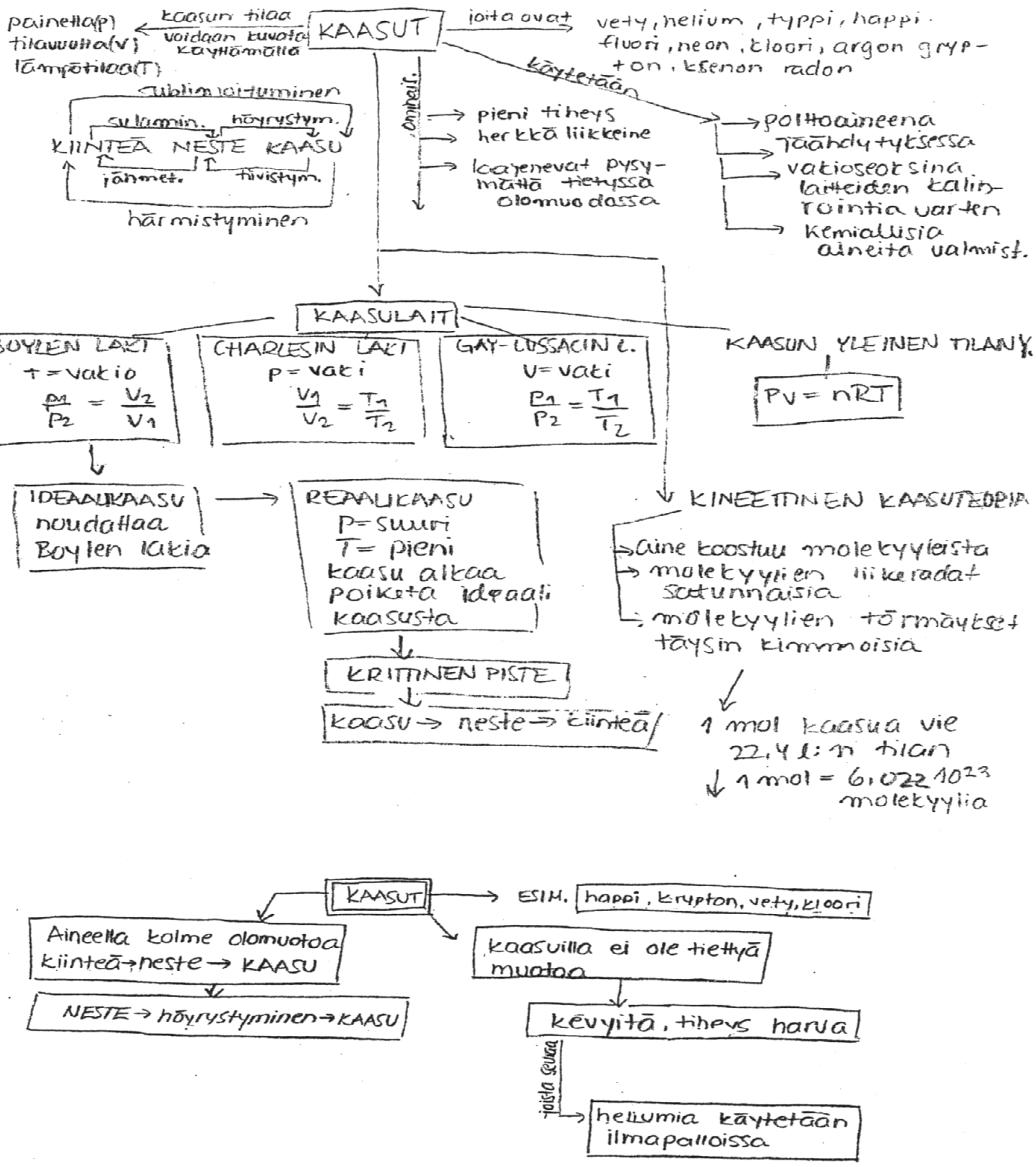
The Overall Structure scale was based on Langer's (1980) classification of knowledge levels. In pretest the overall structure of the concept maps was - with only one exception - quite simple, indicating that students had not developed a clear understanding of gases (table 46). They were at "diffused organized knowledge" level being able to report personal experience or tangential cognitive links. In post-test, the overall structure was clearly better, yet the majority of the concept maps were still rather simple representing "diffused organized knowledge". Many students (33 %) had constructed "partially organized knowledge" and were able to provide examples of the concepts and define them in terms of their main characteristics. Only two students had developed "highly organized knowledge" about gases showing that they can produce elaborations of the concepts which are provided to their superordinates and related concepts, and the concepts are defined precisely.

With regard to the Content scale (see table 46), the increase of factual information was quite noticeable. In pretest there were many students who obtained only low scores, but in post-test the results were much better and the number of students having good scores was relatively high. For concrete examples of improvement in constructing concept maps see the following two sets of concept maps in figures 7 and 8. The corresponding essays are in appendix 31.



Pretest scores (left one)	*Post-test scores* (right one)
OS = 2	OS = 2
SSC = 6	SSC = 8
C = 8	C = 14

FIGURE 7 A sample case of concept maps constructed by a student during pretest and post-test (small progress during the process). For essay section see appendix 31



Pretest scores (lower one)	*Post-test scores* (upper one)
OS = 2	OS = 8
SSC = 9	SSC = 35
C = 19	C = 69

FIGURE 8 A sample case of concept maps constructed by a student during pretest and post-test (good progress during the process). For essay section see appendix 31

Another perspective on improvements made during pretest and post-test measurements is provided by gain scores (the post-test score minus the pretest score for each student) (see table 47). The majority (66 %) of the students did not improve the overall structure of their concept maps and only very few of them gained more than 2 points, that is, improved their concept maps by more than one level according to Langer's (1980) knowledge level classification. With regard to the "Specific Structure and Coherence" and "Content" there was a small number of students whose scores decreased between the pretest and post-test and a number of students made no improvement. The majority of students gained 1- 16 points and there was also a considerable number of students who made noticeable improvements in constructing their concept maps.

TABLE 47 Students' (n= 243) gain scores of Concept Maps + Essays 1-2. Percentage distributions. Abbreviations: OS= Overall Structure; SSC= Specific Structure and Coherence; C = Content; $_1$ = pretest score, $_2$ = post-test score

Data info	Gain scores of individual scales			Gain scores based on sum scores
	OS	**SSC**	**C**	**$(OS_2+SSC_2+C_2)$ - $(OS_1+SSC_1+C_1)$**
M	0.7	4.5	10.8	15.9
SD	1	3.9	9.4	13.4
values:				
0	66			
2	33			
4	0.5			
6	0.5			
negative values		4	5	4
0		7	8	4
1 - 4		47	16	11
5 - 8		27	16	13
9 - 12		11	21	16
13 - 16		4	10	12
17 - 20			10	8
21 - 24			7	9
25 - 28		-0.4	4	7
29 - 32			1	5
33 - 40			1	7
41 - 48				2
50 -			1	2

Comparisons

Males performed statistically significantly better (based on means) than females in the Multiple-Choice Questionnaire pre- and post-test measurements, whereas females outperformed males in the Concept Map + Essay pre- and post-test measurements (appendix 19). There were no significant differences between the four socioeconomic groups in knowledge about gases in any measurements (appendix 20). Strongly goal-oriented students who were planning to include science subjects as part of their future studies were statistically significantly better than weakly goal-oriented students in the Multiple-Choice Questionnaire total scores in post-test, in gain scores regarding gas law items from the Multiple-Choice Questionnaire and in sum scores from the Task Papers 1-5 (appendix 21). Finnish students' scores were better than those of Canadian students in all gain scores of the Multiple-Choice Questionnaire 1-2 and also in post-test measurement of the Multiple-Choice Questionnaire (appendix 22).

8.5.2 The effects of learning tasks, video programmes, and selected other variables on students' knowledge

This sub-section contains the results of covariance and regression analyses used to investigate the effects of learning tasks, video programme versions and selected other variables on students' learning outcomes regarding their knowledge about gases. The analyses of covariance were based on 2 x 4 factorial variance analysis design, consisting of two task groups (tasks/ no tasks) and four video groups (preview + basic sections/ basic sections+application section/ basic sections only/ no video). These two factors were used in all the variance analyses discussed in this sub-section. All the covariates included in the following covariance analyses were selected based on observed correlations (minimum of .20) and logical criteria (which of the existing variables can be regarded as logical independent variables for the dependent variable).

The assumptions of (co)variance analysis are: the data are gathered using a random sampling method, for each cell there is a normal distribution, and all of the cell variances are the same. For all analyses in this sub-section applies that the data were gathered using random sampling. However, it must be noted that cluster sampling was used and therefore individual students were not randomly assigned to the treatment groups, but groups of students (see section 7.2). The equality of variances assumption was checked by using Levene's test of equality of error variances. The results of this test are included in each table. The assumption regarding the normal distribution was checked by studying the distribution of residuals (using Kolmogorov-Smirnov tests, histograms and normal Q-Q Plots) produced by each covariance model. The normal distribution test information is in appendix 26.

The results of the covariance analyses will be presented in the following order according to the dependent variables: total sum of the Multiple-Choice Questionnaire 1-2 gain scores, total sum scores of the five Task Papers, total sum of the Concept Map + Essay 1-2 gain scores. These three analyses provide three different perspectives on students' learning outcomes regarding their knowledge about gases.

The first covariance analysis consisted of the Multiple-Choice Questionnaire 1-2 sum gain scores as a dependent variable and it also included "Physics course grades" and "Finnish course grades" as covariates. There were some differences between the cell variances according to Levene's test of homogeneity of variances (p= .026). Therefore, some caution in interpreting the results of the covariance analysis might be appropriate.

The results (see table 48) suggest that the effects of the two covariates, Physics and Finnish course grades, and the effect of the task factor (*Supports hypothesis 7*) were statistically significant. Significant interactive effects of the video factor and the task factor were also found and therefore the interpretation of the effect of the task factor cannot be straightforward. A closer look at the parameter estimates of the covariance model indicates that the interaction effect of the task and the video factor can mostly be attributed to two video groups, video group 1 (preview + basic sections) and video group 2 (basic sections + application sections). In both of these video groups, the mean difference between the "tasks used" and "no tasks used" groups was statistically significantly greater than corresponding differences in video group 4 (control groups using no video). The size of the squared multiple correlation (R^2= .17) indicated a reasonable explained total variance.

Squared partial Eta values indicate that proportionally compared the greatest effects can be attributed to the task factor and interaction of the task and the video factors. The effects of Physics and Finnish course grades mean were clearly smaller than the factor effects. The observed power at .05 level varied from .45 to .98. The power estimates, excepting the lowest ones, suggest quite a good power for rejecting the null hypothesis regarding the effects of the factors, interactive effects of the factors and the covariates. Separate further analyses using gas law item total gain scores and kinetic theory of gases total gain scores as dependent variables did not produce any considerable differences in the covariance model seen in table 48. Therefore, these further analyses will not be presented. The normal distribution assumption was met well: the residuals were normally distributed according to the Kolmogorov-Smirnow test (p= .200); the same conclusion was obvious based on a histogram and a Normal Q-Q plot, as well (see section 1 in appendix 26).

McNemar tests for the Multiple-Choice Questionnaire items (table 49) were computed to see more clearly whether there were differences between the items in how many changes (from 0 to 1), indicating a learning effect had occurred, compared with changes (from 1 to 0) indicating a deterioration of learning. Table 49 shows that in the majority of items there were statistically significantly more positive (from 0 to 1) changes than negative (from 1 to 0) changes. Only in items M9 and M14 was the number of positive changes compared to negative changes not statistically significant. Also worth noting is the fairly high number of negative changes in many items, which is one more indication that gases were a difficult topic for the students.

Table 50 consists of results of a covariance analysis where the total sum of the Task Papers 1-5 was a dependent variable and Physics -, Mathematics - and Finnish course grades means, and "hours used for studying the topics of the minicourse at home" were used as covariates. The variances of the treatment groups did not significantly differ from each other according to Levene's test (see table 50).

The results (table 50) suggest that the effects of two covariates, "Physics course grades mean" and "hours used for studying the topics of the minicourse at home" and the effect of the video factor were statistically significant. The detected effects, however, were contrary to hypotheses 5 and 6 (see also the contrasts section). No significant interactive effects of the video factor and the task factor were found in the main section of the table. The size of the squared multiple correlation (R^2= .46) indicated quite a large explained total variance. The squared partial Eta values indicate that proportionally compared physics course grades mean had the greatest effect. A closer look at the parameter estimates revealed a statistically significant (p= .046) interactive effect attributed to video group 1 (preview + basic sections) in which the mean difference between the "tasks used" and "no tasks used" groups was statistically significantly greater than corresponding differences in video group 4 (control groups using no video). Furthermore, the results of video group 3 (basic sections only) were statistically significantly poorer than in the non-video control groups.

The observed power of the factors and covariates at .05 level varied from .51 to .99, suggesting that the power for rejecting the null hypothesis was rather good. The residuals were not quite normally distributed according to the Kolmogorov-Smirnow test (p= .029); However, according to a histogram and a normal Q-Q Plot, the deviation from a normal distribution is not very serious (see section 2 in appendix 26). Therefore, it seems that the normality assumption as a whole can be regarded as acceptable.

Table 51 shows the results of a covariance analysis where the gas law related Task Papers 1-4 total sum score was used as a dependent variable. The independent variables were video groups and task groups as factors and Physics -, Mathematics - and Finnish course grades means, and "hours used for studying the topics of the minicourse at home" as covariates. It must be noted that only 248 cases were available for this analysis. There were some differences between the cell variances according to Levene's test of homogeneity of variances (p= .020). Therefore, some caution in interpreting the results of the covariance analysis might be appropriate.

The results (table 51) suggest that the effects of three covariates, Physics- and Mathematics course grades means and "hours used for studying the topics of the minicourse at home" as well as the effect of the video factor were statistically significant (p= from .044 to .000). The detected effects of the video factor (video groups 2 and 3), however, were contrary to hypotheses 5 and 6 (see also the contrast section). There were also interactive effects of the video factor and the task factor (p= .034). However, a deeper look at the parameter estimates revealed no statistically significant interactive effects which could be attributed to certain factor groups. The parameter estimates do show that video group 3 (basic sections only) performed statistically significantly poorer than the control groups using no video. This is also seen in the contrasts section, which, in addition, shows that video group 2 was also performing significantly poorer than the non-video control groups .

The size of the squared multiple correlation (R^2= .43) indicated quite a large explained total variance. The squared partial Eta values indicate that proportionally compared physics course grades mean had the greatest effect. The observed power of the factors and covariates at .05 level varied from .52 to .99 suggesting that the power for rejecting the null hypothesis is quite good.

The residuals were not quite normally distributed according to the Kolmogorov-Smirnow test (p= .002); However, according to a histogram and a normal Q-Q Plot of residual, the deviation from a normal distribution is not very serious (see section 3 in appendix 26). Therefore, it seems that the normality assumption can be regarded as acceptable.

TABLE 48 Covariance analysis: The Multiple-Choice Questionnaire total gain score (dependent), video groups and task groups as factors, Physics and Finnish course grades as covariates (n= 320)

Task group	Video group gain score means (standard deviations)				Combined group mean
	preview + basic sections (1)	basic sections + application section (2)	basic sections (3)	no video (4)	
tasks (A)	15.9 (8.0)	15.1 (7.4)	10.5 (5.7)	11.8 (6.4)	13.4 (7.3)
no tasks (B)	9.5 (6.0)	9.0 (9.9)	9.8 (7.4)	11.6 (8.1)	9.9 (7.8)
Combined group mean	13.0 (7.8)	12.3 (9.1)	10.1 (6.7)	11.7 (7.1)	11.8 (7.8)

Levene's Test of Equality of Error variances: F = 2.32 df1 = 7, df2 = 312, p = .026

Tests of Between-Subject Effects:

Source of Variation	Type III SS	DF	MS	F	p	Partial Eta Sqr.	Observed Power using alpha .05
Corrected Model	32883	9	365.4	7.06	.000	.17	1
Intercept	144.5	1	144.5	2.79	.096	.01	.39
Physics course grades mean (fys_ka)	310.4	1	310.4	5.99	.015	.02	.69
Finnish course grades mean (äid_ka)	272.1	1	272.1	5.26	.023	.02	.63
Video group	267.6	3	89.2	1.72	.162	.02	.45
Task group	870.5	1	870.5	16.82	.000	.05	.98
Video group * task group	679.5	3	226.5	4.38	.005	.04	.87
Error	16043.9	310	51.8				
Total	19332.2	319	(R^2 = .17)				

Statistically Significant Parameter Estimates of the Covariance Model:

Covariates/factors	r with dependent	B	Std Err.	t-value	p	Partial Eta Sqr.	Observed power using alpha .05
Physics course grades mean (fys_ka)	**.24 *****	1.03	0.42	2.45	.015	.02	.39
Finnish course grades mean (äid_ka)	**.23*****	1.18	0.52	2.29	.023	.02	.69
A[1] versus C[3]	-	5.63	2.28	2.46	.014	.09	.69
B[2] versus C[3]	-	6.52	2.24	2.92	.004	.03	.83

*** p < .001;
1) A = in video group 1: the mean difference between the "tasks used" and "no tasks used" groups
2) B = in video group 2: the mean difference between the "tasks used" and "no tasks used" groups
3) C = in video group 4: the mean difference between the "tasks used" and "no tasks used" groups

TABLE 49 McNemar tests for pretest-post-test changes in individual items (0= wrong guess or answer, 1=correct guess or answer) (n= 325)

Multiple-Choice-1 item / values		Corresponding Multiple-Choice-2 item/ values		Chi-Square	p
		1	0		
M1	0	45	24	8.86	.003
	1	236	20		
M2	0	69	152	8.41	.004
	1	66	38		
M3	0	157	125	115.59	.000
	1	28	15		
M4	0	199	78	163.96	.000
	1	36	12		
M5	0	77	23	11.8	.001
	1	186	39		
M6	0	109	74	22.93	.000
	1	94	48		
M7	0	84	84	7.59	.006
	1	106	51		
M8	0	107	51	69.95	.000
	1	153	14		
M9	0	56	224	3.48	.062
	1	8	37		
M10	0	118	98	64.46	.000
	1	87	22		
M11	0	131	56	92.8	.000
	1	124	14		
M12	0	133	66	65.49	.000
	1	97	29		
M13	0	73	31	11.89	.001
	1	185	36		
M14	0	74	157	2.22	.136
	1	38	56		

TABLE 50 Covariance Analysis: Total sum score of the Task Papers 1-5 (dependent), video groups and task groups as factors, Physics -, Mathematics - and Finnish course grades means, and "hours used for studying the topics of the minicourse at home" as covariates (n= 238)

Task group	Video group total sum score means (standard deviations)				Combined group mean
	preview + basic sections (1)	basic sections + application section (2)	basic sections (3)	no video (4)	
tasks (A)	44.2 (8.6)	36.3 (11.3)	36.0 (9.0)	43.1 (8.0)	40.2 (10.0)
no tasks (B)	35.8 (11.5)	39.4 (7.8)	35.6 (9.2)	40.9 (9.0)	37.8 (9.4)
Combined group mean	40.7 (10.7)	37.7 (9.9)	35.7 (9.0)	42.3 (8.3)	39.1 (9.8)

Levene's Test of Equality of Error variances: F = 1.42 df1 = 7 , df2 = 230 , p = .200

Tests of Between-Subject Effects:

Source of Variation	Type III SS	DF	MS	F	p	Partial Eta Sqr.	Observed Power using alpha .05
Corrected Model	10421	11	947.4	17.42	.000	.46	1
Intercept	3.8	1	3.8	0.07	.791	.00	.06
Physics course grades mean (fys_ka)	1388	1	1388	25.52	.000	.10	.99
Mathematics course grades mean (mat_ka)	197.8	1	197.8	3.64	.058	.02	.48
Finnish course grades mean (aid_ka)	27.8	1	27.8	0.51	.475	.00	.11
Hours used for studying the topics of the minicourse (exp9)	352.3	1	352.3	6.48	.012	.03	.72
Video group	526	3	175.3	3.22	.023	.04	.74
Task group	74.7	1	74.1	1.37	.242	.01	.22
Video group * task group	393.6	3	131.2	2.41	.068	.03	.60
Error	12291.3	226	54.4				
Total	386272	238	(R^2 = .46)				

Statistically Significant Parameter Estimates of the Covariance Model:

Covariates/factors	r with dependent	B	Std Err.	t-value	p	Partial Eta Sqr.	Observed power using alpha .05
Physics course grades mean (fys_ka)	.60 ***	3.4	0.68	5.05	.000	.10	.99
Hours used for studying the topics of the minicourse (exp9)	.31 ***	0.5	0.21	2.55	.012	.03	.72
Video group 3 (basic sections only)	-	-4.2	2.09	-2	.046	.02	.51
A[1] vs. B[2]	-	5.8	2.88	2.01	.046	.02	.52

Statistically significant contrasts: Estimates for the total sum score adjusted for the four covariates

Contrasts (Method: Simple)		Contrast estimate	std.err.	p	95% Confidence Interval
Video groups	**2 vs. 4**	-2.84	1.35	.036	-5.49 ... -0.18
	3 vs. 4	-4.11	1.46	.005	-6.98 ... -1.24

*** p < .001; 1) A = in video group 1: the mean difference between the "tasks used" and "no tasks used" groups; 2) B = in video group 4: the mean difference between the "tasks used" and "no tasks used" groups

TABLE 51 Covariance analysis: The gas law related Task Papers 1-4 total sum scores (dependent), video groups and task groups as factors, Physics -, Mathematics - and Finnish course grades means, and "hours used for studying the topics of the minicourse at home" as covariates (n= 248)

Task group	Video group total sum score means (standard deviations)				Combined group mean
	preview + basic sections (1)	basic sections + application section (2)	basic sections (3)	no video (4)	
tasks (A)	37.5 (7.2)	29.9 (10.2)	31.8 (8.8)	34.3 (9.1)	34.3 (9.1)
no tasks (B)	33.2 (10.2)	36.3 (6.3)	30.0 (8.8)	33.9 (9.0)	33.9 (9.0)
Combined group mean	35.7 (8.8)	32.6 (9.2)	30.8 (8.8)	34.1 (9.0)	34.1 (9.0)

Levene's Test of Equality of Error variances: F = 2.4 df1 = 7 , df2 = 240 , p = .020

Tests of Between-Subject Effects:

Source of Variation	Type III SS	DF	MS	F	p	Partial Eta Sqr.	Observed Power using alpha .05
Corrected Model	8585.6	11	780.5	16.02	.000	.43	1
Intercept	6.3	1	6.3	0.13	.720	.00	.06
Physics course grades mean (fys_ka)	1054.8	1	1054.8	21.65	.000	.08	.99
Mathematics course grades mean (mat_ka)	300.2	1	300.2	6.16	.014	.03	.70
Finnish course grades mean (aid_ka)	1.48	1	1.48	0.03	.862	.00	.05
Hours used for studying the topics of the minicourse (exp9)	199.5	1	199.5	4.1	.044	.02	.52
Video group	677.7	3	225.9	4.64	.004	.06	.89
Task group	17.9	1	17.9	0.37	.545	.00	.09
Video group * task group	430	3	143.3	2.94	.034	.04	.69
Error	11500.3	236	48.7				
Total	308954	248	(R^2 = .43)				

Statistically Significant Parameter Estimates of the Covariance Model:

Covariates/factors	r with dependent	B	Std Err.	t-value	p	Partial Eta Sqr.	Observed power using alpha .05
Physics course grades mean (fys_ka)	.57 ***	2.9	.62	4.65	.000	.08	.99
Mathematics course grades mean (mat-ka) .55 ***	.55 ***	1.3	.54	2.48	.014	.03	.70
Hours used for studying the topics of the minicourse (exp9)	.27 ***	0.4	.20	2.02	.044	.02	.52
Video group 3 (basic sections only)	-	-5.7	1.89	-3.02	.003	.04	.85

Statistically significant contrasts: Estimates for the gain score adjusted for the four covariates

Contrasts (Method: Simple)		Contrast estimate	std.err.	p	95% Confidence Interval
Video group	**2 vs. 4**	-3.22	1.24	.010	-5.66 ... -0.78
	3 vs. 4	-4.61	1.35	.001	-7.26 ... -1.96

*** p < .001

Table 52 shows the results of a covariance analysis where the kinetic theory related Task Paper 5 total sum score was used as a dependent variable. The independent variables were video groups and task groups as factors and Physics course grades mean and "hours used for studying the topics of the minicourse at home" as covariates. Note that 269 cases were available for this analysis. There were statistically significant differences between the cell variances according to Levene's test of homogeneity of variances (p= .000). Given the differences in the cell variances, there must be some caution in interpreting the results of the covariance analysis.

The results (table 52) suggest that the effects of the two covariates, Physics course grades mean and "hours used for studying the topics of the minicourse at home" as well as the effects of the video factor and the task factor were statistically significant (p= from .040 to .000). There were also interactive effects of the video factor and the task factor (p= .000). The size of the squared multiple correlation (R^2= .29) indicated a reasonable explained total variance. The squared partial Eta values indicate that the task group factor and the interaction of the task group and the video group factors had the greates effects.

A closer look at the the parameter estimates of the covariance model (table 52) indicates that video group 3 (basic sections only) performed statistically significantly better than the control groups using no video and the groups using tasks prior to viewing video sections had significantly better results than the groups not using the tasks. However, it must be noted that video group 3 (basic sections only) and the task factor had a significant interactive effect: contrary to all other video groups, inside video group 3 the mean difference between the "tasks used" and "no tasks used" groups was statistically significantly greater and negative than corresponding differences in video group 4 (control groups using no video). That is, inside video group 3 "no tasks used " groups performed better than "tasks used" groups. All these three above described effects were equally strong (squared partial Eta values were .07). The contrasts section in table 52 shows that there were statistically significant differences among the two factors, which give support to some hypotheses (*supports hypotheses 4, 5, 6, and 7)*. The interactive effect discussed above must be noted as an exception together with this support for hypotheses 4 - 7.

The observed power of the factors and covariates at .05 level varied from .56 to .99 suggesting that the power for rejecting the null hypothesis is quite good (table 52). The residuals did not significantly differ from normal distribution according to the Kolmogorov-Smirnow test (p= .200). Also a histogram and a normal Q-Q Plot of residuals showed that the normality assumption was well met (see section 4 in appendix 26).

Table 53 shows the results of a covariance analysis where the Concept Map + Essay 1-2 total sum of gain scores was used as a dependent variable. The independent variables were video groups and task groups as factors; also the following covariates were included: "hours used for studying the topics of the minicourse at home", Finnish course grades mean and "hours a week spent on all homework". Note that 210 cases were available for this analysis. There were statistically significant differences between the cell variances according to

Levene's test of homogeneity of variances (p= .002). Given the differences in the cell variances, some caution in interpreting the results of the covariance analysis is appropriate.

The results (table 53) suggest that only the interactive effects of the video factor and the task factor were statistically significant (p= .000). Also the squared partial Eta value for these interactive effects was clearly the highest among the factors and covariates. The size of the squared multiple correlation (R^2= .26) indicated a reasonable explained total variance.

A closer look at the parameter estimates (table 53) indicates that video group 2 (basic sections + application section) performed statistically significantly poorer than the control groups using no video. The interactive effects of the video factor and the task factor were attributed to video group 1 (preview + basic sections) and video group 2 (basic sections + application section). In both of these video groups the mean difference between the "tasks used" and "no tasks used" groups was statistically significantly greater than corresponding differences in video group 4 (control groups using no video). In these two video groups the results supported hypotheses 7, whereas in the other two video groups (3= basic sections; 4= no video) the results were the opposite.

The observed power of the factors and covariates at .05 level varied quite a lot, from .23 to .99 (table 53); However, for the parameter estimates, the observed power was good throughout (from .72 to .92) suggesting that the power for rejecting the null hypothesis for these estimates was good. The residuals did not significantly differ from normal distribution according to the Kolmogorov-Smirnow test (p= .200). Also a histogram and a normal Q-Q Plot of residuals showed that the normality assumption was well met (see section 5 in appendix 26).

Table 54 shows the results of a covariance analysis where the Concept Map + Essay 1-2 Specific Structure and Coherence gain scores was used as a dependent variable. The independent variables were video groups and task groups as factors and "hours a week used for all homework"as a covariate. Note that 242 cases were available for this analysis. There were some differences between the cell variances according to Levene's test of homogeneity of variances (p= .006). Given the differences in the cell variances, some caution in interpreting the results of the covariance analysis is recommended.

The results (table 54) suggest that the covariate ("hours a week used for all homework"), video factor and interactive effects of the video factor and the task factor were statistically significant (p= from .044 to .000). The squared partial Eta value for these interactive effects was clearly the highest among the factors and covariates. The size of the squared multiple correlation (R^2= .20) indicated a reasonable explained total variance.

A closer look at the parameter estimates (table 54) indicates that the interactive effects of the video factor and the task factor were attributed to video group 1 (preview + basic sections) and video group 2 (basic sections + application section). In both of these video groups the mean difference between the "tasks used" and "no tasks used" groups was statistically significantly greater t-han corresponding differences in video group 4 (control groups using no video).

In these two video groups the results supported hypotheses 7, whereas in the other two video groups (3= basic sections; 4= no video) the results were the opposite. Furthermore, the contrasts show that video group 3 (basic sections) performed statistically significantly (p= .028) poorer than video group 4 (control groups using no video). However, since the number of cases in video group 3 was rather small, the above described difference was not shown as a statistically significant in the parameter estimates section of the covariance model, where the effect of the covariate is considered.

The observed power of the factors and covariates at .05 level varied from .39 to .99, most of the values indicating that the power for rejecting the null hypothesis for these estimates was good (table 54). The residuals differed statistically significantly (p= .002) from normal distribution according to the Kolmogorov-Smirnow test. However, a histogram and a normal Q-Q Plot of residuals seem to suggest the deviation is not very serious (see section 6 in appendix 26). On the whole, the normality assumption was acceptable.

TABLE 52 Covariance analysis: The kinetic theory related Task Paper 5 total sum scores (dependent), video groups and task groups as factors, "Physics course grades means", and "hours used for studying the topics of the minicourse at home" as covariates (n= 269)

Task group	Video group total sum score means (standard deviations)				Combined group mean
	preview + basic sections (1)	basic sections + application section (2)	basic sections (3)	no video (4)	
tasks (A)	6.8 (2.9)	6.1 (3.4)	4.1 (1.4)	5.6 (3.0)	5.8 (3.0)
no tasks (B)	3.2 (2.4)	3.3 (2.3)	5.2 (2.8)	2.2 (2.3)	3.6 (2.7)
Combined group mean	5.3 (3.2)	4.9 (3.2)	4.7 (2.3)	4.4 (3.2)	4.8 (3.0)

Levene's Test of Equality of Error variances: F =4.39 df1 = 7 , df2 = 261 , p = .000

Tests of Between-Subject Effects:

Source of Variation	Type III SS	DF	MS	F	p	Partial Eta Sqr.	Observed Power using alpha .05
Corrected Model	718.3	9	79.8	11.9	.000	.29	1
Intercept	0.08	1	0.08	0.01	.914	.00	.05
Physics course grades mean (fys_ka)	99.5	1	99.5	14.83	.000	.05	.97
Hours used for studying the topics of the minicourse at home (exp9)	30.2	1	30.2	4.5	.040	.02	.56
Video group	53.5	3	17.8	2.66	.049	.03	.65
Task group	259.5	1	259.5	38.69	.000	.13	1
Video group * task group	211.2	3	70.4	10.5	.000	.11	.99
Error	1737.4	259	6.7				
Total	8642	269	(R^2 = .29)				

Statistically Significant Parameter Estimates of the Covariance Model:

Covariates/factors	r with dependent	B	Std Err.	t-value	p	Partial Eta Sqr.	Observed power using alpha .05
Physics course grades mean (fys_ka)	.22 ***	0.5	.14	3.85	000	.05	.97
Hours used for studying the topics of the minicourse at home (exp9)	.21 **	0.2	.07	2.12	.035	.02	.56
Video group 3 (basic sections only)	-	3.1	.69	4.47	000	.07	.99
Task group A (tasks used)	-	2.8	.66	4.28	000	.07	.99
A[1] versus B[2]	-	-4	.94	-4.27	000	.07	.99

Statistically significant contrasts: Estimates for the gain score adjusted for the two covariates

Contrasts (Method: Simple)		Contrast estimate	std.err.	p	95% Confidence Interval
Task groups	**A vs. B**	2.01	.32	.000	1.38 ... 2.65
Video groups	**1 vs. 4**	1.15	.47	.014	0.23 ... 2.07
	2 vs. 4	0.91	.44	.040	0.04 ... 1.78
	3 vs. 4	1.07	.48	.025	0.13 ... 2.00

** p < .01 *** p < .001; 1) A = in video group 3: the mean difference between the "tasks used" and "no tasks used" groups; 2) B = in video group 4: the mean difference between the "tasks used" and "no tasks used" groups

TABLE 53 Covariance analysis: The Concept Map + Essay 1-2 total sum of gain scores (dependent), video groups and task groups as factors, "hours used for studying the topics of the minicourse at home", Finnish course grades mean, and "hours a week used for all homework"as covariates (n= 210)

Task group	**Video group total sum gain score means (standard deviations)**				**Combined group mean**
	preview + basic sections (1)	**basic sections + application section (2)**	**basic sections (3)**	**no video (4)**	
tasks (A)	26.9 (15.5)	19.2 (13.0)	6.7 (9.2)	17.3 (12.7)	17.6 (14.2)
no tasks (B)	12.9 (8.9)	10.3 (7.6)	16.4 (7.1)	18.2 (14.3)	13.2 (9.3)
Combined group mean	19.4 (14.5)	15.1 (11.7)	10.5 (9.6)	17.5 (12.9)	15.9 (12.7)

Levene's Test of Equality of Error variances: F =3.39 df1 = 7 , df2 = 202 , p = .002

Tests of Between-Subject Effects:

Source of Variation	**Type III SS**	**DF**	**MS**	**F**	**p**	**Partial Eta Sqr.**	**Observed Power using alpha .05**
Corrected Model	8698.4	10	869.8	6.95	.000	.26	1
Intercept	0.002	1	0.002	0	.997	00	.05
Hours used for studying the topics of the minicourse at home (exp9)	455.7	1	455.7	3.64	.058	.02	.48
Finnish course grades mean (aid_ka)	186.1	1	186.1	1.49	.224	.01	.23
Hours a week spent on all homework (g9)	376.2	1	376.2	3	.085	.02	.41
Video group	988.7	3	329.6	2.63	.051	.04	.64
Task group	257.9	1	257.9	2.06	.153	.01	.30
Video group * task group	4217.2	3	1405.7	11.22	.000	.15	.99
Error	24922.7	199	125.2				
Total	83662	210	(R^2 = .26)				

Statistically Significant Parameter Estimates of the Covariance Model:

Factors	**B**	**Std Err.**	**t-value**	**p**	**Partial Eta Sqr.**	**Observed power using alpha .05**
Video group 2	-10.4	4.06	-2.56	.011	.03	.72
A[1] vs. C[3]	16.6	4.89	3.4	.001	.06	.92
B[2] vs. C[3]	13.5	4.87	2.78	.006	.04	.79

Statistically significant contrasts: No significant contrasts in this factor model

1) A = in video group 1: the mean difference between the "tasks used" and "no tasks used" groups
2) B = in video group 2: the mean difference between the "tasks used" and "no tasks used" groups
3) C = in video group 4: the mean difference between the "tasks used" and "no tasks used" groups

TABLE 54 Covariance analysis: The Concept Map + Essay 1-2 Specific Structure and Coherence gain scores (dependent), video groups and task groups as factors, "hours a week used for all homework"as covariate (n= 242)

Task group	Video group gain score means (standard deviations)				Combined group mean
	preview + basic sections (1)	basic sections + application section (2)	basic sections (3)	no video (4)	
tasks (A)	7.0 (5.4)	6.1 (3.9)	1.8 (3.1)	4.7 (3.8)	5.0 (4.5)
no tasks (B)	3.6 (3.3)	2.9 (2.1)	4.0 (2.3)	4.7 (3.7)	3.6 (2.8)
Combined group mean	5.4 (4.8)	4.6 (3.5)	2.7 (3.0)	4.7 (3.7)	4.5 (4.0)

Levene's Test of Equality of Error variances: F = 2.92 df1 = 7, df2 = 234, p = .006

Tests of Between-Subject Effects:

Source of Variation	Type III SS	DF	MS	F	p	Partial Eta Sqr.	Observed Power using alpha .05
Corrected Model	736.9	8	92.1	7.09	000	.20	1
Intercept	14.8	1	14.8	1.14	.287	.01	.19
Hours a week used for all homework (g9)	118.2	1	118.2	9.09	.003	.04	.85
Video group	107.1	3	35.7	2.75	.044	.03	.66
Task group	37.4	1	37.4	2.88	.091	.01	.39
Video group * task group	332.8	3	110.9	8.53	000	.10	.99
Error	3028.8	233	13				
Total	8550	242		(R^2 = .20)			

Statistically Significant Parameter Estimates of the Covariance Model:

Covariates/factors	r with dependent	B	Std Err.	t-value	p	Partial Eta Sqr.	Observed power using alpha .05
Hours a week used for all homework (g9)	.21 **	0.9	0.3	3.02	.003	.04	.85
Video group 2	-	-2.4	1.19	-2.06	.041	.02	.54
A[1] vs. C[3]	-	3.8	1.42	2.68	.008	.03	.76
B[2] vs. C[3]	-	4	1.44	2.79	.006	.03	.79

Statistically significant contrasts: Estimates for the gain score adjusted for the covariate

Contrasts (Method: Simple)		Contrast estimate	std.err.	p	95% Confidence Interval
Video groups	3 vs. 4	-1.68	.76	.028	-3.18 ... -0.18

** p < .01
1) A = in video group 1: the mean difference between the "tasks used" and "no tasks used" groups
2) B = in video group 2: the mean difference between the "tasks used" and "no tasks used" groups
3) C = in video group 4: the mean difference between the "tasks used" and "no tasks used" groups

Table 55 shows the results of a covariance analysis where the Concept Map + Essay 1-2 Content gain scores were used as a dependent variable. The independent variables were video groups and task groups as factors and "hours used for studying the topics of the minicourse at home"as a covariate. Note that 214 cases were available for this analysis. There were some differences between the cell variances according to Levene's test of homogeneity of variances (p=

.002). Given the differences in the cell variances, some caution in interpreting the results of the covariance analysis is recommended.

The results (table 55) suggest that the covariate (“hours used for studying the topics of the minicourse at home”), video factor and interactive effects of the video factor and the task factor were statistically significant (p= from .039 to .000). The squared partial Eta value for these interactive effects was clearly the highest among the factors and covariates. The size of the squared multiple correlation (R^2= .23) indicated a reasonable explained total variance.

A closer look at the parameter estimates (table 55) indicates that video group 2 (basic sections + application section) performed statistically significantly poorer than video group 4 (control groups using no video). The interactive effects of the video factor and the task factor were attributed to video group 1 (preview + basic sections) and video group 2 (basic sections + application section). In both of these video groups the mean difference between the “tasks used” and “no tasks used” groups was statistically significantly greater than corresponding differences in video group 4 (control groups using no video). In these video groups 1 and 2 the results supported hypotheses 7, whereas in the other two video groups (3= basic sections; 4= no video) the results were the opposite. Furthermore, given the small number of cases in video group 3, the differences in the means (compared to video group 4) were not shown as a statistically significant in the parameter estimates section of the covariance model, where the effect of the covariate is considered.

The observed power of the factors and covariates at .05 level varied from .27 to .99, most of the values indicating that the power for rejecting the null hypothesis for these estimates was good (table 55). The residuals differed statistically significantly (p= .001) from normal distribution according to the Kolmogorov-Smirnow test. However, a histogram and a normal Q-Q plot of residuals seem to suggest the deviation is not very serious (see section 7 in appendix 26). On the whole, the normality assumption was acceptable.

Finally, it should be noted that intra-cluster correlations may sometimes cause problems in studies where cluster sampling methods have been applied. Intra-cluster correlation refers to the kind of "homogeneity effect" that is caused by natural clusters of people, such as school classes which tend to make the people inside the group more homogenous compared with a random sample from the target group. Methods have been developed for estimating the size of intra-cluster correlation for controlling its effects in different statistical methods, such as the analysis of variance or covariance (see e.g. Lehtonen, Nissinen & Pahkinen 1992; Searle, Casella & McCulloch 1992). There were small differences between the participating physics groups in a number of dependent variables used in the following covariance analyses, indicating that there may be some intra-cluster correlation in the data. This may have some effect on the standard errors of the coefficients. Since the differences between the physics groups *per se* were not of interest in the present study, the intra-cluster correlations can be regarded here as nuisance factors. Based on the variance component estimates presented in appendix 30, however, it seems clear that in most of the covariance analyses the between physics groups variance is relatively small, indicating that the intra-cluster correlation should not cause considerable problems. More detailed analyses of the effects of the intra-cluster correlation would require larger data with more physics groups.

TABLE 55 Covariance analysis: The Concept Map + Essay 1-2 Content gain scores (dependent), video groups and task groups as factors, "hours used for studying the topics of the minicourse at home"as covariate (n= 214)

Task group	Video group gain score means (standard deviations)				Combined group mean
	preview + basic sections (1)	basic sections + application section (2)	basic sections (3)	no video (4)	
tasks (A)	18.9 (11.3)	12.3 (8.9)	4.4 (6.2)	11.0 (8.9)	11.5 (10.0)
no tasks (B)	8.4 (6.6)	6.9 (5.7)	11.7 (4.6)	12.4 (10.3)	9.1 (6.8)
Combined group mean	13.6 (10.6)	9.9 (8.0)	7.1 (6.7)	11.3 (9.1)	10.6 (9.0)

Levene's Test of Equality of Error variances: F =3.29 df1 = 7 df2 = 206 p = .002

Tests of Between-Subject Effects:

Source of Variation	Type III SS	DF	MS	F	p	Partial Eta Sqr.	Observed Power using alpha .05
Corrected Model	4013.5	8	501.7	7.8	.000	.23	1
Intercept	10368.5	1	10368.5	161.18	.000	.44	1
Hours used for studying the topics of the minicourse at home (exp9)	441.6	1	441.6	6.87	.009	.03	.74
Video group	546.8	3	182.3	2.83	.039	.04	.67
Task group	118.4	1	118.4	1.84	.176	.01	.27
Video group * task group	2103.2	3	701.1	10.9	.000	.14	.99
Error	13187.2	205	64.3				
Total	17200.7	213	(R^2 = .23)				

Statistically Significant Parameter Estimates of the Covariance Model:

Covariates/factors	r with dependent	B	Std Err.	t-value	p	Partial Eta Sqr.	Observed power using alpha .05
Hours used for studying the topics of the minicourse at home (exp9)	.24 **	0.6	0.23	4.68	.000	.03	.74
Video group 2	-	-6.1	2.86	-2.14	.034	.02	.57
A[1] vs. C[3]	-	12.0	3.49	3.43	.001	.05	.93
B[2] vs. C[3]	-	8.2	3.44	2.39	.018	.03	.66

Statistically significant contrasts: No statistically significant contrasts in this covariance model

** p < .01;
1) A = in video group 1: the mean difference between the "tasks used" and "no tasks used" groups
2) B = in video group 2: the mean difference between the "tasks used" and "no tasks used" groups
3) C = in video group 4: the mean difference between the "tasks used" and "no tasks used" groups

8.6 Experiences of the minicourse dealing with gases

8.6.1 Students' experiences of the minicourse based on structured items

This section deals with students' experiences of the minicourse from different perspectives. Approximately 1/3 of the students responded they had not studied the topics of the minicourse at home (34 %), and only a few students had studied more than three hours: 1 hour (19%), 2 hours (19%), 3 hours (10%), 4 hours (4%), 5 hours (6%), 6 hours (3%), 7 hours or more (5%). Part of the reason for this may be that some students may have felt that the minicourse was just for research purposes and not for "normal" learning, even when the participating teachers were asked to tell their students that the learning would be evaluated. One teacher said that she did not act according to this procedure, which may have affected the activity.

Nevertheless, many students seemed to agree that gases and their behaviour were both an interesting and useful topic to learn about (see table 56). Not so many students wished to have more of the same type of courses. A partial explanation to this is most probably the high amount of paperwork, an aspect to be discussed more thoroughly later in the text.

TABLE 56 Students' (n= 329) experiences of the minicourse in general (Percentage distributions)

Variable	strongly disagree (1)	disagree (2)	un-certain (3)	agree (4)	strongly agree (5)	M	SD
I found gases and their behaviour as an interesting topic to learn about (exp1)	5	10	32	46	7	3.4	0.9
I think it was useful to learn about gases and their behaviour (exp3)	1	6	30	55	8	3.6	0.8
I wish we had more this kind of courses (exp12) *	20	18	26	30	6	2.8	1.2
AGGREGATE (erelcour)*	1	10	42	45	2	3.4	0.7

* n = 324

Based on table 57, well above a third of the students felt confident they had understood the things studied in the minicourse, with most of the students stating that they did not have big difficulties in understanding. More discussion about students' perceived understanding follow the presentation of students' answers to open-ended questions regarding their experiences of the minicourse.

The only significant difference between females and males regarding their experiences of the minicourse was that males were significantly (p= .015) more confident about their understanding than females (see appendix 19). There were no significant differences in experiences of the minicourse between the weakly and strongly goal-oriented students (see appendix 21).

TABLE 57 Students' (n= 329) experiences of understanding the things taught in the minicourse (Percentage distributions)

Variable	strongly disagree (1)	disagree (2)	un-certain (3)	agree (4)	strongly agree (5)	M	SD
I feel confident that I understand the things we studied in the course (exp7)	4	12	40	39	5	3.3	0.9
I had big difficulties in under- standing the things taught in the course (exp8)[1*]	16	50	25	6	3	2.3	0.9
AGGREGATE (eunderst)		4	91	5		2.8	0.3

* n =330; 1) The direction of the scale was reversed for the aggregate variable

As seen in table 58, most students had either positive or neutral "feelings" about the written materials they were provided with for the minicourse. Comparisons of the items concerning the "Student Textbook" with the items dealing with the "Student Workbook" and the Task Papers show that there were no dramatic differences in students' experiences concerning these different types of written materials. Again, some extra discussion follows later based on the results obtained from open-ended questions.

Table 59 shows that about half the students felt that the video programme had really helped them to understand the Gas laws and the kinetic theory of gases. Over half the students agreed that the video programme had made the lessons more interesting than a normal lesson. However, about a third of the students also agreed they would have well understood the things without the video programme. Generally this implies that the video programme has worked relatively well as supplementary material during the instruction. There are, however, some weaknesses that must be noted before drawing any conclusion about the effectiveness and usefulness of the video programme. After presenting the learning results and students' answers to open-ended questions dealing with the learning materials used in the minicourse, a more thorough and sound "verdict" can be made.

Students were asked to estimate their prior knowledge about gases also after the instruction was over and the post-test (the Multiple-Choice Questionnaire 2) was administered (see table 60). Students' corresponding estimations prior to the instruction period were presented earlier in table 39. These estimations correlated significantly (.57 $p < .001$), suggesting that students' estimations were relatively stable over time though some changes occurred in them. The stability in the estimations could also be seen in that the means did not differ from each other significantly (prior to instruction M=2.72 SD=1.02 and after instruction M=2.67 SD=0.92, p=.537). Note that the number of cases in these analyses was lower than in table 39 and consequently the means and standard deviations were different, as well.

TABLE 58 Students' (n= 324) experiences of the written material used in the minicourse (Percentage distributions)

Variable	strongly disagree (1)	disagree (2)	un-certain (3)	agree (4)	strongly agree (5)	M	SD
The content of the textbook was interesting (exp10)	5	17	37	39	2	3.1	0.9
The workbook and task papers had challenging problems and questions (exp11)	4	14	33	43	6	3.3	0.9
The content of the questions and problems in the workbook and task papers was interesting (exp13)*	6	21	46	25	2	2.9	0.9
The textbook was easy to understand (exp14)*	6	16	22	42	14	3.4	1.1
The structure of the textbook was unclear (exp17)[1] **	6	40	28	17	9	2.8	1.1
Some questions and problems in the workbook and task papers made me realize I need to know more about the behaviour of gases (exp19)*	4	11	39	40	5	3.3	0.9
AGGREGATE (eexpwri)	1	8	47	43	1	3.2	0.6

1) the direction of the scale was reversed for the aggregate variable; * n = 323; ** n =321;

TABLE 59 Students' (n= 239) experiences of the video programme used in the minicourse (Percentage distributions) (Note: two control groups had no video programmes)

Variable	strongly disagree (1)	disagree (2)	un-certain (3)	agree (4)	strongly agree (5)	M	SD
The video programme really helped me to understand the gas laws (exp15)*	8	14	24	45	10	3.4	1,1
The video programme really helped me to understand the kinetic theory of gases (exp16)	8	19	37	31	5	3	1
The video programme made the lessons more interesting than usual lessons (exp20)**	7	15	26	42	10	3.3	1.1
I could have well understood all the things without the video programme (exp21)	3	14	42	26	15	3.4	1
AGGREGATE (eexpvid)	5	15	37	41	2	3.1	0.8

* n = 237 ** n = 240

TABLE 60 Students' (n= 330) estimation of their prior knowledge of gases at the end of the minicourse and their estimation of the minicourse compared with usual physics lessons

Variable	strongly disagree (1)	disagree (2)	un-certain (3)	agree (4)	strongly agree (5)	M	SD
I already knew fairly well the things we were taught (exp2)	25	58	13	3	1	2	0.7
I knew very little about gases and their behaviour before this course (exp5)[1]*	3	9	17	48	23	3.8	1
AGGREGATE (epriknow)	15	53	23	8	1	2.1	0.8
The instruction in this course was not different from lessons we usually have in physics (exp18)**	34	46	11	5	4	2	1

1) the original answering scale was reversed; * n = 329 ** n = 321

8.6.2 Students' experiences of the minicourse based on open-ended questions

Students' answers to the open-ended questions presented in the Experience Questionnaire were first classified into several categories reflecting the core content of students' answers. The detailed, classified answers to each open-ended question can be found in appendix 27. The following is a brief review in the form of a list of the most frequent answers to the questions; only categories with a minimum of 20 respondents are included. As can be seen, the majority of students' responses to the open-ended questions reflect the same picture already seen in their responses to the structured items presented in the preceding sub-section. The main results will be briefly discussed after the following review.

What was best in this course?
* The video programme 78
* It was something new/gave variety to studying 58
* The "Student Textbook" and other written materials 45
* Learning new things about gases 20

What was worst in this course?
* Too much paperwork 117
* Errors in the "Student Textbook" 71
* Too tight timetable for learning 43
* The video programme 25

My best insight during the course appeared when...
* I was studying and understood the gas laws 23
* I was solving the problems 21

During the course it was really interesting to...
* Learn new things about the gases and gas laws 57
* Watch the video 48
* Work on problems/equations/tests 25

During the course I often felt...
* Confused or uncertain about understanding 36
* I understood/learned the things 35
* There was too much paperwork/too little time for the paperwork 35
* Tired/frustrated/stressed/nervous 30

Students'comments on the "Student Textbook"
* There were errors in the "Student Textbook" 180
* Clear/well organized/easy to understand 97
* Good/fine/nice/OK 48

Students' comments about the video programme
* OK/fine/good/great/funny 47
* Clarifying/well-developed/explained simply 33
* Made understanding and learning things or main aspects easier/better 32
* Irritating/bad music 21

Students' comments about the "Student Workbook" and the Task Papers
* Clear/nice/good/fine/well-made task/problems 71
* Understandable/sufficiently easy or difficult 24
* Some too difficult (given the time available) 26
* Some/all tasks/problems too simple or easy 24
* Fairly good/proper/normal 21
* Too few problems/tasks available or too few problems requiring calculations 21
* Too little time available for the Task Papers/problems 20

Students' comments about the minicourse, in general
* Refreshing/different for a change 59
* Good/OK/well done 58
* Interesting 36
* Fairly good/I learned fairly well 35
* There should have been more time for learning 26
* Too much paperwork/questionnaires 24
* Prefers "normal" physics lessons 21

Given the fact that there was too much data collection and paperwork involved in the minicourse and that there were a number of confusing errors in the "Student Textbook" used by the students, their experiences of the minicourse dealing with gases were quite positive. Without the overload of the paperwork, which resulted in too much pressure and tightened the timetable, and without the errors in the text causing confusion and frustration, the experiences would have very probably been considerably more positive. For instance, students' experiences of the "Student Textbook"" in a similar study carried out in Canada were clearly more positive (Puukari 1994). The Canadian version of the "Student Textbook" did not contain any serious errors and the nomenclature of the gas laws, which caused confusion among the Finnish students, was more familiar to the Canadian students.

Despite the problems, many of the Finnish students seemed to find the video programme a useful tool for learning, had positive experiences in learning about gases and even found the "Text book" errors and all, clear, well organized and easy to understand. Many students also liked the "Student Workbook" and the Task Papers, though these and other materials used during the minicourse were also criticized by quite a large number of students. An important positive aspect for many students was that the video-aided approach to study physics gave a welcome change to the "regular" way to learn physics, though some students preferred the regular way of learning, that is, teacher presenting, teacher and students discussing and doing tasks and problems.

A small, but very important detail was that surprisingly many students (and also some teachers) found the music used in the video programme irritating. The piano-dominated, slightly non-melodic music, which was used repeatedly in between the video programme sections, did not seem to work. This gave a necessary reminder of how important it is to test the music on a test audience representing the target groups.

8.6.3 Teachers' experiences of the minicourse

Teachers were given a similar type of questionnaire as students with only slight adjustments. All 16 participating physics teachers answered. The following is a summary of some core aspects of teachers' responses. The detailed answers are in appendix 28.

Generally, teachers' answers seemed to confirm many aspects students already mentioned. It was especially clear that the timetable of the minicourse was too tight. It was too tight even though the researcher gave teachers instructions to emphasize the gas laws and the main aspects of the kinetic theory, and to go through the other aspects more quickly, such as the measurement of pressure. These notions were quite similar to those given by the Canadian teachers (see Puukari 1994, 142-145). One reason for the strict timetable was also that there was too much data collection. The data collection was meant to be used for learning purposes, as well, but the original idea suffered from an overload of the paperwork. It may also be the case that, for example, the concept map was too demanding for some students, since for a number of them this was the first time they had used this technique - at least for physics learning purposes.

It is also worth noting that teachers' answers indicated more positive experiences than students' answers. For instance, a large number of teachers gave quite positive feedback about the "Student Textbook" and the video programme used during the minicourse. The reason for this could be that the teachers did not want to express negative aspects for the reason of politeness and because the answers were not anonymous. However, it seems more probable that the teachers looked at the minicourse and the materials from a different perspective than the students and were more able to see the larger picture and put the critical remarks into a proper perspective. Teachers also gave a number of useful suggestions for improving the learning materials used during the minicourse and some of them expressed their willingness to use the video programme in the future, as well - but in their own way without the intensive paperwork and tight timetable.

Finally, it is interesting to note a couple of details, which illustrate the difficulty of evaluation in making clear conclusions based on the feedback. Both in students' and teachers' answers to the open-ended questions there were some contradictory comments about the learning materials. For example, a number of students felt the video programme was the worst part of the minicourse, whereas a clearly larger number of students felt it was the best part of the minicourse. In a similar way, individual teachers in their suggestions for developing the instructional materials (see table 10 in appendix 28) on the one hand suggested that some sections of the "Student Textbook" should be more concise and on the other hand proposed that the text could be more extensive. This gives an idea of how difficult it is to respond to the diversity of expectations in developing learning materials. Both compromises and decisions regarding focus and emphasises are an inevitable part of developing learning materials. Educational video programmes seem to be particularly challenging with regard to the planning process.

8.6.4 Factors predicting students' experiences of the minicourse

A stepwise regression analysis was computed to predict students' experiences of the minicourse dealing with gases. The dependent, aggregate variable consisted of three variables measuring students' interest in the topic (gases) of the minicourse, perceived usefulness of the topic and a wish to have more of the same kind of courses. The independent variables for the analysis of regression correlation matrix (see table 61) were chosen based on logical criteria and correlations. The assumptions of the regression analysis (linearity, equality of variances, normality) were relatively well met according to the data presented in appendix 29.

TABLE 61 Inter-correlations of the variables used in a stepwise linear regression analysis; dependent variable: "Experiences of the minicourse in general" (erelcour) (n= 220)

Variable[1]	Variable				
	1	**2**	**3**	**4**	**5**
1 Relation to the minicourse (erelcour)	1				
2 Experiences of the written materials (eexpwri)	.72***	1			
3 Experiences of the video programme (eexpvid)	.46***	.53***	1		
4 Relation to physics (greltoph)	.40***	.31***	.03	1	
5 Connection of science to real life (gscireal)	.32***	.32***	.16*	.22**	1

* p < .05 ** p < .01 *** p < .001 1) see appendix 10 for full description of the variable

Table 62 shows that the best predictors of the experiences of the minicourse were the experiences of the written materials, relation to physics and experiences of the video programme. Together these three variables explained 56% of students' experiences of the minicourse. F-statistics indicated a statistically highly significant effect for the whole regression model (p= .000). All three regression coefficients were also highly significant (from .009 to .000). The beta coefficients indicate that the experiences of the written materials were relatively the best predictor. *Summa summarum*, the results of the regression analysis seem to indicate clearly that the more positive experiences the students had of written materials and the video programme and the more positive was their relation to physics, the more positive were their experiences of the minicourse in general. The most powerful predictor was students' experiences of the written materials. Given the errors in the "Student Textbook", which caused confusion and frustration among many students, the results of the regression analysis give some ground to assume that those students who were better able to overcome their frustration and confusion also had more positive experiences of the minicourse in general.

TABLE 62 Stepwise linear regression analysis: Experiences of the minicourse as a dependent and "Experiences of the written materials", "Relation to physics" and "Experiences of the video programme as independent variables. (n= 220)

Independent variable	B	Std. Error	Beta	t	p	R^2
(Constant)	-.069	.25		-0.28	.780	
1 Experiences of the written materials (eexpwri)	.63	.06	.58	10.19	.000	.51
2 Relation to physics (greltoph)	.30	.07	.22	4.54	.000	.55
3 Experiences of the video programme (eexpvid)	.12	.05	.14	2.63	.009	.56

Analysis of Variance:

Source of variation	DF	Sum of Squares	Mean Square	F	p
Regression	3	56.07	18.69	93.57	.000
Residual	216	43.15	0.20		
Total	219	99.22			

9 SUMMARY AND DISCUSSION

This chapter begins with a brief discussion about the generalizability of the results related to validity and reliability, followed by a more general methodological discussion dealing with the experimental design, the data collection methods and other important methodological questions. The results will then be discussed using the following organization of text for each sub-section (research problem):
a) Brief summary of the main results
b) Discussion
c) Instructional implications
Note that the results regarding the hypotheses in section 9.3 are indicated in italics. The section ends by looking at future perspectives, where the results of the present study are discussed within a broader framework of technology--aided learning environments.

9.1 Generalizability of the results

The generalizability of the results will be discussed from the point of view of the internal and external validity of the experimental design. Also the validity and the reliability of the data collection methods will be noted.

The internal validity of the experimental design indicates how certain it is that the effects in the dependent variable are caused by the independent variables. The main concerns with the internal validity were: 1) expectations about testing in one treatment group were different than in other treatment groups, 2) the expected time to be used for the experimental phase was exceeded by some treatment groups, 3) the treatment groups using learning tasks had more paperwork than other treatment groups, 4) loss of respondents between pretest and post-test, and 5) the subjects were randomly assigned to the treatment groups as groups, not as individuals.

The expectations about testing were different in treatment group H (a control group using no learning tasks and no videos). The teacher of this group told the researcher - long after the experiment was over - that she had not informed her group that the tests carried out during the experimental phase would be used for real evaluation. Despite this, the learning results of this treatment group were good and it did not seem to affect the experiment in a negative way. Naturally, the results of this group would probably have been at least a little bit better, had it been told the instructions in the agreed way. The other teachers of the treatment groups did not say that they had given the instructions differently from the agreed way. Some treatment groups had exceeded the time they were expected to use for the experimental phase. The extra time, however, was not very long in proportion to the total expected time and the extra time did not systematically accumulate in certain treatment groups. Given the extra paperwork, it seems probable that the treatment groups using the learning tasks prior to watching the video sections, were more loaded and might have had better learning results without the extra paperwork. This may be the reason why the effects of the learning tasks were rather modest.

A number of respondents were lost during the pretest and post-test due to the fact that many students did not fill-in their test papers properly; there were also a few students who were absent during the post-test data collection. The "mortality", as this phenomenon has been named in the experimental literature (e.g. Campbell & Stanley 1963), had a larger effect on the analyses where qualitative methods (Concept Maps + Essays 1-2) were used for evaluating the learning than in the analyses where quantitative methods (the Multiple Choice Questionnaire 1-2) were used. Fortunately, it seems that the mortality was not particularly accumulated in certain treatment groups, which suggests that its effects on internal validity are not serious. In addition, the fact that the subjects were randomly assigned to the treatment groups as groups, not as individuals, may have had some negative effect on the internal validity of the experimental design. Random assignment on an individual basis was not possible since the experiment was carried out as part of the regular senior high school physics course programme. The use of cluster sampling, however, does not seem to have caused a serious problem, since the estimated effects of intra-cluster correlations were relatively small. Finally, one possible problem with regard to the internal validity can be that teachers may have interpreted the guidelines about carrying out the empirical phase in differents ways and that there were probably differences in students' and teachers' experiences of using concept maps.

On the whole, the analysis of the above described problems suggests that the internal validity of the experimental design can be considered to be reasonably good. It is recommended, though, to treat the results concerning the effects of the video and the task factors with some caution.

External validity of the experimental design was quite good with regard to the sampling (it was random) , except that the cluster sampling method was used, which did not allow individual students to be randomly assigned to the treatment groups. Instead, groups of students were randomly assigned to the treatment groups. From the standpoint of "ecological validity" the external validity was also quite good. Good ecological validity in the present study means that the circumstances in the experiments can be considered rather similar to normal school circumstances. The following two exceptions were noted: 1) there was more paperwork to do than in normal physics courses, and (2) the time constraints were harder than in normal physics lessons. However, since these conditions were the same in all the treatment groups (except that learning task groups, due to their extra tasks, had more paperwork than others), these two aspects should not cause any considerable problems for the external validity. Actually, there is reason to presume that had the students (and teachers) had more time and less paperwork, the learning results would have been better.

Perhaps the most serious limitation with regard to generalizability was that in many analyses based on concept maps + essays 1-2, the number of missing data was quite large. The problem is that this part of the data may be slightly biassed as a whole, even though there seemed not to be considerable systematic differences between the treatment groups (see the discussion concerning the internal validity above). There is reason to assume that the missing data (students who were absent or who did not fill the papers according to instructions) include more students who were more frustrated about the tasks and may have not been as motivated as the ones who did their work properly.

The validity of the data collection methods (ability to measure what they are meant to measure), and *the reliability of the data collection methods* (ability to resist random errors) were both considered to be quite good with only a few exceptions in some reliability estimations (see section 7.7). In addition, in most analyses dealing with the learning effects, aggregated variables were used for the sake of better reliability. Therefore, the validity and reliability of the data collections methods with regard to the generalizability of the results seem to be fairly good. *Summa summarum*, the generalizability of the results can be regarded as quite good with some reservations concerning the results obtained from Concept Maps + Essays.

9.2 Methodological questions

In this section some general methodological questions will be discussed in addition to the issues discussed in the previous section. Perhaps the most important thing to ask has to do with the type of instructional approach used in this study to teach science concepts: is the approach a relevant one, can it produce good learning results? Many science learning studies and more generally studies dealing with conceptual change and schema construction, have quite clearly shown how difficult it is to change students' misconceptions and make them reconstruct schemata, if the concepts are provided to them directly. Therefore, it was not expected that the approach would have had a dramatic impact on students' learning results. However, there were some elements in the methodology of the study which made it interesting. These elements will be discussed in the following paragraphs.

The way this study differs from most of the previous studies is that the video programme versions produced for the study were designed directly based on the “Student Textbook” used during the empirical phase. The “Student Textbook” was designed also to match one complete unit (or sub-unit) in the physics curriculum, “the behaviour of gases”. The video programmes were not a "one-time- stimulus", but they were used on several occasions when some central aspects, such as the different gas laws, were discussed in the classroom. Furthermore, the “Student Textbook” used by all the treatment groups included same type of illustrations as all the video programme versions. This gave an opportunity to investigate the effects of animated illustrations. It is, of course, impossible to know exactly how large a proportion of the differences in learning can be attributed to the animation. Nevertheless, it was presumed that if the animation can really make a difference, this should be seen as a systematic difference between the treatment groups. The same applies to the use of learning tasks prior to viewing each of the five video sections (or prior to teaching each of the five topics without a video programme in control groups). The five topics (and video sections) were as follows: Boyle’s law, Charles’ law, the third gas law, the combined gas law, and the kinetic theory of gases.

The approach to teaching concepts in the present study was rather direct, though one of the main ideas in presenting the gas laws by using animation in the video programme was to let students observe what happens, for example, when volume is kept constant and temperature increases. The question remains, would it have been a better idea to have students make the inferences about the gas laws by themselves, without giving any information directly?. This would have represented discovery learning. There is some information available suggesting that discovery learning may not always work as desired. One reason for the limited results has been that discovery type of learning is often too time consuming. Another understandable reason for modest results has been that students have become frustrated when they have been expected to "discover" something that has already been discovered and their teacher already knows. Therefore, more direct ways of teaching concepts, and learning strategies have been used combined with reflective discussions, learning tasks that require inferences etc. (see e.g. Biggs, 1991; Haapasalo, 1991).

Results have been promising and do suggest that also "direct" teaching of scientific concepts work can help students not only to remember but also to understand the concepts they were taught. Based on these and on the results obtained in the present study, the following conclusion can be made: The type of instructional approach to teaching scientific concepts used in the present study is relevant. However, there must be more time for reflective classroom discussions dealing with the concepts, the video sections could be slightly longer and many of the video sections could be used for predict-observe type of learning by using pauses while watching the video sections. In addition, it is very clear that there must be less testing and paperwork than in this study. With these guidelines the type of video-aided approach used in the present study will probably lead to considerably better learning results. A more detailed discussion of the learning results will presented in section 9.3.

There is yet another important question: should there have been “hands-on activities”, experiments in a physics laboratory? Generally and briefly the answer is “yes”. However, there are schools that do not have the necessary equipment or materials to do experiments, some experiments are too expensive or too dangerous to conduct, and there are phenomena that are not directly observable. In these cases a video programme may offer a chance to "observe" these phenomena. In this study, the topic “the behaviour of gases” included aspects (the gas laws) that could have been studied experimentally in many schools (but not in all), and aspects (the molecular motion of gases) that were not observable. It seems that video programmes may have a better potential to facilitate learning about "non-observable" things, such as the aspects of the kinetic theory of gases, than about more "observable" things, such as the gas laws. The reason for this is not just observability in itself, but also the fact that, for instance, the kinetic theory is conceptually more complicated to understand than the gas laws (which is not to say that gas laws are easy). Nevertheless, video programmes and experiments - or any other way of teaching scientific concepts - should not be seen as mutually-exclusive opposites. Video-aided approaches can be one efficient way to teach physics concepts when the use of videos is combined with proper teaching and learning strategies and the content and structure of the video programmes are well-designed.

One important methodological aspect in this study was the use of experimental design. Why should experimental designs be used in studying physics learning? Ross and Morrison (1996) discuss the use of experimental research methods from several perspectives. Some of their notions are of particular importance with regard to the approach used in the present study: “... experiments are not intrinsically problematic as a research approach, but have sometimes been used in very strict, formal ways that have blinded educational researchers from looking at past results to gain understanding about learning processes. To increase their utility to the field, experiments should be used in conjunction with other research approaches and with nontraditional, supplementary ways of collecting and analysing results.”(p. 1168). They speak in favour of balancing internal and external validity in order to achieve needed control and at the same time obtain meaningful and applicable findings. According to their thinking, experimental research can be used in “increasing theoretical and practical understanding of how to use media more effectively to deliver instruction. Furthermore, Ross and Morrison (1996, 1164-66) note the importance of using multiple and treatment-oriented assessments including both quantitative and qualitative data for evaluating outcomes in experiments. These aspects will be discussed in the following two paragraphs.

Experimental research is not particularly popular nowadays, one reason being that qualitative approaches to studying learning have become very popular. Typically, experimental research has been criticized for the way it artificially manipulates reality and how it - in spite of all the designs and procedures - fails to control many important “intervening variables”. Experimental research may also limit researchers’ observations and thinking by concentrating only on some aspects of reality. As for artificial manipulation of reality, which can be a serious problem, the experimental design and the procedures used in this study were designed to avoid the problem of artificial manipulation. In practice this means that, for example, the whole minicourse "the behaviour of gases" during which the experiments were conducted was based on actual physics curriculums and the data collection methods were designed so that they could be used as a natural part of teaching. As far as incomplete control over intervening variables is concerned, one can briefly say that some control is better than no control. The third argument against experimental research – that it limits researcher's thinking and observation – is, of course, true. However, the same problem is present in every study regardless of the approach used.

An important part of the experimental design used in the present study was the role of triangulation (see e.g. Cohen & Manion 1989, 274-275): a number of different ways to measure the learning of gases was used, including a new way to combine concept maps and essays. This methodological approach appeared to be very demanding, but it provided an important qualitative perspective on learning. Without this qualitative perspective, the quantitative measures of learning would have given a much more limited understanding of the learning results. It must be noted, however, that due to the relatively large number of subjects, the qualitatite data obtained were quantified according to specific criteria and they were then used in covariance analyses.

One critical question with regard to the experimental design is whether the teachers who participated in the study obtained sufficient orientation to carry out the empirical phase of the study. As described in section 7.6 each teacher had an individual face-to-face orientation to the whole study including all the materials and the data collections methods. These orientation sessions lasted - depending on the treatment group and the teacher - from 1,5 hours to 2 hours. All the teachers were given their own folder containing all the instructions and materials needed in the order they were to be used during the empirical phase. Even though all the participating teachers were given the orientation and the folder, they had to do quite a lot of work in order to become familiar with the type of instructional approach they were expected to use and to be able to carry out the data collection and instructional tasks in a proper way. Given the fact that all the participating teachers were qualified and experienced physics teachers, there is reason to believe that the orientation given to them was sufficient. Yet, a second orientation session, after the teachers had studied all the materials in their folders, might have been a good idea. Finally, teachers' and students' responses to questions dealing with their experiences of the minicourse gave important information on developing the type of video-aided approach used in this study. These responses will be discussed in section 9.3.

9.3 Discussion of the results

This section discusses the results obtained in this study. The discussion will be organized according to the research problems presented in section 7.1. A brief summary of selected main results of each research problem will be presented followed by discussion and educational implications. Unless otherwise noted the results concern the Finnish students. Note that the results concerning the hypotheses of the present study are in *italics.*

1. How do teachers use videos in school according to students?

Summary: Videos were not often used in physics, and they were used less frequently in physics than in other subjects, except in mathematics. The most frequent ways to use videos in physics were "introducing new concepts", "showing how theory applies to practice", "summarizing the content studied", and "proving a basis for discussion". Tasks were not often used while viewing videos.

Discussion: The results give an indication that videos could be used more frequently in physics, especially for illustrating physical laws and processes. It is also important that learning tasks would be used as an integral part of viewing videos.

Educational implications: Teacher training institutes and teachers' in-service training should provide information and training in using videos (and other media) in science teaching. Producers of educational material should produce video programmes especially designed for school use to attract science teachers to use them.

Affective and cognitive factors in students' learning

2. How do students perceive their intelligence?

Summary: There were 140 "entity theorists" and 161 "incremental theorists" among the students. Entity theorists believe intelligence is something given that cannot be changed and incremental theorists think that it is possible to develop one's intelligence. The majority of the students preferred learning goals, and only fewer than one third of them preferred easy performance goals. Most of the students indicated they are confident in their intelligence. When classified into Dweck and Henderson's (1989) model, only five students fall into the group characterized by learned helplessness type of behaviour patterns.

Correlations of the entity-incremental" scale (aggregated variable) with other variables were low and could not be logically explained, whereas "Confidence in intelligence" had some correlations with other aggregated variables worth noting:

- Difficulties in Physics -.38 (p= .000),
- Relation to Physics .38 (p= .000),
- Multiple-Choice Questionnaire pretest score .37 (p= .000),
- The Surface Approach -.33 (p= .000), and
- Experiences of the video programme -.21 (p= .001).

No significant differences were detected between females and males, weakly and strongly goal-oriented students, or between different socioeconomic groups, except that the males were somewhat more confident in their intelligence than the females, the higher middle SES group more confident than the lower middle SES group and the strongly goal-oriented students more confident than the weakly goal-oriented students. The Canadians tended more towards incremental understanding of intelligence than the Finns.

Discussion: It was not possible to carry out further analyses using Dweck and Henderson's (1989) entire model, since the sample was small, and there would have been too many empty cells in the analyses of variance. The correlations of "entity-incremental" scale with other variables were contradictory and were not interpretable according to the theory, whereas students' confidence in their intelligence had expected correlations: students who were confident on their intelligence, experienced less difficulties in physics, had a more positive relation to physics, scored better on the Multiple-Choice Questionnaire, and used less the Surface Approach to learning. However, confidence in intelligence did not correlate with learning gain scores. Perhaps the most interesting notion, from the standpoint of this study, was that the more confident students were in their intelligence, the more negative were their experiences of the video programme. Although the correlation was not particularly strong, it may suggest that more confident students can manage without the video programme better than less confident students.

Educational implications: Even though students' perceptions about their intelligence produced some interpretable correlations, the whole picture remained vaguer. Therefore the role of these variables was slight, and they were not used in further analyses dealing with students' learning about gases.

3. What approaches to learning do students apply in school?

Summary: Based on the decile scaled scores, scaled after Biggs' (1987a) norm population, the Finnish students had lower scores on the Surface Approach (SA) than the Australian norm population. The correlations between the approaches were:
- Surface Approach - Deep Approach -.31 ($p < .001$)
- Surface Approach - Achieving Approach .04
- Deep Approach - Achieving Approach .40 ($p < .001$).

Females had significantly higher scores on the Achieving Strategy ($p = .000$) and lower scores on the Surface Strategy sub-scale ($p = .000$). *Strongly goal-oriented students used the Deep Approach (p= .000; hypothesis 1a), the Achieving Approach (p= .000; hypothesis 1b), and the Deep-Achieving Approach (p < .01; hypothesis 1a/b) significantly more than weakly goal-oriented students. Correspondingly, the weakly goal-oriented students used the Surface Approach more than the strongly goal-oriented students (p = .021; hypothesis 1 c)*. No significant differences were found among socioeconomic groups. Correlations of these approaches (sub-scales) with other variables, particularly with learning outcomes, will be discussed later with results regarding students' knowledge about the behaviour of gases. The factor structure was not quite as clear as in Biggs' (1987a,b) original study.

Discussion: Although the factor structure was not quite consistent with the structure obtained by Biggs, the other results support the theoretical ideas of Biggs (1987a,b), who designed the Learning Process Questionnaire for measuring students' approaches to learning. Particularly important was that the correlation of the Surface Approach and the Deep Approach was negative, since they in a sense represent two ends in a continuum describing how students go about their learning. A positive correlation would have implied inconsistency. Also the fairly high correlation of the Deep Approach and the Achieving Approach was expected. It is worth noting that students who have a clear educational goal (the strongly goal-oriented students) are more willing to achieve good marks in science in order to have a chance to continue their education, and they apply the Deep Approach in their learning more than students who do not have as clear goals (the weakly goal-oriented students).

Educational implications: Students should be encouraged to use the Deep-Achieving Approach instead of the Surface Approach in most situations. The decision on which approach should be used, however, depends on the nature of the task and the situation, and, in addition, it requires metacognitive skills. Biggs (1987a,b) presents many other educational implications based on students' profiles on the six sub-scales (each approach is a combination of a motive scale and a strategy scale). In this study students' scores on these scales were mainly used in explaining learning outcomes. Therefore, detailed analyses of students' profiles were not studied.

Given the results on the role of strong goal-orientation (see also other research problem summaries in this section 9.3), one clear implication is that students should be supported in their decisions regarding their education after senior high school and be encouraged to make their goals more clear. Also information that enhances students' understanding of the usefulness of science knowledge irrespective of their future subject choices may facilitate their goal-orientation.

4. What are students' attitudes towards school and physics?

Summary: Generally, students' attitudes towards and thoughts about school and physics were quite positive: The great majority of the students had a positive "relation to school and education" about 2/3 of the students had a "positive relation to physics", about half the students had "positive views about the connection of science to real life". A rather small proportion of students (15%) experienced difficulties in physics. A good half of the students indicated that the use of visual information (e.g. pictures, visual images, video programmes) helps them in understanding physics better. About half of the students had positive "attitudes towards studying gases", many of them showing uncertainty about their attitudes.

Students' means on some individual items were compared to means on identical items in the Finnish IEA/SISS study. The most systematic difference, with only one exception, was that dispersions were larger in the IEA/SISS study. There were also some statistically significant differences in the means. However, based on the actual sizes of the means, there were no dramatic differences between these two populations, perhaps with the following exceptions: students in this study tended to agree more than IEA/SISS students that "it is important to know science in order to get a good job", and did not find physics to be as "difficult when it involves calculations" as the IEA/SISS students did.

Gender differences were found in two aggregated variables and in one individual item: Males thought physics to be difficult significantly ($p < .01$) more than females when it involves calculations. As hypothesized, *females had significantly ($p= .000$) more positive attitudes towards school and education than males (support for hypothesis 2)*, though the difference was not particularly remarkable. No significant differences were found between the socioeconomic groups. *Strongly goal-centered students had clearly more positive attitudes towards school and education than weakly goal-centered students (support for hypothesis 3a) as well as towards physics (support for hypothesis 3b)*. The attitudes towards studying gases changed in a more positive direction between pretest and post-test, two of the changes being statistically significant. Possible differences between the treatment groups in attitude changes were also tested using a covariance analysis, but no significant differences were found. Instead, four covariates appeared to be statistically significant. "Experiences of the written materials" had the strongest effect suggesting that students whose experiences of the written materials were positive correspondingly found studying gases a positive activity.

Discussion: The results mostly confirmed the observations of previous studies (e.g. Kelly, 1978; Tarmo, 1986). Since the students had chosen physics of their free will, it was not a surprise that most of them had more or less positive attitudes towards physics, and towards school, in general. One interesting detail was noted as the results were compared to the IEA/SISS study, which may suggest that students nowadays see studying science as a way to get a good job more than students in 1980's. If this is the case, then it might be interesting to know what has caused the change: Is it STS ideology (see e.g. STS Science education, 1990) that emphasizes the connection between science, technology and society? (a desired thing), or could it be that students nowadays have more instrumental motives, in general? Some indirect indications of this latter interpretation were already noted in results concerning the students' approaches to learning. Finally, the fact that females had more positive attitudes towards school and education than males, was expected and it confirms the existence of this difference between females often detected in studies.

Educational implications: Although students' attitudes were generally quite positive, there are some areas where there is still work to do. One area, often mentioned in research literature, is to facilitate students' understanding about the connections physics and science have to real life. This need was implied in the results of some items. A more difficult problem is to figure out how to motivate those students that have negative attitudes towards school and physics, and such cases did occur. This question will be discussed in more details in the section dealing with students' experiences of the minicourse.

5. What knowledge do students have about the behaviour of gases and how does their knowledge develop during the minicourse?

Summary: Generally, the behaviour of gases was a difficult topic for the students, as many earlier studies have shown as well. Even after teaching there were a number of items that only 13 to 42 percent of the students answered correctly in the Multiple-Choice Questionnaire. The Finnish students had achieved their best score on the first item, which dealt with the reason why a large volume of steam is produced when a small volume of water is boiled (80% correct in the pretest and 87% in the post-test). The 9th item was the most difficult one for the vast majority of the students, and it dealt with the kinetic theory of gases (14% correct in the pretest and 20% in the post-test). Based on total scores of the Multiple-Choice Questionnaire, the learning effects (differences between post-test and pretest scores) in all treatment groups were statistically significant ($p= .000$).

The Task Papers 1-5 and Concept Maps + Essays 1-2 were used for collecting qualitative data on students' knowledge about gases. The majority of the students were able to score reasonably well in the Task Papers 1-4, which dealt with the gas laws, whereas the results were clearly less successful in the Task Paper 5, which dealt with the kinetic theory of gases. In the Concept Map + Essays 1-2 the distribution among the students was rather large, particularly in scales measuring Specific Structure and Coherence and Content. The majority of the students were able to increase their scores in these two scales by relatively few points, with only a small number able to increase their scores by more than 12 points.

Males performed statistically significantly better (based on means) than females in the Multiple-Choice Questionnaire pre- and post-test measurements, whereas females outperformed males in the Concept Map + Essay pre- and post-test measurements. There were no significant differences between the four socioeconomic groups in knowledge about gases in any measurements. Strongly goal-oriented students who were planning to include science subjects as part of their future studies were statistically significantly better than weakly goal-oriented students in the Multiple-Choice Questionnaire total scores in the post-test, in gain scores regarding the gas law items from the Multiple-Choice Questionnaire and in sum scores from the Task Papers 1-5. Finnish students' scores were better than those of Canadian students in all gain scores of the Multiple-Choice Questionnaire 1-2 and also in post-test measurement of the Multiple-Choice Questionnaire. The McNemar test for pretest-post-test changes in individual items showed there were differences between the items in the number of students who got a correct answer (1) in post-test with the pretest answer being wrong (0), and vice versa. Although the proportion of desired changes (from 0 to 1) was generally larger, there were also rather many undesired changes (from 1 to 0), indicating that students had difficulties in answering.

More sophisticated covariance analyses were carried out for estimating the effects of the video programme versions, the learning tasks and some covariates on learning outcomes (total gain scores of the Multiple-Choice Questionnaire 1-2 and the Concept Map + Essays 1-2). Separate covariance analyses were made for the Multiple-Choice Questionnaire items (sum score) dealing with gases and for items (sum score) dealing with the kinetic theory of gases. Similarly, separate covariance analyses were made for the Concept Map + Essay gain scores based on the scales measuring a) Specific Structure and Coherence and b) Content. In all the covariance analyses the basic assumptions of the covariance analysis were met either reasonably well or well. The sizes of the squared multiple correlation R2 varied from .17 to .46, indicating that the covariance models were able to explain a reasonably good proportion of the total variance in the learning outcomes.

In the covariance analyses, there were often significant interaction effects between two factors, the video groups and the task groups, suggesting that particularly in video groups 1 (preview section + basic sections) and 2 (basic section + application section) *those who used tasks prior to viewing each of the five studied video sections did better than those who did not use tasks. This means that hypothesis 7 was given partial support*. The effects of the three different video programme versions (video groups 1-3), compared to the control group (no video), did not produce a consistent pattern over the covariance analyses. *The only occasion where video groups 1-3 performed statistically significantly better than the control group was in the covariance analysis, where the dependent variable was based on kinetic theory related items from the Multiple-Choice Questionnaire gain scores. In this case, hypotheses 4-6 were given support*. Among the covariates used in the analyses, "physics course grades mean", "hours a week used for all homework", and "hours used for studying the topics of the minicourse at home" were the best covariates in explaining the learning outcomes. In all the covariance analyses, video group 1 (preview section + basic sections) had the best learning outcomes (except in one analysis where the control group had the best result) and video group 3 (basic sections) had the poorest results.

Discussion: The results confirmed that even senior high school students tend to have difficulties in understanding the behaviour of gases (see e.g. Laurén, 1990; Nussbaum, 1985; Séré, 1985; Tiberghien, 1985) This result seems very clear. One of the proposed explanations is that the gas laws demand multi-variable reasoning, which, according to many studies conducted by Piaget and other researchers (see e.g. Rozier & Viennot, 1991), is difficult for most people. Secondly, the kinetic theory of gases is difficult also in that the processes it describes and explains are not observable. Students may have got used to relying on their senses for many years, and alternative conceptions (schemata) may restrict changes due to this. In spite of the difficulties, most students made considerable progress between the pretest and the post-test. Levävaara (1994) also used concept mapping as a data collection method and (and as a learning tool) when she studied secondary school students' development in understanding the concept of energy. There was a major increase (100-200%) in the number of concepts and links associated with energy during the instruction and also the number of scientific concepts clearly increased. The quantification process of the concept map in the present study differed from that of Levävaara's study, and there was also an essay that was simultaneously scored together with the concept map. Nevertheless, the progress was evident in both studies and in many other studies where concepts maps have been used (see e.g Novak 1981; Stile & Alvarez 1986; Willerman and Mac Harg 1991).

The covariance analyses gave partial support to the theoretical remarks about the meaning of learning tasks (see e.g. Kari, 1987). As for schema theories we could presume that the use of learning tasks before viewing a video section and prior to starting "normal" instruction, helped students to better concentrate on aspects they were studying. This seemed to be the case when the learning outcomes were measured both by using quantitative and qualitative data collection methods.

Although the video factor did not produce consistent results in the covariance analyses, it was very interesting to note that the video programme versions had significant effects on learning outcomes based on kinetic theory related items in the Multiple-Choice Questionnaire gain scores when compared to the control groups using no video. The same type of result was obtained from the Canadian data (see Puukari 1994) This was a pleasant surprise for the researcher because the animation sections in the video programmes used for illustrating the kinetic theory, were not particularly good due to technical limitations of the software used for creating the animation sections. From the standpoint of schema theories we could assume that the animation sections helped the students construct better schemata on the kinetic theory of gases.

Educational implications: One implication seems quite clear: teachers should use learning tasks when using video programmes to facilitate learning of new concepts or ideas. In this study written learning tasks were used for standardization purposes to avoid unwanted variation in presenting the tasks. Naturally, it is also possible to present the tasks orally. The main point in using prior-to--viewing tasks is to direct students' attention to those aspects that are important, such as the key elements in a theory. Although the approach to teaching concepts in this study was obviously more direct than in many studies concerning schema construction, there is at least one common element: An attempt to make students realize the main principles, or key components of the theory or the phenomenon.

Another implication must be discussed with caution, because the results were not consistent in different covariance analyses: it seems that the video versions which contain a preview section in the beginning of the programme or an application section together with basic sections which present the basic physics curriculum material may be slightly more effective than a video programme which presents only the basic physics curriculum material. This conclusion seems reasonable, but on the basis of the results obtained in the present study it cannot be a final one.

6. What experiences do students and teachers have of the minicourse dealing with the behaviour of gases?

Summary: About one third of the students responded they had not studied the topics of the minicourse at home (34 %), and only a few students had studied more than three hours. Many students seemed to agree that gases and their behaviour were both an interesting and useful topic to learn about. Well above one third of the students felt confident they had understood the things studied in the minicourse with most of the students stating that they had not had big difficulties in understanding. The only significant difference between females and males regarding their experiences of the minicourse was that males were significantly ($p = .015$) more confident about their understanding than females. There were no significant differences in experiences of the minicourse between the weakly and strongly goal-oriented students.

Most students had either positive or neutral "feelings" about the written materials they were provided with for the minicourse. About half the students felt that the video programme had really helped them to understand the Gas laws and the kinetic theory of gases. Over half the students agreed that the video programme had made the lessons more interesting than a usual lesson. However, about a third of the students also agreed they would have well understood the things without the video programme. Generally this implies that the video programme has worked relatively well as supplementary material during the instruction

Students' answers to open-ended questions were in accordance with the picture obtained from their responses to the structured questions, but the open-ended questions revealed some interesting new information. An important positive aspect for many students was that the video-aided approach to study physics gave a welcome change to the "regular" way to learn physics, though some students preferred the regular way of learning, that is, teacher presenting, teacher and students discussing and doing tasks and problems. A very important detail was that surprisingly many students (and also some teachers) found the music used in the video programme irritating. The piano-dominated, slightly non-melodic music, which was used repeatedly in between the video programme sections, did not seem to work. This gave a necessary reminder of how important it is to test the music on a test audience representing the target groups. The most striking feedback, however, was that there was too much paperwork and the timetable for most of the students was too tight. Furthermore, the majority of the respondents mentioned the errors in the "Student Textbook", which was used as a common textual basis during the empirical phase.

Teachers' answers seemed to follow the same lines as students' answers. It was especially clear that the timetable of the minicourse was too tight. These notions were quite similar to those given by the Canadian teachers (see Puukari 1994, 142-145). Teachers' answers indicated more positive experiences than students' answers. For instance, a large number of teachers gave quite positive feedback about the "Student Textbook" and the video programme used during the minicourse. Teachers also gave a number of useful suggestions for improving the learning materials used during the minicourse and some of them expressed their willingness to use the video programme in the future in their own way without the intensive paperwork and tight timetable.

A stepwise regression analysis was used in investigating what aspects best predict students' experiences of the course (an aggregated variable indicating students' interest in the topic (gases), usefulness of the topic, and their wish to have more similar types of courses). The best predictors were the experiences of the written materials, relation to physics and experiences of the video programme. Together these three variables explained 56% of students' experiences of the minicourse. The results suggest that the more positive experiences the students had of written materials and the video programme and the more positive their relation to physics was, the more positive were their experiences of the minicourse in general. The most powerful predictor was students' experiences of the written materials.

Discussion: From the standpoint of "normal" school learning there was clearly too much paperwork during the minicourse. As for designing learning materials, students' experiences raised some important questions. One of them is that it is very difficult to design something that would please everyone. This was shown in students' responses to the learning materials: there were even completely opposite reactions to the same aspects. This is an important question that has to be taken seriously. It is not possible to induce any theoretically coherent principles for designing learning materials by collecting general feedback from students and teachers, though this feedback provides invaluable information that has to be considered. The possible (and probable) deviations in the feedback information have to be analysed to find out what might explain the deviations. Otherwise the designer gets contradictory proposals that do not provide useful guidelines for developing the materials. Another important aspect is to have "hard data" or objective information about the ways the materials actually work and affect students' learning outcomes and learning processes. In this respect the present study has produced valuable information, which is not often available.

With regard to the design of the video programme used in this study the following remarks can be made: 1) Although the covariate analyses of the present study and of an earlier study (Puukari 1994, 119-123) gave some indication that the video programme works better in teaching the kinetic theory of gases than the gas laws, there were some evident drawbacks in the animation sections. Without those problems (e.g. the movement of the "molecules" was not smooth and the timing of some movements did not exactly match the narration) the video programme would probably have worked better, and the risk of possible misunderstandings about the kinetic theory would have been smaller. 2) Based on students' feedback, the video programme seemed to be too boring for the target group, senior high school students. Also the selection of music is important - even in video programmes designed for teaching physics concepts. Before making the final choices it would be useful to gather at least a small test audience consisting of persons representing the target group, and ask for feedback. .

Educational implications: Some educational implications regarding the design of educational materials were already addressed in the discussion above. As to the use of video programmes in classrooms, it is important that the teacher tries to prepare students not just by using learning tasks or giving directions for viewing, but also by making them ready to confront the possible negative features in the video programmes. For example, it might help if the teacher makes a joke about possible bad music and asks students not to pay too much attention to it, or by noting technical limitations in animation sections. In this study the researcher told teachers that it is important to explain to the students what the limitations in the animation sections were and ask them to avoid possible misunderstandings caused by these limitations.

9.4 General discussion and future perspectives

A considerably large number of students had not converted the original temperatures to the Kelvin scale when solving problems regarding Charles' law. This suggests that the importance of conversions should be explicitly taught and presented both in the text and in the video programme, and teachers are naturally needed here as well.

Given the negative, often affectively-loaded comments students gave in their responses to open-ended questions regarding the errors in the "Student Textbook", too tight timetable, etc. it is very interesting to consider Gagné's (1985) understanding about a schema. He notes that each schema is likely to be accompanied by an affective proposition about that schema. This influences personal choices associated with the schema. These affective components of schemata can be one plausible explanation why people sometimes react so differently to the same features of reality. For instance, in this study some students felt the video programme was the best part of the minicourse, while some others saw it as the worst part of the minicourse. It may well be the case that for many students the errors in the "Student Textbook" or the negative experiences of the music in the video programme were so strongly linked to their schemata that it was hard for them to find a positive relation to the content presented via these learning materials. This gives reason to encourage teachers to discuss the concerns and experiences students may have of the topics and materials used in a course. With proper discussion, teachers can help students overcome their possible negative reactions and find a more positive basic orientation towards learning

Rumelhart and Norman (1978, 1981a) identified three possible ways in which existing knowledge can be modified by new experience: 1) *Accretion* refers to the gradual accumulation of factual information by the process of activating an existing schema and assimilating another instantiation of that schema. 2) *Tuning* means a kind of evolution of a schema. These evolutionary changes in schema are due to different processes, like generalizing or constraining the extent of a concept's applicability or otherwise improving the accuracy of the concept resulting in better connections to the actual data. 3) *Restructuring* refers to creation of new structures designed for reinterpretation of old information or construction of new information. The use of restructuring increases as a function of age and requires more expertise.

This classification of possible schema changes seems to have connections with Langer's (1980) classification of learner's prior knowledge into three different levels, which was used as one basis for analysing the concept maps in the present study: 1) *Diffused organized knowledge* (lowest level). At this level learners can only report personal experience or tangential cognitive links. 2) *Partially organized knowledge*. At this level learners can provide examples of a concept and define it in terms of its main characteristics. 3) *Highly organized knowledge*. At this level elaborations of the concept are provided to its superordinate and related concepts, and the concept is defined precisely. If one can agree that the three levels of the above Langer's classification have logical links to Rumelhart & Norman's (1978, 1981a) corresponding three levels of schema changes, then it can be said that most of the schema changes observed in this study fall into the first two categories, accretion and tuning, and only relatively few of the changes could be regarded as restructuring. With these results in mind, it can be said that most students' existing schemata on gases are quite strong and resist changes. Note that the criteria used in defining the level of knowledge in students' Concept Maps + Essays are in appendix 13.

Given the quite large size of the sample in the present study, the methodological approach used was quantitative. Qualitative data collection methods (particularly Concept Maps + Essays) were used and the data was then quantified for the purposes of data analyses. A detailed qualitative analysis of student's schemata as represented in their Concept Maps + Essays, was not intended. Therefore, the existing evidence with regard to the role of schema changes among the students, is limited. More generally, the results regarding the schema changes indicate that it was very hard for the majority of the students to develop a highly organized understanding about gases: restructuring of existing schemata usually requires a lot of effort. One can assume that a constructivist approach in learning physics could lead to better results. However, given the design of this study, this question requires further studies.

With regard to the role of animation in the video programme it was interesting to note that the video programme seemed to work better in teaching the kinetic theory of gases than the gas laws. Brown and Clement (1987) encourage teachers to help students in developing visualizable, qualitative models of physical phenomena. Based on the present study it seems that properly designed animation may provide one effective way to assist students in their visualizations and constructions of qualitative models. At the same time it is important to provide opportunities to build links between the qualitative and quantitative models of the physical phenomenon at hand. It seems that experts usually first build a qualitative model of the problem and then apply quantitative approaches to solve the problem (see e.g. Halliday & Resnich 1974). The special strength of video animation is that they can direct students' attention to those qualitative aspects that are most crucial. In order to create well-designed animation for physics learning good planning and production teams are needed where also experts in physics teaching are actively involved.

In many European countries, including Finland, there is an increased demand for finding more students in mathematics and natural sciences at universities. An important factor in strengthening the role of these subjects at university level is the success in previous studies at senior high school and upper grades of comprehensive school. Physics is among the most important subjects with regard to developing new technological innovations. Therefore, it is important to seek new ways to teach physics in order to motivate students for further studies and introduce physics as a potential future career.

There are several ways to improve physics learning at senior high school. Deliberate use of video programmes in introducing new concepts which require good qualitative understanding of complex processes is one well-founded way to develop physics learning. The present study suggests that quite a large number of students benefit from video-sections as part of physics instruction. Successful use of video programmes requires programmes that fit the current curriculum well. It is also important that physics teachers become more aware of possibilities video programmes can provide in certain areas of physics and develop their pedagogical and technical skills needed in using videos. Given the fact that video programmes are quite expensive, it is very important that the planning process covers well requirements for good quality.

Video and animation sections have been widely used in computer-based and web-based learning environments (e.g. Kozma, 1993; Mayton, 1991; Rieber 1991; Mayer & Anderson) and in spite of some critical observations, they have proved to be quite useful tools in learning. The usefulness in using videos, animations and simulations also in teaching physics has been recognized in recent literature (see e.g. Christian & Belloni 2001). The future evolution of technology seems to lead towards an increased use of individualized and collaborative learning environments which utilize computers and various types of computer networks (see e.g. Inglis et al. 1999; Jolliffe et al. 2000; McConnel 2000; Meisalo et al. 2000; Pyykkö & Ropo, 2000; Salmon, 2000). These developments impose more demands on teachers and teacher education in providing teachers with opportunities to acquire the skills needed in a pedagogically fruitful use of the new technology (e.g. Maier & Warren 2000). During the last years several projects have started developing human-centered technology that can be used for learning purposes in a flexible way (see e.g. Isomäki et al. 2001). In the future this will probably lead to more user-friendly, reliable and flexible learning environments, where also videos and video animation have an important role.

Even though technological development seems to be at the core of innovative discourses it is important to take a broader perspective on learning. Ahtee (1994b) describes essential components of teaching physics using similar division into "three worlds" as Popper (see Popper & Eccless 1977): The real world (phenomena, observations), the world of theory (concepts, models) and the everyday world (conceptions, thinking and knowledge structures). Traditional teaching in physics focuses on theory, an empiristic view of teaching on the real world by inducing generalizations via observations, and the constructivist view takes also the everyday world of the learner into consideration (see also Erätuuli 1994). With regard to studying the phenomena in physics, Erätuuli and Meisalo (1991) pointed out based on their studies in grades 7-9 of comprehensive schools that pupils should be given tasks including measurements related to their familiar environment using mostly rather simple measuring equipment. Using simple equipment allow students to concentrate on important content questions instead of paying too much attention to equipment itself. These activities can develop pupils' planning skills and persistency and also increase their interest in physics.

In senior high schools experimental approaches are needed as well. For instance, Seinelä (1992) has studied the experimental-inducive approach in senior high school physics teaching. He emphasizes the importance of challenging students to become involved in active thinking instead of mechanically conducting experiments. With proper pedagogical approaches laboratory experiments and an experimental approach can be an effective way to develop students' understanding of physical phenomena (see also Tinnesand & Chan 1987). Also Ahtee et al. (1994) note the importance of developing science education in a "know how" direction from a "know what" state.

Videos, computers and other technological tools should not be regarded as something opposing real world activities. For instance, computers are nowadays also often used in measurement to support concept formation in physics (e.g. Lavonen 1994; Rahkonen 1990, 1994). Computers when connected to other measurement equipment can be used for several purposes, such as making calculations and graphical printing. Especially real-time graphing has proved to be useful in a number of physics learning situations. Lavonen (1994, 101) emphasizes the role of direct observations and experiments instead of computer simulations. Experimental approach, as recognized in the current Finnish curriculum in Physics, has an important role in physics learning (see also e.g. Arons 1997, 9-11; Gott & Duggan 1995). However, computers used as an integral part of a school laboratory can be very useful. In a similar way, video and animation sections, either as part of video programmes or interactive multimedia learning environments, should not be seen as substitutes of real-life learning environments or laboratory work. Instead, video materials provide opportunities for students to broaden their perspectives by watching experiments and processes beyond the possibilities of school laboratories or real-life environments. Videos also provide means to illustrate complex processes using animation sections which focus on core aspects of the studied processes. These strengths will probably mean that videos will continue to be a relevant pedagogical tool in the future as well. However, without proper pedagogical planning and pedagogically sound use videos will not lead to good learning outcomes. Together with qualified physics teachers and active students the use of videos will lead to success and the deep learning needed in the development of physics in our societies.

YHTEENVETO

Tutkimuksen päätavoitteena oli tarkastella koeasetelman avulla kaasujen käyttäytymistä käsittelevien video-ohjelmaversioiden ja video-ohjelman jaksojen katselua varten annettujen tehtävien vaikutusta kaasulakien ja kineettisen kaasuteorian oppimistuloksiin lukion fysiikan ensimmäisen vuoden ryhmissä. Näiden ryhmien oppilaat osallistuivat noin 5 oppitunnin mittaiseen kaasujen käyttäytymistä käsittelevään minikurssiin. Koeasetelmana käytettiin 2 x 4 faktorin asetelmaa, jossa oli neljä video-ohjelma versiota (ohjelman tiivistelmä + perusjaksot/ ohjelman perusjaksot + kaasujen soveltavaa käyttöä koskeva jakso/ perusjaksot/ ei video-ohjelmaa) sekä kaksi oppimistehtäväryhmää (videojaksojen katsomiseen liittyvä orientoiva tehtävä/ ei tehtävää).

Kaasuja koskevaa *oppimista arvioitiin* sekä kvantitatiivisten (monivalintatehtävät) että kvalitatiivisten menetelmien (käsitekartta + essee) avulla. Lisäksi kyselyiden avulla tutkittiin oppilaiden käsitystä omasta älykkyydestään (Dweck & Henderson 1987), oppilaiden käyttämiä lähestymistapoja oppimiseen (Biggs 1987a,b) sekä oppilaiden suhdetta ja asennoitumista kouluun, fysiikkaan ja kaasujen opiskeluun sekä audiovisuaalisten oppimateriaalien hyödyntämiseen fysiikan oppimisessa. Lisäksi kerättiin tietoa siitä, kuinka eri oppiaineissa ja erityisesti fysiikassa oli käytetty videoita apuna. Koko prosessin päätteeksi kerättiin vielä tietoa sekä oppilaiden että opettajien kokemuksista

Tutkimukseen empiiriseen vaiheeseen käytettiin aikaa keskimäärin noin 240 minuuttia eli reilun viiden oppitunnin (a' 45 min) verran. Tutkimuksen ajaksi kaikille fysiikan ryhmille jaettiin käytettäväksi hanketta varten laadittu opetusteksti, tehtävävihko sekä yksittäisiä koeasetelman yhteydessä käytettyjä tehtäviä. Tutkimukseen osallistui Keski-Suomesta kaikkiaan 16 fysiikan ryhmään, jotka poimittiin satunnaisesti Keski-Suomen fysiikan ryhmien perusjoukosta (syksyn 1992 tilanne). Fysiikan ryhmät sijoitettiin kahdeksaan käsittelyryhmään arpomalla siten, että jokaiseen käsittelyryhmään tuli kaksi fysiikan ryhmää. Lisäksi joitakin tästä Suomen aineistosta saatuja tuloksia verrattiin Edmontonista, Kanadasta, saatuihin vastaaviin tuloksiin (ks. Puukari 1994). Kanadassa fysiikan ryhmiä oli vain 1 fysiikan ryhmä per käsittelyryhmä ja yhden ryhmän aineisto katosi postituksen aikana, minkä vuoksi koko koeasetelmaa ei voitu hyödyntää Kanadan aineisto analyysissa. Kaikkiaan Kanadan aineistossa oli 143 oppilasta. Ellei erikseen toisin mainita, tässä yhteenvedossa kuvattavat tulokset koskevat Suomen aineistosta saatuja tuloksia.

Koeasetelmassa oli merkittävää se, että kaasuja käsittelevä minikurssi rakennettiin suoraan voimassa olleiden fysiikan opetussuunnitelmien pohjalta ja se käsiteltiin Suomessa siihen aikaan lukuvuodesta, jolloin kaasuja käsiteltiin ohjelman mukaisesti. Kanadassa kaasuja koskeva teema oli valinnaisena opintojaksona. Huomattavaa oli myös se, että oppimistuloksia pyrittiin arvioimaan monipuolisesti sekä kvantitatiivisten että kvalitatiivisten menetelmien avulla. Tutkimuksessa hyödynnettiin uudentyyppistä käsitekartan ja esseen yhdistelmää, jonka laadullinen tieto kvantifioitiin huolellisesti sitä varten laadittujen kriteeristön pohjalta.

Tutkimuksen teoreettinen viitekehys rakennettiin kolmen pääkomponentin varaan: 1) kognitiivinen psykologia, erityisesti skeemateoriat, 2) luonnontieteiden, erityisesti fysiikan oppimista koskevat empiiriset tutkimukset ja niiden pohjalta tehdyt teoreettiset hahmotelmat sekä 3) audiovisuaalista oppimista ja audiovisuaalisia välineitä, erityisesti videoita koskevat empiiriset tutkimukset ja niiden pohjalta hahmotellut teoriat. Video-ohjelmien käyttöä hyödyntävä opetus ja oppiminen muodostavat laajan, monimutkaisen kokonaisuuden, jota ei voi tutkimuksellisesti lähestyä yhden, rajatun teorian avulla vaan on hedelmällisempää hyödyntää moniulotteisempaa teoriapohjaa. Tämän tutkimuksen kokemusten pohjalta moniulotteinen teoreettinen lähestymistapa tuntuu tarjoavan toimivan lähtökohdan video-ohjelmia hyödyntävän opetuksen ja oppimisen tutkimiseen.

Tutkimustulosten luotettavuutta tarkasteltiin useista eri näkökulmista ja erilaisia luotettavuuden arviointitapoja hyödyntäen. Aineiston keruumenetelmiä koskevat luotettavuustarkastelut (validiteetti ja reliabiliteetti) osoittivat, että kokonaisuutena tarkasteltuna eri menetelmät kykenivät antamaan suhteellisen luotettavaa tietoa. Tutkimustulosten yleistettävyyden kannalta oli tässä tutkimuksessa tärkeä käsitellä myös koeasetelman sisäistä ja ulkoista validiteettia.

Sisäinen validiteetti osoittaa, kuinka luotettavasti koeasetelma tuo esille selittävien muuttujien (tässä tutkimuksessa erityisesti faktorien, video-ohjelmaversioiden ja tehtävien) vaikutuksen selitettävään muuttujaan (kaasuja koskeviin oppimistuloksiin). Sisäistä validiteettia heikensivät seuraavat tekijät: yhdessä fysiikan ryhmässä testaamista koskevat odotukset poikkesivat muiden ryhmien odotuksista, osa ryhmistä ylitti jonkin verran empiiriseen vaiheeseen tarkoitetun ajan, oppimistehtäviä käyttäneillä käsittelyryhmillä oli muita enemmän paperityötä, henkilökato alku- ja loppumittauksen välillä ja se, että tutkittavat arvottiin käsittelyryhmiin kokonaisina ryhminä eikä yksilöinä. Näiden ongelmien lähempi tarkastelu osoitti, että ongelmista huolimatta sisäistä validiteettia voidaan pitää kohtuullisen hyvänä. Jonkin asteinen varovaisuus tulosten tulkinnassa on kuitenkin paikallaan.

Koeasetelman ulkoinen validiteetti tarkoittaa sitä, kuinka hyvin koeasetelmasta saatavat tulokset voidaan yleistää tutkittavien perusjoukkoon ja erilaisiin olosuhteisiin. Perusjoukkoon yleistämisen kannalta tilanne oli hyvä, sillä otanta toteutettiin satunnaisesti klusteriotantaa käyttämällä. Rajoittavana tekijänä, kuten jo edellä todettiin oli se, että tutkittavat jouduttiin käytännön syistä arpomaan käsittelyryhmiin ryhminä eikä yksilöinä. Erilaisiin olosuhteisiin yleistämisen kannalta koeasetelma toimi hyvin siinä, että koeasetelman olosuhteet vastasivat suhteellisen hyvin normaaleja fysiikan oppituntien tilanteita (oppilaat toimivat normaalissa luokissa omien opettajiensa kanssa ja käsittelivät opetussuunnitelmaan sisältyviä kysymyksiä). Poikkeavuutta normaaliin tilanteeseen toi se, että oppilailla oli tavallista enemmän paperityöstä ja että aikataulu oli tavallista tiukempi. Ilman näitä poikkeamia, oppimistulokset olisivat todennäköisesti olleet parempia. Kokonaisuutena tarkasteltuna voidaan tutkimustulosten yleistettävyyttä pitää kohtuullisen hyvänä.

Tutkimusmetodologian kannalta tässä tutkimuksessa oli kiintoisaa myös se, että video-ohjelmaversiot suunniteltiin opetustekstin pohjalta niin, että opetustekstin ja video-ohjelmien perusjaksojen sisällöt olivat varsin yhtenäiset. Tutkimuksen kannalta oleellisena erona näiden materiaalien kesken oli se, että video-ohjelmassa käytettiin animaatiota kaasulakien ja kineettisen kaasuteorian prosessien kuvaamiseen, kun taas opetustekstin havainnollistamiskeinot perustuivat kuvien/piirrosten ja kuvioiden käyttöön. Liikettä lukuun ottamatta havainnollistamisessa pyrittiin käyttämään samankaltaisia keinoja. Tämä tarjosi mahdollisuuden arvioida animaatioiden merkitystä oppimiselle.

Tutkimuksen tulokset. Fysiikan opettajat käyttivät opetuksessaan videoita suhteellisen vähän. Eniten niitä käytettiin uusien käsitteiden esittelyyn, osoittamaan, kuinka teoriaa sovelletaan käytäntöön, opiskeltujen sisältöjen yhteenvedon esittämiseen sekä keskustelupohjan tarjoamiseen. Dweckin ja Hendersonin (1987) mittavälineiden mukaan vajaa puolet oppilaista piti älykkyyttä suhteellisen muuttumattomana ominaisuutena ja reilut puolet katsoi, että sitä on mahdollista kehittää. Kanadalaisille oppilaille oli suomalaisiin verrattuna jonkin verran tyypillisempää nähdä mahdollisuus kehittää älykkyyttä. Suurin osa oppilaista ilmaisi kuitenkin luottavansa älykkyyteensä. Pojat osoittivat keskimäärin hieman enemmän luottamusta älykkyyteensä kuin tytöt. Biggsin (1987a,b) mittavälineillä tehdyt oppimisen lähestymistapoja koskevien tulosten mukaan suomalaiset oppilaat tukeutuivat oppimisessaan australialaisia, normeerauksessa mukana olleita oppilaita vähemmän, Pinta- lähestymistapaan (the Surface Approach). Tutkimushypoteesien mukaisesti vahvasti päämääräorientoituneet oppilaat, jotka aikoivat suuntautua fysiikan alalle tulevissa opinnoissaan, käyttivät heikosti päämääräsuuntautuneita (ei suuntaudu fysiikan opintoihin, ei ole ajatellut tulevia opintojaan tai ei aio jatkaa opintojaan lukion jälkeen) oppilaita tilastollisesti merkitsevästi enemmän ($p = .000$) Syvä-lähestymistapaa (the Deep Approach), Saavutus-lähestymistapaa (the Achieving Approach) ja vastaavasti heikosti päämääräsuuntautuneet oppilaat käyttivät tilastollisesti merkitsevästi ($p= .000$) enemmän Pinta-lähestymistapaa kuin voimakkaasti päämääräsuuntautuneet oppilaat.

Oppilaiden selvällä enemmistöllä oli varsin myönteinen asennoituminen koulua ja koulutusta kohtaan. Noin 2/3 oli myönteinen suhde fysiikkaan. Ja noin puolella oppilaista oli myönteisiä näkemyksiä tieteen kytkennöistä jokapäiväiseen elämään. Vain suhteellisen pieni osa (15%) oppilaista koki vaikeuksia fysiikassa. Reilut puolet oppilaista ilmoitti, että visuaalisen informaation, kuten kuvien ja video ohjelmien käyttö auttaa heitä ymmärtämään fysiikkaa paremmin. Joitakin oppilaiden asenteita ja suhdetta kouluun ja fysiikkaan käsittelevien yksittäisiä muuttujia verrattiin suomalaisen IEA/SISS tutkimuksen vastaaviin muuttujiin. Systemaattisin ero oli siinä, että IEA/SISS tutkimukseen osallistuneiden oppilaiden muuttujien hajonnat olivat suuremmat kuin tämän tutkimuksen oppilaiden. Valtaosassa muuttujista ei ollut kovin huomattavia eroja keskiarvoissa. Sen sijaan tyttöjen ja poikien välillä havaittiin tutkimushypoteesin mukaisia eroja: tyttöjen asenteet koulua ja koulutusta kohtaan olivat tilastollisesti merkitsevästi ($p = .000$) myönteisemmät kuin poikien asenteet. Tutkimushypoteesin mukaisesti samoin vahvasti päämääräsuuntautuneilla oppilailla oli selvästi ($p= .000$) myönteisemmät asenteet koulua ja koulutusta kohtaan kuin heikosti päämääräsuuntautuneilla oppilailla. Tulokset ovat samansuuntaisia aiempien tutkimusten kanssa (mm. Kelly, 1978; Tarmo, 1986). Oppilaiden asenteet kaasujen opiskelua kohtaan muuttuivat jokin verran positiivisemmiksi alku- ja loppumittauksen välillä. Kovarianssianalyysin mukaan vaikutti siltä, että niillä oppilailla, joilla oli myönteisiä kokemuksia empiirisen vaiheen aikana käytetyistä kirjallisista materiaaleista, oli vastaavasti myönteisempi asennoituminen kaasujen opiskelua kohtaan.

Keskeisimmät tutkimustulokset käsittelivät oppilaiden kaasuja koskevia tietoja ja niiden kehittymistä kaasuja käsittelevän minikurssin aikana. Tärkeimpänä mielenkiinnon kohteena oli erityisesti käytettyjen oppimateriaalien (eri video-ohjelmaversiot) ja oppimistehtävien (videojaksojen katsomista orientoivat tehtävät) vaikutuksen oppimistuloksiin. Monien aiempien tutkimusten mukaisesti (mm. Laurén, 1990; Nussbaum, 1985; Rozier & Viennot, 1991; Séré, 1985; Tiberghien, 1985) myös tämän tutkimuksen oppilaille kaasujen käyttäytyminen osoittautui vaikeaksi teemaksi, jossa vanhojen skeemojen muuttaminen on työlästä. Sekä kvantitatiivisesti että kvalitatiivisesti hankittu aineisto tuki tätä johtopäätöstä. Huolimatta siitä, että oppilaiden tulokset näissä aineistoissa paranivat selvästi (ja tilastollisesti merkitsevästi) alku- ja loppumittauksen välillä, oli tuloksissa paljon toivomisen varaa. Esimerkiksi monivalintakyselyn loppumittauksessa oli osioita, joihin vain 13 - 42 oppilaista kykeni vastaamaan oikein. Oppilaiden keskinäiset erot olivat varsin suuret. Yleensä oppilaat selviytyivät paremmin niistä tehtävistä, joissa käsiteltiin kaasulakeja kuin niistä, joissa aiheena oli kineettinen kaasuteoria. Pojat suoriutuivat tyttöjä paremmin monivalintatehtävistä kun taas tytöt menestyivät poikia paremmin käsitekartta-essee tehtävissä. Vastaavasti vahvasti päämääräorientoituneet oppilaat selviytyivät heikosti päämääräorientoituneita oppilaita paremmin osassa oppimistuloksia koskevista mittauksista.

Kovarianssianalyysien avulla tarkasteltiin tutkimuksen koeasetelman kahden faktorin (neljä video-ohjelmaversiota, joista yksi ilman videoita ja kaksi oppimistehtäväryhmää, joista toinen ilman oppimistehtävää) ja aineistosta valikoitujen kovarianttimuuttujien vaikutusta riippuvaan muuttujaa, oppimistuloksiin. Oppimistuloksia mitattiin useammalla eri tavalla ja kovarianssianalyysit tehtiin erikseen kullekin eri tavoin mitatulle oppimistuloksia koskevalle summamuuttujalle. Lisäksi tehtiin erilliset analyysit monivalintakyselyn ja tehtäväpapereiden (käytettiin viiden videojakson jälkeen arvioitaessa oppimista) niiden osioiden summamuuttujille, jotka mittasivat joko kaasulakien tai kineettisen kaasuteorian oppimista. Samoin käsitekartta+esseetehtävän kahdelle skaalalle tehtiin omat kovarianssianalyysinsa kokonaissummamuuttajaan perustuvan analyysin rinnalle. Kovarianssianalyysien oletukset tulivat kohtuullisen hyvin täytetyiksi.

Kovarianssianalyysien selitysosuudet vaihtelivat välillä .17 ja .46, mikä osoittaa, että kovarianssimallit kykenivät selittämään kohtuullisen suuren osan kaasujen oppimista koskevasta vaihtelusta. Kovarianssianalyyseissa havaittiin videofaktorin ja tehtäväfaktorin välillä yhdysvaikutusta siten, että videoryhmässä 1 (tiivistelmäjakso + perusjaksot) ja videoryhmässä 2 (perusjaksot + sovellusjakso) ne ryhmät, joilla oli ennen viiden kaasuja käsittelevän videojakson katselua orientoiva oppimistehtävä, suoriutuivat paremmin kuin ilman orientoivaa oppimistehtävää toimineet ryhmät. Tämä tulos antoi osittaista tukea tutkimushypoteesille, jonka mukaan orientoivaa oppimistehtävää käyttävien oppimistulokset ovat parempia. Kanadan aineistossa monivalintakyselyn pohjalta tehdyissä kaikissa analyyseissa (ks. Puukari 1994) orientoivat oppimistehtävät paransivat oppimistuloksia merkittävästi.

Kolmen video-ohjelmaversion vaikutusta koskevat tulokset (suhteutettuna kontrolliryhmään, joka ei käyttänyt video-ohjelmaa) eivät muodostaneet johdonmukaista kuvaa verrattaessa eri kovarianssianalyyseja keskenään. Kuitenkin yhdessä kovarianssianalyysissa, jossa selitettävänä muuttujana oli monivalintakyselyn kineettistä kaasuteoriaa koskevien osioiden summamuuttuja, kolme video-ohjelmaryhmää menestyivät tutkimushypoteesien mukaisesti tilastollisesti merkitsevästi paremmin kuin kontrolliryhmä. Vastaavanlainen tulos saatiin Kanadan aineiston pohjalta (Puukari 1994). Kovarianttimuuttujista parhaiksi oppimistulosten selittäjiksi nousivat fysiikan kurssien kokeiden keskiarvo, kaikkiin kotiläksyihin käytetty aika viikossa sekä minikurssin aiheiden opiskeluun käytetty aika.

Saatujen tulosten perusteella vaikuttaa siltä, että video-ohjelmien animaatiojaksot edistävät parhaiten monimutkaisten ja vaikeasti havainnoitavien prosessien oppimista, tässä tutkimuksessa kineettisen kaasuteorian oppimista. Skeemateorioiden näkökulmasta katsottuna voidaan ajatella, että pelkistetty animaatio auttaa oppijaa kiinnittämään huomiota ilmiön keskeisiin laadullisiin ulottuvuuksiin. Tässä tutkimuksessa video-ohjelman selostus ja animaatio pyrittiin saamaan mahdollisimman hyvin täsmäämään keskenään, jotta ohjelman selostus ja kuvaosuudet tukisivat toisiaan ja näin edistäisivät tehokkaasti oppimista. Tähän kuvan ja selostuksen keskinäiseen kytkentään on kiinnitetty huomiota myös aiemmin animaatioita koskevissa tutkimuksissa (mm. Mayer & Anderson 1992; Mayer & Simms 1994). Video-ohjelman katsomiseen orientoivia oppimistehtäviä kannattaa hyödyntää, vaikka tässä tutkimuksessa niiden käyttö ei kaikilta osin tuottanutkaan tutkimushypoteesin mukaista parannusta oppimistuloksiin. Opiskeltavan ilmiön tai käsitteen kannalta keskeisiin näkökohtiin huomiota suuntaavat tehtävät voivat tukea oppilaita heidän rakentaessaan asiaa koskevaa skeemaa.

Oppilaiden ja opettajien kokemukset kaasuja käsitelleestä minikurssista kokonaisuutena olivat suurelta osin varsin myönteisiä. Kriittisimpiä huomioita esitettiin empiirisen vaiheen aikana käytetystä opetustekstistä, koska siihen oli jäänyt kiusallisia painovirheitä. Samoin koettiin negatiivisena ajan vähyys suhteessa varsin runsaisiin kirjallisiin tehtäviin, joita sisältyi minikurssin eri vaiheisiin. Virheitä ja joitakin teknisiä puutteita lukuun ottamatta suurin osa oppilaista ja opettajista pitivät minikurssin yhteydessä käytettyjä materiaaleja (opetusteksti, harjoitustehtävävihko ja video-ohjelma) hyödyllisinä ja kiinnostavina. Monet oppilaat kokivat videoita hyödyntävän lähestymistavan hyvänä vaihteluna normaaliin, pääosin luennointiin pohjautuvaan opetukseen. Osa oppilaista ei kuitenkaan kokenut video-ohjelmaa oman oppimisensa kannalta tarpeelliseksi. Mielenkiintoisena yksityiskohtana kannattaa mainita monien oppilaiden kriittiset huomiot video-ohjelmassa ohjelmajaksojen välillä käytetystä musiikista, joka oli pianovoittoinen, ei-melodinen. Tämä palaute, johon myös osa opettajista yhtyi, oli tärkeä muistutus siitä, että myös video-ohjelma musiikki kannattaa testauttaa koeyleisön avulla, joka koostuu loppukäyttäjäryhmän edustajista.

Askeltavan regressioanalyysin avulla oppilaiden kokonaisvaltaisia kokemuksia minikurssista ennustivat parhaiten kokemukset kirjallisista materiaaleista, suhde fysiikkaan sekä kokemukset video-ohjelmasta, joiden yhteinen selitysosuus oli 56%. Minikurssin kokemuksia koskevien tulosten perusteella voidaan perustellusti olettaa, että mikäli opetustekstissä ei olisi ollut virheitä, aikaa olisi ollut enemmän ja paperityötä vähemmän ja video-ohjelman musiikki olisi ollut kohderyhmälle sopivampi sekä videoanimaatiot olisi voitu toteuttaa teknisesti paremmin, olisivat kokemukset olleet selvästi myönteisemmät ja oppimistulokset paremmat. On myös tärkeä muistaa, että opettajan rooli myös oppimateriaalien puutteiden huomioon ottamisessa sisällöllisesti sekä oppilaiden motivoinnin kannalta on merkittävä.

Video-ohjelmia hyödyntävä lähestymistapa tarjoaa yhden mahdollisuuden edistää fysiikan oppimista, mikä on ajankohtainen tavoite monissa maissa (esim. LUMA-hankkeet Suomessa). Onnistunut video-ohjelmien käyttö edellyttää kuitenkin opetussuunnitelmaan kytkeytyviä sisältöjä, pedagogisesti, kuvallisesti ja teknisesti toimivia ratkaisuja video-ohjelman sisältöihin ja toteutukseen sekä opettajien aktiivista pedagogista työskentelyä esimerkiksi käyttämällä katsomiseen orientoivia oppimistehtäviä. Lisäksi tarvitaan päämääräsuuntautuneita oppilaita, jotka ovat valmiita paneutumaan asioihin. Tulevaisuudessa video-ohjelmia voidaan entistä laajemmin ja monipuolisemmin hyödyntää paitsi erillisinä ohjelmina, myös osana tietokonepohjaisia, avoimia oppimisympäristöjä. Tavoitteena on edistää fysiikan oppimista niin, että tämän yhteiskunnan teknologisten innovaatioiden kannalta keskeisen tieteenalan kehitys voidaan turvata jatkossakin.

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APPENDIX 1

Projekti: Video-ohjelmat fysiikan opetuksessa
University of Alberta ja Jyväskylän yliopisto
Oppimiskysely
(OPPIMISK)

OPPIMISKYSELY

MITÄ OPPIMISKYSELY KÄSITTELEE?

Seuraavissa kysymyksissä käsitellään sitä, millaiseksi koet älykkyyden ja oppimisen. Ole hyvä ja lue kunkin jakson ohjeet ja vastaaa kysymyksiin.

KIITOS JO ETUKÄTEEN!

TÄYTÄ SEURAAVAT TIEDOT ENSIN

Sukunimi: ________________________ Etunimi: __________________

Koulu: ____

Luokkatunnus: __________

(continues)

APPENDIX 1 (continued)

Ihmisillä on erilaisia käsityksiä älykkyydestään. Lue kukin alla olevista väittämistä ja ympäröi yksi merkki, joka osoittaa missä määrin olet samaa mieltä väitteestä.

Älykkyyttä on tietty määrä, eikä sen muuttamiseksi voi tehdä paljoakaan.

Täysin samaa mieltä	samaa mieltä	hieman samaa mieltä	hieman eri mieltä	eri mieltä	täysin eri mieltä

Älykkyys on ihmisessä jotain sellaista, jota ei voi muuttaa kovin paljon.

Täysin samaa mieltä	samaa mieltä	hieman samaa mieltä	hieman eri mieltä	eri mieltä	täysin eri mieltä

Uusia asioita voi oppia, mutta perusälykkyyttä ei voi muuttaa.

Täysin samaa mieltä	samaa mieltä	hieman samaa mieltä	hieman eri mieltä	eri mieltä	täysin eri mieltä

Pane merkki sen tyyppisten tehtävien kohdalle, joita haluaisit tehdä.

Haluaisin:

(1) ___ Tehtäviä, jotta eivät ole liian vaikeita niin, että en saisi niin monta väärin.

(2) ___ Tehtäviä, joista opin jotain, vaikka ne olisivatkin niin vaikeita, että saan monia väärin

(3) ___ Tehtäviä, jotka ovat melko helppoja niin, että selviydyn hyvin.

(4) ___ Tehtäviä, jotka ovat riittävän vaikeita osoittamaan, että olen terävä

(continues)

APPENDIX 1 (continued)

Alla on neljä paria väittämiä. Lue kukin pari ja valitse kumpi niistä parhaiten pitää paikkaansa sinun kohdallasi. Ympäröi sitten merkki, joka osoittaa, kuinka hyvin se pitää paikkaansa sinun kohdallasi. Valitse sitten <u>yksi</u> merkki kustakin väittämäparista.

Yleensä pidän itseäni älykkäänä.					Epäilen, olenko älykäs.
pitää täysin paikkansa	Pitää paikkansa	pitää hieman paikkansa	pitää hieman paikkansa	pitää paikkansa	pitää täysin paikkansa

En ole varma, että olen tarpeeksi älykäs menestyäkseni.					Olen aika varma, että Olen tarpeeksi älykäs menestyäkseni.
pitää täysin paikkansa	Pitää paikkansa	pitää hieman paikkansa	pitää hieman paikkansa	pitää paikkansa	pitää täysin paikkansa

Kun saan uutta materiaalia olen yleensä varma että kykenen oppimaan sen.					Kun saan uutta materiaalia, ajattelen Usein, että en kenties kykene oppimaan sitä.
pitää täysin paikkansa	Pitää paikkansa	pitää hieman paikkansa	pitää hieman paikkansa	pitää paikkansa	pitää täysin paikkansa

En luota kovin älylliseen kyvykkyyteeni.					Olen aika luottavainen älylliseen kyvykkyyteeni.
pitää täysin paikkansa	Pitää paikkansa	pitää hieman paikkansa	pitää hieman paikkansa	pitää paikkansa	pitää täysin paikkansa

APPENDIX 2

Projekti: Video-ohjelmat fysiikan opetuksessa
University of Alberta ja Jyväskylän yliopisto
Oppimisprosessikysely
(OPPIMISP)

OPPIMISPROSESSIKYSELY

MITÄ OPPIMISPROSESSIKYSELY KÄSITTELEE?

Tämä kyselylomake sisältää joukon kysymyksiä siitä, millaiseksi koet koulun ja millä tavoin opit koulussa.

Muista, että ei ole mitään erityistä oikeaa tapaa oppia. Kaikki riippuu siitä, mikä sopii sinulle ja niihin asioihin, joita olet oppimassa. Jos vastauksesi mielestäsi riippuu siitä, mitä olet oppimassa, anna vastaus, joka sopisi kaikkein tärkeimpään oppiaineiseesi.

KUINKA VASTATA?

Ole hyvä ja vastaa kaikkiin 36 kysymykseen. Ei ole mitään oikeaa tai väärää vastausta. Kuhunkin kysymykseen on 5 vastausvaihtoehtoa. Valitse vain yksi vastaus kuhunkin kysymykseen ja ympäröi sen numero kynälläsi.

Luettuasi väittämän valitse jokin seuraavista vaihtoehdoista sen mukaan, kuinka osuvasti se kuvaa sinua:

1 **Ei pidä koskaan paikkansa -** et koskaan tekisi näin
2 **ei todennäköisesti pidä paikkansa** -saatat tehdä näin
3 **pitää joskus paikkansa** - tekisit näin puolet ajasta
4 **pitää yleensä paikkansa** - tekisit yleensä näin
5 **pitää aina paikkansa** -tekisit aina näin

Esimerkki:

Teen kotitehtäväni parhaiten radion soidessa.

Jos tekisit aina näin (jos se pitäisi aina paikkansa) ympäröisit numeron 5 kyselylomakkeestasi. Jos tekisit joskus näin, ympäröisit numeron 3.

KIITOS YHTEISTYÖSTÄSI!

TÄYDENNÄ SEURAAVAT TIEDOT ENSIN

Sukunimi: ______________________________ Etunimi: _________________

Koulu: ______________________________________

Luokkatunnus: ___________

(continues)

APPENDIX 2 (continued)

	ei pidä koskaan paik- kansa	ei toden- näköi- sesti pidä paik- kansa	pitää joskus paik- kansa	pitää yleensä paik- kansa	pitää aina paik- kansa
1. Valitsin nykyiset oppiaineeni pääasiassa koulun jälkeisten uramahdollisuuksien vuoksi, ei siksi että olisin erityisen kiinnostunut niistä.	1	2	3	4	5
2. Toisinaan koulutyö voi antaa minulle syvän henkilökohtaisen tyydytyksen tunteen.	1	2	3	4	5
3. Yritän saada hyvät arvosanat kaikissa oppiaineissa sen edun vuoksi, jonka ne antavat minulle kilpaillessani toisten kanssa koulusta lähtiessäni.	1	2	3	4	5
4. Pyrin opiskelemaan vain sitä, mitä on määrätty, en yleensä tee mitään ylimääräistä.	1	2	3	4	5
5. Opiskellessani yritän usein pohtia, kuinka hyödyllistä opiskeltava materiaali olisi todellisessa elämässä.	1	2	3	4	5
6. Teen säännöllisesti muistiinpanoja annetuista lisäläheistä ja liitän ne aiheen tuntimuistiinpanoihin.	1	2	3	4	5
7. Huono koenumero saa minut lannistumaan ja murehtimaan, kuinka selviydyn seuraavasta kokeesta.	1	2	3	4	5
8. Kun huomaan toisten joskus tietävän asian paremmin kuin minä, tunnen tarvetta sanoa, mikä minun mielestäni on oikein.	1	2	3	4	5
9. Minulla on vahva halu tehdä parhaani kaikissa opinnoissani.	1	2	3	4	5
10. Ainut tapa oppia monia oppiaineita on opetella ne huolella ulkoa.	1	2	3	4	5
11. Uutta materiaalia lukiessani muistelen usein jo tuntemaani materiaalia ja näen jälkimmäisen uudessa valossa.	1	2	3	4	5
12. Yritän työskennellä vankasti koko lukukauden ja kertaan säännöllisesti, kun kokeet ovat lähellä.	1	2	3	4	5
13. Pidinpä siitä tai en, voin nähdä, että opiskelu on minulle hyvä tapa saada hyvin palkattu tai turvattu työ.	1	2	3	4	5
14. Monet oppiaineet voivat tulla hyvin mielenkiintoisiksi, kun kerran on päässyt niihin sisälle.	1	2	3	4	5
15. Pidän siitä, että koetulokset pannaan julkisesti esille niin, että voin nähdä, kuinka paljon parempi olin muita luokallani olevia.	1	2	3	4	5
16. Pidän parempina niitä aineita, joissa minun täytyy vain oppia faktoja kuin niitä, jotka edellyttävät runsasta lukemista ja materiaalin ymmärtämistä.	1	2	3	4	5
17. Ennen kuin olen tyytyväinen minun täytyy työskennellä aiheen parissa tarpeeksi niin, että voin muodostaa oman näkemykseni.	1	2	3	4	5
18. Yritän aina tehdä kaikki minulle annetut tehtävät heti, kun ne on annettu minulle.	1	2	3	4	5

(continues)

APPENDIX 2 (continued)

	ei pidä koskaan paikkansa	ei todennäköisesti pidä paikkansa	pitää joskus paikkansa	pitää yleensä paikkansa	pitää aina paikkansa
19. Silloinkin, kun olen opiskellut ahkerasti kokeeseen, olen hyvin huolissani, että en kenties selviydy siitä hyvin.	1	2	3	4	5
20. Joidenkin aiheiden opiskelu voi olla todella mielenkiintoista.	1	2	3	4	5
21. Menestyisin mieluummin koulussa hyvin, vaikka se saattaisikin tehdä minusta epäsuositun joidenkin luokkatovereideni keskuudessa.	1	2	3	4	5
22. Useimmissa aineissa yritän hoitaa asiat niin, että teen vain tarpeeksi päästäkseni läpi, enkä yhtään enempää.	1	2	3	4	5
23. Yritän yhdistää yhdessä aineessa oppimani siihen, mitä jo tiedän muissa aineissa.	1	2	3	4	5
24. Luen muistiinpanoni uudelleen pian oppitunnin jälkeen varmistaakseni, että pystyn lukemaan ja ymmärtämään niitä.	1	2	3	4	5
25. Mielestäni opettajien ei tulisi odottaa lukion oppilaiden työskentelevän kurssivaatimusten ulkopuolella olevien aiheiden parissa.	1	2	3	4	5
26. Tunnen, että jonain päivänä voin kyetä muuttamaan maailmassa asioita, joiden nyt näen olevan väärin.	1	2	3	4	5
27. Työskentelen saadakseni parhaita numeroita eri oppiaineissa pidinpä aineista tai en.	1	2	3	4	5
28. On parempi oppia vain faktat ja yksityiskohdat jostain aiheesta kuin yrittää ymmärtää sitä perusteellisesti.	1	2	3	4	5
29. Useimmat uudet aiheet ovat kiinnostavia ja kulutan usein ylimääräistä aikaa yrittäessäni saada niistä lisää selville.	1	2	3	4	5
30. Kokeenpalautuksen jälkeen käyn kokeen huolella läpi korjaten kaikki virheet ja yrittäen selvittää, miksi alunperin tein virheet.	1	2	3	4	5
31. Jatkan opintojani vain niin pitkään kuin on tarpeen hyvän työpaikan saamiseksi.	1	2	3	4	5
32. Pääpyrkimykseni elämässä on löytää, mihin uskoa ja toimia sitten sen mukaisesti.	1	2	3	4	5
33. Näen koulussa menestymisen eräänlaisena pelinä, ja pelaan voittaakseni.	1	2	3	4	5
34. En kuluta aikaani sellaisten asioiden opiskeluun, joista tiedän, että niitä ei kysytä kokeissa.	1	2	3	4	5
35. Kulutan suuren osan vapaa-ajastani saadakseni lisää tietoa niistä mielenkiintoisista aiheista, joita on käsitelty eri oppiaineiden tunneilla.	1	2	3	4	5
36. Yritän yleensä lukea kaikki lähteet ja asiat, joita opettaja on kehottanut lukemaan.	1	2	3	4	5

KIITOS! OLE HYVÄ JA TARKISTA, ETTÄ OLET VASTANNUT KAIKKIIN VÄITTÄMIIN

APPENDIX 3

Project: Video Programs in Physics Instruction
University of Alberta and University of Jyväskylä
general questionnaire
(GENERALQ)

GENERAL QUESTIONNAIRE

WHAT THE GENERAL QUESTIONNAIRE IS ABOUT

You have earlier received a paper describing the project "Video Programs in Physics Instruction". This questionnaire is the first phase the project. It is used to gather information on your background, usage of videos in your school and your relation to school and physics.

HOW TO ANSWER

Please, read the instructions in each section and answer the questions **from your own point of view**.

THANK YOU FOR YOUR COOPERATION!

FILL IN THE FOLLOWING INFORMATION FIRST:

Last name: ____________________________ First name: _______________

School: ____

Grade: ________ Class: ___________________________

(continues)

APPENDIX 3 (continued)

BACKGROUND INFORMATION

Please, circle the appropriate alternative or write the information on the empty lines.

1. I am **1** female **2** male

2. I am ______ years old

3. My father's occupation is ____
4. My father's education is ____
5. My mother's occupation is ____
6. My mother's education is ____

7. What kind of a school course are you taking this year?
   1 academic - mainly academic subjects leading to further education at a university or college
   2 vocational - mainly subjects to prepare for a particular occupation when you leave school
   3 general - subjects not leading to a particular occupation or further education when you leave school
   4 other -(if your course is NOT one of the three above, please describe it on the lines below)

____

8. Do you expect to include any science subjects as part of your further education?
   1 I expect to include science subjects
   2 I do not expect to include science subjects
   3 I do not expect to continue my education after leaving high school
   4 I have not yet decided

9. About how many hours **a week** do you usually spend on homework or other school work <u>out</u> <u>of</u> <u>class</u> for <u>all</u> subjects (including science)?
   1 I never have homework
   2 up to 2 hours
   3 3 - 5 hours
   4 6 - 10 hours
   5 11 - 20 hours
   6 more than 20 hours

10. About how many hours **a week** do you usually spend on homework or other school work <u>out</u> <u>of</u> <u>class</u> for <u>science</u> subjects?
   1 I never have science homework
   2 up to 2 hours
   3 3 - 5 hours
   4 6 - 10 hours
   5 more than 10 hours

11. Are you working part-time or full-time during this school term?
   1 no **2** yes, about _____ hours **a week**

12. About how many hours **a week** do you usually spend on watching **T.V.**?
   1 I never watch T.V.
   2 up to 2 hours
   3 3 - 5 hours
   4 6 - 10 hours
   5 11 - 20 hours
   6 more than 20 hours

(continues)

APPENDIX 3 (continued)

13. About how many hours **a week** do you usually spend on watching **videos**? (**excluding** videos recorded from T.V.)
    1 I never watch videos
    2 up to 2 hours
    3 3 - 5 hours
    4 6 - 10 hours
    5 11 - 20 hours
    6 more than 20 hours

14. What are your main **hobbies or other activities**, and about how many hours **a week** do you usually spend on them?

		hours/week
1.	______________________	_______
2.	______________________	_______
3.	______________________	_______
4.	______________________	_______

15. How many hours do you usually sleep **a day**? _____ hours a day

VIDEO PROGRAMS IN MY SCHOOL

<u>How often have your own teachers used video programs or video cameras in instruction during this term</u>? Circle the number of the alternative that best reflects the situation in the following subjects.
NOTE: Strike out the subjects you do not take in senior high school.

	never	some-times	rather often	often	very often
1. Physics	1	2	3	4	5
2. Chemistry	1	2	3	4	5
3. English	1	2	3	4	5
4. Mathematics	1	2	3	4	5
5. Biology	1	2	3	4	5
6. Foreign languages	1	2	3	4	5
7. Religion	1	2	3	4	5
8. Geography	1	2	3	4	5
9. Psychology	1	2	3	4	5
10. Social studies	1	2	3	4	5

(Continues)

APPENDIX 3 (continued)

THE WAYS VIDEOS HAVE BEEN USED IN PHYSICS

Answer the following questions by circling the number of the alternative that best reflects your experience. if there are other ways your physics teacher has used videos not mentioned in the alternatives, indicate them in the empty lines provided.

OUR PHYSICS TEACHER HAS USED VIDEOS:	never	some-times	rather often	often	very often
1. for summarizing the content we were studying.	1	2	3	4	5
2. to fill up time.	1	2	3	4	5
3. by giving us tasks to do during or after viewing the program.	1	2	3	4	5
4. to give us videotaped feedback about our performance in lab.	1	2	3	4	5
5. to provide a basis for discussion.	1	2	3	4	5
6. to give instructions for working. (e.g. in a laboratory)	1	2	3	4	5
7. to introduce new concepts.	1	2	3	4	5
8. by giving us video cameras for gathering information.	1	2	3	4	5
9. by giving us video cameras for making a video program according to a written manuscript.	1	2	3	4	5
10. just to give something to do.	1	2	3	4	5
11. to show how the theoretical information we were studying applies to practice.	1	2	3	4	5
12. ______________________________ ______________________________	1	2	3	4	5
13. ______________________________ ______________________________	1	2	3	4	5

(Continues)

APPENDIX 3 (continued)

RELATION TO SCHOOL AND PHYSICS

Read each statement carefully and answer the following questions by circling the alternative that best reflects your opinion. The questions are about your relation to school generally and to Physics specially.

To each statement there are five answering alternatives. The alternatives are:
(1) strongly disagree
(2) disagree
(3) uncertain
(4) agree
(5) strongly agree

	strongly disagree	**disagree**	**uncertain**	**agree**	**strongly agree**
1. I like school.	1	2	3	4	5
2. I use visual images of physics concepts and processes in order to understand the topics I am studying.	1	2	3	4	5
3. Physics is an interesting subject for me.	1	2	3	4	5
4. I find physics challenging.	1	2	3	4	5
5. Physics is a difficult subject.	1	2	3	4	5
6. Science programs on television and in videocassettes have helped me to understand physics better.	1	2	3	4	5
7. Science is useful for solving the problems of everyday life.	1	2	3	4	5
8. It is important to know science in order to get a good job.	1	2	3	4	5
9. I use the pictures and drawings in physics textbooks to form a better understanding of the topic I am studying.	1	2	3	4	5
10. In my future career I would like to use the science I learned at school.	1	2	3	4	5
11. I am confident that If I try to do my best I can understand physics well.	1	2	3	4	5
12. I want to learn more about the world we live in.	1	2	3	4	5
13. While I am solving physics problems I try to form a clear idea about the components in the problem before trying any equations.	1	2	3	4	5

(continues)

APPENDIX 3 (continued)

	strongly disagree	disagree	uncertain	agree	strongly agree
14. I generally dislike my schoolwork.	1	2	3	4	5
15. Physics in an enjoyable school subject.	1	2	3	4	5
16. If properly taught, almost all students could learn physics.	1	2	3	4	5
17. Physics is relevant to everyday life.	1	2	3	4	5
18. Science is a very good field for creative people to enter.	1	2	3	4	5
19. There are too many facts to learn in physics.	1	2	3	4	5
20. I read just the text in physics books without paying attention to pictures and drawings.	1	2	3	4	5
21. Physics is difficult when it involves calculations.	1	2	3	4	5
22. I want as much education as I can get.	1	2	3	4	5
23. Physics is difficult when it involves handling apparatus.	1	2	3	4	5
24. School is not very enjoyable.	1	2	3	4	5
25. The physics taught at school is interesting.	1	2	3	4	5
26. I am bored most of the time in school.	1	2	3	4	5
27. I find school challenging.	1	2	3	4	5
28. I have difficulties in relating physics to things happening in the real world.	1	2	3	4	5
29. Visual presentations make it easier for me to understand physics.	1	2	3	4	5
30. Studying physics without knowing how the information is used in real life does not make sense to me.	1	2	3	4	5
31. I try to solve physics problems by searching for the right equations.	1	2	3	4	5
32. I often worry that I am not able to learn physics well enough.	1	2	3	4	5

(continues)

APPENDIX 3 (continued)

STUDYING GASES AND THEIR BEHAVIOUR

	strongly disagree	disagree	uncertain	agree	strongly agree
1. I find gases and their behavior as an interesting topic to learn about.	1	2	3	4	5
2. I already know fairly well how gases behave.	1	2	3	4	5
3. I think it is useful to know more about gases and their behaviour.	1	2	3	4	5
4. Studying gases and their behaviour does not make sense to me.	1	2	3	4	5
5. I know very little about gases and their behaviour.	1	2	3	4	5
6. I am relieved this is the last item in this questionnaire.	1	2	3	4	5

THANK YOU FOR ANSWERING!

PLEASE, CHECK THAT YOU HAVE ANSWERED ALL THE QUESTIONS BEFORE YOU RETURN THE QUESTIONNAIRE.

APPENDIX 4

University of Alberta
Edmonton
Canada T6G 2G5

Department of Secondary Education
Faculty of Education
341 Education South, Telephone (403) 492-3674
Fax: (403) 492-0236 Email: SE04@MTS.UCS.UALBERTA.CA

October 4, 1991

Mr. Sauli Puukari
Dept. of Educational Psychology
University of Alberta
Edmonton, AB
T6G 2G5

Dear Mr. Puukari:

Permission is hereby given for you to use selected IEA test items that were part of the Canadian Study as part of the instrumentation for your Ph.D. dissertation research. Please acknowledge the source of these items in an appropriate way in the dissertation.

Sincerely,

HKass.

DR. H. KASS
PRINCIPAL INVESTIGATOR, WESTERN REGION
CANADIAN STUDY,
INTERNATIONAL ASSOCIATION FOR THE
EVALUATION OF EDUCATIONAL ACHIEVEMENT

HK/kr

APPENDIX 5

Project: Video Programs in Physics Instruction
University of Alberta and University of Jyväskylä
1st Concept Map + Essay
(CONMAP1)

1ST CONCEPT MAP + ESSAY

DESCRIPTION OF THE ASSIGNMENT

1) **List all the concepts** you know that are related to gases and their behaviour.

2) **Form a concept map** by writing the concepts into circles and by using arrows to indicate the relations between these circled concepts. Try to form as well organized concept map as you can.

3) **Write an essay** dealing with gases and their behaviour utilizing the information in your concept map. Remember to explain the relations between the concepts in your essay. You may use **drawings and graphs** as part of your essay, if you wish.

NOTE: Use separate papers for making drafts and then use the blank page for the final concept map and the next pages for the essay.

THANK YOU IN ADVANCE!

FILL IN THE FOLLOWING INFORMATION FIRST

Last name: ______________________ First name: _______________

School: ____

Grade: _______ Class: ___________________

(continues)

APPENDIX 5 (continued)

THE FINAL CONCEPT MAP

(continues)

APPENDIX 5 (continued)

ESSAY "GASES AND THEIR BEHAVIOUR"

(Continues)

APPENDIX 5 (continued)

APPENDIX 6

Project: Video Programs in Physics Instruction
University of Alberta and University of Jyväskylä
Multiple-choice Questions-1
(MULTIQ1)

MULTIPLE-CHOICE QUESTIONS-1

DESCRIPTION OF THE ASSIGNMENT

The following questions deal with gases and their behaviour. Every question has 5 answers to choose from. Only **one** of these choices is a correct answer to the question. Please, **circle the letter of the alternative you consider to be the right one or closest to the right one.**

Since you have not yet studied these questions in physics, you may not know the answers. Do not worry about this. The purpose of these questions is to **check the knowledge you may already have about the behaviour of gases** .

NOTE: If you do not **KNOW** the answer, try to make a good **GUESS** by analyzing the 5 alternatives and by using the knowledge you have. **If you answer a question by guessing, circle the letter G below the question number.**

Read the whole question and the five alternatives carefully before answering.

THANK YOU IN ADVANCE!

FILL IN THE FOLLOWING INFORMATION FIRST

Last name: ________________________ First name: _________________

School: ____

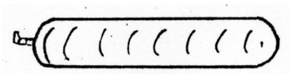
Grade: ____ Class: _________________

(continues)

APPENDIX 6 (continued)

1. **When a small volume of water is boiled, a large volume of steam is produced. Why?**
   A The molecules are further apart in steam than water.
G B Water molecules expand when heated and make the steam molecules bigger than the water molecules.
   C the change from water to steam causes the number of molecules to increase.
   D Atmospheric pressure affects water molecules more than steam molecules.
   E Water molecules repel each other when heated.

2. **An iron container is weighted after the air in it has been pumped out (evacuated). Then it is filled with hydrogen gas and weighed again.**



What is the weight of the container full of hydrogen compared to the weight of the evacuated container?
   A less
G B greater
   C the same
   D greater or less depending on the volume of the gas in the container
   E greater or less depending on the temperature of the gas in the container

3. **A jar of oxygen gas and a jar of hydrogen gas are at the same temperature. Which of the following physical quantities has the same value for the molecules of both gases?**
G A the average velocity
   B the average momentum
   C the average force
   D the average potential energy
   E the average kinetic energy

4. **The gas laws are valid for real gases, <u>except</u>**
   A when temperature is high and pressure low
G B when conditions differ from standard atmospheric conditions (STP)
   C at 0°C at sea level
   D when temperature is low and pressure high
   E when temperature is moderate and pressure low

5. **When pressure is constant the volume of a gas**
   A varies directly with its Kelvin temperature
G B varies inversely with its Kelvin temperature
   C varies independently of its Kelvin temperature
   D varies only if the Kelvin temperature decreases
   E varies only if the Kelvin temperature increases

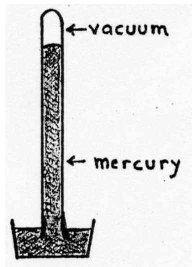
6. **When temperature is constant the volume of a gas**
   A varies directly with the pressure
G B increases when the pressure decreases
   C varies independently of the pressure
   D increases when the pressure increases
   E decreases when the pressure decreases

7. **When volume is kept constant the pressure of a gas**
   A varies independently of the temperature
G B decreases when the temperature increases
   C varies directly with the temperature
   D increases when the temperature decreases
   E varies only when temperature is kept constant

(continues)

APPENDIX 6 (continued)

8. In a simple mercury barometer (see the figure) the mercury in the tube - whose bottom end is open - stays above the level of mercury in the dish. What makes this possible?



G A gravity of the earth
B decreasing movement of the mercury molecules in the tube
C increasing movement of the mercury molecules in the dish
D the weight of mercury in the dish
E the weight of the atmosphere

9. Which of the following statements is <u>not</u> part of or <u>cannot</u> be derived from the <u>Kinetic Theory of Gases</u>.
A gas molecules are in random constant motion
G B at low temperatures and under high pressures gases become liquids
C gas molecules collide elastically with each other
D at high temperatures and under low pressures gases obey Boyle's Law
E at high temperatures and under low pressures gases obey Combined Gas Law

10. Which of the following statements is <u>not</u> true: At the zero point of Kelvin Scale..
A molecular motion of gases would stop according to the Kinetic Theory
G B gases would not obey Boyle's Law
C my nose would be very frozen
D Celsius temperature would be approximately -273
E molecular motion would be very slow and non-linear

11. A mole ..
A can be mathematically derived from Charles's Law
G B is a unit for a product of pressure and volume
C can be predicted by extrapolation
D is the number of molecules in one cubic meter of oxygen at standard pressure and temperature
E is the number of molecules in a 22.4 litres of a gas at standard atmospheric pressure and temperature

12. Which statement is <u>not</u> true about pressure. Pressure of a gas...
A decreases when volume increases at constant temperature
G B is caused by moving particles
C can be defined as a force exerted on a unit area of surface
D can be reduced by lowering the temperature
E is caused by particles which increase their mass in elastic collisions

13. When a gas is heated, its molecules
A start losing their kinetic energy
G B start increasing their volume
C start moving closer to each other
D start moving faster
E start increasing their kinetic energy faster than the ideal gas law predicts

14. Which of the following statements is <u>wrong</u>. When the temperature of a gas decreases, the molecules of the gas
A start losing their average kinetic energy
G B start moving at a different speed
C start moving slower
D start reducing their volume as the gas laws predict
E reduce their velocity

THANK YOU FOR ANSWERING!
Please check that you have answered every question

APPENDIX 7

Project: Video Programs in Physics Instruction
Task Papers

TASK PAPER 1

4.1. BOYLE'S LAW

INSTRUCTIONS:

Complete the following two problems by yourself as well as you can. You can use the textbook and your notes while working on the problems. Write down how you solved the problems on empty space provided.

FILL IN THE FOLLOWING INFORMATION FIRST:

Last name: ______________________ First name: ___________

School: ____

Grade: _____ Class: ______________________

(1) A tire has a volume of 14.0 dm^3 and a pressure of 2.20 bar. What will be the volume of the gas in the tire if it would freely expand until the pressure decreases to standard atmospheric pressure?

(continues)

APPENDIX 7 (continued)

(2) How big a meteorological balloon can be filled with hydrogen to the pressure of 0,11 Mpa from a gas bottle which volume is 40.0 dm^3 and pressure is 12 Mpa? Assume the temperatureis constant.

(continues)

APPENDIX 7 (continued)

Project: Video Programs in Physics Instruction
Task Papers

TASK PAPER 2

4.2. CHARLES' LAW

INSTRUCTIONS:

Complete the following two problems by yourself as well as you can. You can use the textbook and your notes while working on the problems. Write down how you solved the problems on empty space provided.

FILL IN THE FOLLOWING INFORMATION FIRST:

Last name: ______________________ First name: ___________

School: ____

Grade: _____ Class: ______________________

(1) An initial volume of 566 cm^3 air is heated at constant pressure from 10°C to 100°C. What is the final volume?

(continues)

APPENDIX 7 (continued)

(2) Suppose you work at a laboratory, and today you have to collect 3 samples of gas. Each sample has 870 ml of hydrogen collected at 27°C into a bottle that has a piston, which creates a pressure of 200 kPa on the gas (real laboratories use special containers for collecting gas samples). The sample will be taken to the laboratory into a cabin whose temperature is 42°C keeping the pressure constant. Your colleagues need as many large bottles as possible; the larger they are, the better. See the following list of bottles available:

	bottle (ml)	**quantity**
(a)	900	4
(b)	1200	4
(c)	1400	2
(d)	1500	6

Which three bottles would you choose to avoid overfloating in the cabin and to leave as many big bottles as possible?

(continues)

APPENDIX 7 (continued)

Project: Video Programs in Physics Instruction
Task Papers

TASK PAPER 3

4.3. THIRD GAS LAW - GAY-LUSSAC'S LAW

INSTRUCTIONS:

Complete the following two problems by yourself as well as you can. You can use the textbook and your notes while working on the problems. Write down how you solved the problems on empty space provided.

FILL IN THE FOLLOWING INFORMATION FIRST:

Last name: ______________________ First name:___________

School: ____

Grade: _____ Class: ______________________

(1) A rigid steel tank contains carbon dioxide at 30°C and 505 cm of mercury pressure. If the temperature of the tank and its contents is reduced to -33°C, what is the final pressure?

(continues)

APPENDIX 7 (continued)

(2) When the door of a fridge is open the temperature in the fridge is 14°C. When the airproof door is closed the temperature will decrease to 4°C. What is the difference between the pressure inside and outside the fridge and what is the force exerted on the door as the area of it is 0,44m^2? Atmospheric pressure in the room is 100 kPa.

(continues)

APPENDIX 7 (continued)

Project: Video Programs in Physics Instruction
Task Papers

TASK PAPER 4

4.4. COMBINED GAS LAW

INSTRUCTIONS:

Complete the following two problems by yourself as well as you can. You can use the textbook and your notes while working on the problems. Write down how you solved the problems on empty space provided.

FILL IN THE FOLLOWING INFORMATION FIRST:

Last name: ______________________ First name: ___________

School: ____

Grade: _____ Class: ______________________

(1) What is the pressure of one mole of hydrogen whose volume is 0.020 m^3 and whose temperature is 21°C?

(continues)

APPENDIX 7 (continued)

(2) Suppose a factory has a machine that uses 50 litres of a mixture of gases in a production process at a temperature of 200 K and under a pressure of 15 atm. Suppose that the volume of the mixture of gases during a certain period of the production must be 200 litres and the pressure 7.5 atm Next week the company will have a new computer system that does all the adjustments, but until the next week you have to adjust the temperature of the gas mixture. What would be the temperature you select?

(continues)

APPENDIX 7 (continued)

Project: Video Programs in Physics Instruction
Task Papers

TASK PAPER 5

5. REAL GASES AND THE KINETIC THEORY OF MATTER

INSTRUCTIONS:

Answer the following two questions by yourself as well as you can. You can use the textbook and your notes while working on the questions. Write down your answers to the questions on empty space provided.

FILL IN THE FOLLOWING INFORMATION FIRST:

Last name: ______________________ First name: ___________

School: ____

Grade: _____ Class: ______________________

(1) Why does the behavior of a highly compressed real gas deviate considerably from that of an ideal gas?

(continues)

APPENDIX 7 (continued)

(2) A rigid container has n molecules of gas A in it. An equal number of molecules of gas B is then introduced into it. If average kinetic energies of the molecules in the two gases were equal before the gases were mixed, what change, if any, has taken place in (a) temperature; (b) the pressure inside the container. Explain.

APPENDIX 8

Project: Video Programs in Physics Instruction
University of Alberta and University of Jyväskylä
Experience Questionnaire
(EXPERQ)

EXPERIENCE QUESTIONNAIRE

WHAT THE EXPERIENCE QUESTIONNAIRE IS ABOUT

This questionnaire is used to gather information on your experiences about the course "THE BEHAVIOUR OF GASES AND THE GAS LAWS".

Please, read the instructions in each section and answer the questions **from your own point of view**.

THANK YOU FOR YOUR COOPERATION!

FILL IN THE FOLLOWING INFORMATION FIRST:

Last name: ______________________ First name: ________________

School: ____

Grade: ________ Class: ____________________

(continues)

APPENDIX 8 (continued)

Read each statement carefully and answer the following questions by circling the alternative that best reflects your experience.

EXPERIENCES ABOUT STUDYING GASES AND THEIR BEHAVIOUR

	strongly disagree	disagree	uncertain	agree	strongly agree
1. I found gases and their behavior as an interesting topic to learn about.	1	2	3	4	5
2. I already knew fairly well the things we were taught.	1	2	3	4	5
3. I think it was useful to learn about gases and their behaviour.	1	2	3	4	5
4. Studying gases and their behaviour did <u>not</u> make sense to me.	1	2	3	4	5
5. I knew very little about gases and their behaviour before this course.	1	2	3	4	5
6. I could clearly see how the physics information in this course was related to real world.	1	2	3	4	5
7. I feel confident that I understand the things we studied in the course.	1	2	3	4	5
8. I had big difficulties in understanding the things taught in the course.	1	2	3	4	5

Did you study the topics of the course at home? ___ no ___ yes, about _______ hours

What was best in this course? Explain why.

____
____
____
____

What was worst in this course? Explain why.

____
____
____
____

(continues)

APPENDIX 8 (continued)

If your class did not use a video program in the course, you can skip over the items dealing with the video program.

EXPERIENCES ABOUT THE LEARNING MATERIALS AND INSTRUCTION IN THE COURSE

	strongly disagree	disagree	uncertain	agree	strongly agree
1. The content of the textbook was was interesting.	1	2	3	4	5
2. The workbook and task papers had challenging problems and questions 1	2	3	4	5	
3. I wish we had more this kind of courses.	1	2	3	4	5
4. The content of the questions and problems in the workbook and task papers was interesting to me.	1	2	3	4	5
5. The textbook was easy to under-stand.	1	2	3	4	5
6. The video program really helped me to understand the gas laws.	1	2	3	4	5
7. The video program really helped me to understand the Kinetic Theory of Matter.	1	2	3	4	5
8. The structure of the textbook was <u>un</u>clear.	1	2	3	4	5
9. The instruction in this course was not different from lessons we usually have in physics.	1	2	3	4	5
10.Some questions and problems in the workbookand task papers made me realize I need to know more about the behaviour of gases.	1	2	3	4	5
11.The video program made the 1 lessons more interesting than usual lessons.	2	3	4	5	
12.I could have well understood all the things without the video program.	1	2	3	4	5

Complete the sentences below based on the first thoughts you have:

My best insight during the course appeared when ____
____

During the course it was really interesting to ____
____

During the course I often felt ____
____

(continues)

APPENDIX 8 (continued)

BASED ON MY EXPERIENCES ABOUT THE COURSE
my straightforward comments...

about the textbook are:

about the video program are:

about the workbook and task papers are:

about the course, in general are:

THANK YOU FOR ANSWERING !

APPENDIX 9

Project: Video Programs in Physics Instruction
University of Alberta and University of Jyväskylä
Teachers' Experience Questionnaire
(EXPERQT)

EXPERIENCE QUESTIONNAIRE

WHAT THE EXPERIENCE QUESTIONNAIRE IS ABOUT

This questionnaire is used to gather information on your experiences about the course "THE BEHAVIOUR OF GASES AND THE GAS LAWS".

Please, read the instructions in each section and answer the questions **from your own point of view**.

THANK YOU FOR YOUR COOPERATION!

FILL IN THE FOLLOWING INFORMATION FIRST:

Last name: ______________________ First name: ________________

School: ____

(continues)

APPENDIX 9 (continued)

Read each statement carefully and answer the following questions by circling the alternative that best reflects your experience.

SOME EXPERIENCES ABOUT TEACHING THE COURSE

	strongly disagree	disagree	uncertain	agree	strongly agree
1. I found gases and their behavior as an interesting topic to teach.	1	2	3	4	5
2. I have taught the same topic earlier.	1	2	3	4	5
3. I feel confident that students understood the things taught in the course.	1	2	3	4	5

Did you study the topics of the course prior to teaching them? __ no __ yes, about ______ hours

What was best in this course? Explain why.

____
____
____
____
____
____

What was worst in this course? Explain why.

____
____
____
____
____
____

(continues)

APPENDIX 9 (continued)

If your class did not use a video program in the course, you can skip over the items dealing with the video program.

EXPERIENCES ABOUT THE LEARNING MATERIALS AND INSTRUCTION IN THE COURSE

	strongly disagree	disagree	uncertain	agree	strongly agree
1. The content of the textbook was was interesting.	1	2	3	4	5
2. The workbook and task papers had challenging problems and questions.	1	2	3	4	5
3. The content of the questions and problems in the workbook and task papers was interesting to me.	1	2	3	4	5
4. The textbook was easy to under-stand.	1	2	3	4	5
5. The video program really helped students to understand the gas laws.	1	2	3	4	5
6. The video program really helped students understand the Kinetic Theory of Matter.	1	2	3	4	5
7. The structure of the textbook was <u>un</u>clear.	1	2	3	4	5
8. The instruction in this course was not different from lessons we usually have in physics.	1	2	3	4	5
9. The video program made the lessons more interesting than usual lessons.	1	2	3	4	5
10. Students could have well understood all the things without the video program.	1	2	3	4	5

Complete the sentences below based on the first thoughts you have:

My best insight during the course appeared when ____

____

During the course it was really interesting to ____

____

During the course I often felt ____

____

(continues)

APPENDIX 9 (continued)

BEFORE THIS COURSE MY STUDENTS HAVE HAD THE FOLLOWING COURSES THAT ARE LISTED IN THE CURRENT VALID PHYSICS CURRICULUM OF ALBERTA EDUCATION:

____ **the compulsory courses at grade 10**

____ **the following elective units at grade 10:**

____

____

____

____ **the following compulsory courses at grade 11:**

____

____

____

____

____

____

____ **the following elective units at grade 11:**

____

____

____

The following students (moved from other provinces) have taken the following courses before this course:

____

____

____

____

____

CONTINUE TO THE OTHER SIDE OF THE PAPER IF NEEDED

(continues)

APPENDIX 9 (continued)

BASED ON MY EXPERIENCES ABOUT THE COURSE
my straightforward comments...

about the textbook are:

____

____

____

____

____

about the video program are:

____

____

____

____

____

about the workbook and task papers are:

____

____

____

____

____

about the course, in general are:

____

____

____

____

____

(continues)

APPENDIX 9 (continued)

MY SUGGESTIONS FOR THE IMPROVEMENT OF THE TEXTBOOK, WORKBOOK, AND THE VIDEO PROGRAM ARE:

THANK YOU FOR ANSWERING !

APPENDIX 10. LIST OF VARIABLES USED IN ANALYSES

This variable list contains complete statements used in the original questionnaires. "(FIN)" indicates that the variable is to be used only with Finnish data. When several variables have the same answering alternatives and/or introductory statement in the original questionnaires, these will be presented either at the beginning or at the end of each set of variables. The information for each variable will be in the following order beginning from left to right/up to down: name of the variable, variable label, value scale.

BACKGROUND VARIABLES FROM DIFFERENT QUESTIONNAIRES:

SEX 1 female
2 male
AGE AGE (in years)
FOC FATHERS OCCUPATION
1 lowest level
2 second level
3 third level
4 highest level
FED FATHERS EDUCATION
1 elementary education
2 junior high school
3 senior high school
4 occupational school less than 4 years
5 occupational school more than 4 years
6 university degree
7 postgraduate university degree
MOC MOTHERS OCCUPATION (the same scale as in FOC above)
MED MOTHERS EDUCATION (the same scale as in FED above)
COUNTRY
1 Canada
2 Finland
EXPGROUP EXPERIMENTAL GROUP
1 learning tasks prior to viewing each video sequence /video includes: preview section + basic sections
2 learning tasks prior to viewing each video sequence /video includes: basic sections + application section
3 learning tasks prior to viewing each video sequence /video includes: basic sections
4 learning tasks prior to teaching each topic/no video
5 no learning tasks prior to viewing each video sequence /video includes: preview section + basic sections
6 no learning tasks prior to viewing each video sequence /video includes: basic sections + application section
7 no learning tasks prior to viewing each video sequence /video includes: basic sections
8 no learning tasks prior to teaching each topic /no video
EXP9 HOURS USED FOR STUDYING TOPICS AT HOME
G74 (FIN) TYPE OF COURSE IN MATHEMATICS 1 brief 2 expanded
G75 (FIN) TYPE OF COURSE IN PHYSICS 1 brief 2 expanded
G76 (FIN) AUTOMATIC DATA PROCESSING COURSES 0 no courses 2 takes courses
G7 TYPE OF SCHOOL COURSE
1 academic
2 vocational
3 general
4 International Baccalaureate
FYS_KA Physics courses - grades mean
MAT_KA Mathematics courses - grades mean
ÄID_KA Finnish courses - grades mean
KEM_KA Chemistry courses - grades mean

Recoded and aggregated background and grouping variables:

SES Social Economic Status (foc+fed+moc+med)
(theoretical range: 4 - 22; high scores indicate high status)
ESRECO Social Economic Status (Categorized) (80 valid cases)
1 low SES (4 - 9)
2 lower middle SES (10 - 13)
3 higher middle SES (14 - 18)
4 high SES (19-22)

(continues)

APPENDIX 10 (continued)

G8REC SCIENCE SUBJECTS IN FURTHER EDUCATION
1 no/not decided or does not plan to continue education
2 yes
VIDEO EXPGROUP RECODED: VIDEO/NO VIDEO
1 video
2 no video
APPLIC EXPGROUP REC: APPLICATION SECTION/ NO APPLICATION .SECTION
1 basic sections + application section in the video
2 only basic sections in the video
PREVIEW EXPGROUP REC: PREVIEW SECTION/ NO PREVIEW SECTION
1 preview section in the video
2 no preview section in the video
GAINREC GAIN SCORE (NEGATIVE VALUES ELMINATED)
TASKGRP TASKS PRIOR TO VIEWING
1 yes
2 no
VIDEOGRP VIDEO VERSIONS
1 preview section + basic section in the video
2 basic sections + application section in the video
3 only basic sections in the video
4 no video
EXPGRECO Recoded experiment groups (4=1, others 2)
1 experimental group 4 (assignments/ no video)
2 all other groups

GENERAL QUESTIONNAIRE VARIABLES:
G8 SCIENCE SUBJECTS IN FURTHER EDUCATION
1 include science subjects
2 do not include science subjects
3 does not plan to continue education.
4 has not yet decided
G9 HOURS A WEEK SPENT ON ALL HOMEWORK
1 has never homework
2 up to 2 hours
3 3 - 5 hours
4 6 - 10 hours
5 11 - 20 hours
6 more than 20 hours
G10 HOURS A WEEK SPENT ON SCIENCE HOMEWORK
1 has never homework
2 up to 2 hours
3 3 - 5 hours
4 6 - 10 hours
5 more than 10 hours
G11 WORKING DURING SCHOOL TERM (HOURS/WEEK)
G12 HOURS A WEEK SPENT ON WATCHING T.V.
1 1 never watch T.V.
2 up to 2 hours
3 3 - 5 hours
4 6 - 10 hours
5 11 - 20 hours
6 more than 20 hours

(continues)

APPENDIX 10 (continued)

G13 HOURS A WEEK SPENT ON WATCHING VIDEOS
1 1 never watch videos
2 up to 2 hours
3 3 - 5- hours
4 6 - 10 hours
5 11 - 20 hours
6 more than 20 hours
G14 SLEEPING HOURS A DAY

Video programmes in school:
(How often have your own teachers used video programmes or video cameras in instruction during this term?)
1 never
2 sometimes
3 rather often
4 often
5 very often
G15 Videos used in physics
G16 Videos used in chemistry
G17 Videos used in English
G18 Videos used in mathematics
G19 Videos used in biology
G20 Videos used in foreign languages
G21 Videos used in religion
G22 Videos used in geography
G23 Videos used in psychology
G24 Videos used in social sciences
G77 (Fin) videos in history

The ways videos have been used in physics:
1 never
2 sometimes
3 rather often
4 often
5 very often
Our physics teacher has used videos:
G25 for summarizing the content we were studying.
G26 to fill up time.
G27 by giving us tasks to do, during or after viewing the programme.
G28 to give us videotaped feedback about our performance in lab.
G29 to provide a basis for discussion.
G30 to give instructions for working (e.g. in a laboratory).
G31 to introduce new concepts.
G32 by giving us video cameras for gathering information.
G33 by giving us video cameras for making a video programme according to a written manuscript.
G34 just to give something to do.
G35 to show how the theoretical information we were studying applies to practice.
Relation to school and physics:
1 strongly disagree
2 disagree
3 uncertain
4 agree
5 strongly agree
G36 1 like school.
G37 I use visual images of physics concepts and processes in order to understand the topics 1 am studying.
G38 Physics is an interesting subject for me.
G39 I find physics challenging.
G40 Physics is a difficult subject.

(continues)

APPENDIX 10 (continued)

G41 Science programmes on television and in videocassettes have helped me to understand physics better.
G42 Science is useful for solving the problems of everyday life.
G43 It is important to know science in order to get a good job.
G44 I use pictures and drawings in physics textbooks to form a better understanding of the topic I am studying.
G45 In my future career I would like to use the science I learned at school.
G46 I am confident that if I try to do my best I can understand physics well.
G47 I want to learn more about the world we live in.
G48 While I am solving physics problems I try to form a clear idea about the components in the problem before trying any equations.
G49 I generally dislike my schoolwork.
G50 Physics is an enjoyable school subject.
G51 If properly taught, almost all students could learn physics.
G52 Physics is relevant to everyday life.
G53 Science is a very good field for creative people to enter.
G54 There are too many facts to learn in physics.
G55 I read just the text in physics books without paying attention to pictures and drawings.
G56 Physics is difficult when it involves calculations.
G57 I want as much education as I can get.
G58 Physics is difficult when it involves handling apparatus.
G59 School is not very enjoyable.
G60 The physics taught at school is interesting.
G61 I am bored most of the time in school.
G62 I find school challenging.
G63 I have difficulties in relating physics to things happening in the real world.
G64 Visual presentations make it easier for me to understand physics.
G65 Studying physics without knowing how the information is used in real life does not make sense to me.
G66 I try to solve physics problems by searching for the equations.
G67 I often worry that I am not able to learn physics well enough.
G68 I find gases and, their behaviour as an interesting topic to learn about.
G69 I already know fairly well how gases behave.
G70 I think it is useful to know more about gases and their behaviour.
G71 Studying gases and their behaviour does not make sense to me.
G72 I know very little about gases and their behaviour.
G73 I am relieved this is the last item in this questionnaire.

General Questionnaire - aggregated variables:
Below each of the following aggregated variables there is a list of the single variables used for making it. Note that the sums of single variable values were divided with the number of variables in order to have clearly interpretable value ranges (strongly disagree 1,00 - 5,00 strongly agree)

GVIDUSE WAYS TO USE VIDEOS IN PHYSICS (including only positive ways):
- G25 for summarizing the content we were studying.
- G27 by giving us tasks to do during or after viewing the programme.
- G28 to give us videotaped feedback about our performance in lab.
- G29 to provide basis for discussion.
- G30 to give instructions for working (e.g. in a laboratory)
- G31 to introduce new concepts.
- G32 by giving us video cameras for gathering information.
- G33 by giving us video cameras for making a video programme according to a written manuscript.
- G35 to show how the theoretical information we were studying applies to practice.

GVMREC WAYS TO USE VIDEOS IN PHYSICS (same as above, but categorized): 1 (1,00-1,49) never; 2 (1,50-2,49) sometimes; 3 (2,50-3,49) rather often; 4 (3,50-4,49) often; 5 (4,50-5,00) very often

GVISINPH VISUALITY IN PHYSICS
- G37 I use visual images of physics concepts and processes in order to understand the topics I am studying.
- G41 Science programmes in television and in videocassettes have helped me understand physics better.
- G44 Use pictures and drawings in physics textbooks to form a better understanding of the topic I am studying.
- G64 Visual presentations make it easier for me to understand physics.

(continues)

APPENDIX 10 (continued)

GSCIREALCONNECTION OF SCIENCE TO REAL LIFE
G42 Science is useful for solving the problems of everyday life.
G43 It is important to know science in order to get a good job.
G45 In my future career I would like to use the science in learned at school.
C52 Physics is relevant to everyday life.
G53 Science is a very good field for creative people to enter.
GDIFINPH DIFFICULTIES IN PHYSICS
G40 Physics is a difficult subject.
G54 There are too many facts to learn in physics.
G56 Physics is difficult when it involves calculations.
G58 Physics is difficult when it involves handling apparatus.
G63 I have difficulties in relating physics to real world.
G67 I often worry that I am not able to learn physics well enough.
GRELTOPH RELATION TO PHYSICS:
G38 Physics is an interesting subject for me.
G39 I find physics challenging.
G46 I am confident that if I try to do my best I can understand physics.
G50 Physics is an enjoyable school subject.
G60 The physics taught at school is interesting.
GRELSCHO RELATION TO SCHOOL AND EDUCATION:
G36 I like school.
G57 I want as much education as I can get.
G59 School is not very enjoyable. (original scale was reversed)
G61 I am bored most of the time in school. (original scale was reversed)
GRELGAS RELATION TO STUDYING GASES:
G68 I find gases and their behaviour as an interesting topic to learn about.
G70 I think it is useful to know more about gases and their behaviour.
G71 Studying gases and their behaviour does not make sense to me. (original scale was reversed)
GPRIKNOW ESTIMATION OF PRIOR KNOWLEDGE ABOUT GASES:
G69 I already know fairly well how gases behave.
G72 I know very little about gases and their behaviour. (original scale was reversed)
Recoded scale for the following aggregated variables:
1(1,00-1,49) strongly disagree
2 (1,50-2,49) disagree
3 (2,50-3,49) uncertain
4 (3,50-4,49) agree
5 (4,50-5,00) strongly agree
GVISREC Visuality in physics (rec)
GSCIREC Connection of science to real life (rec)
GDIFREC Difficulties in physics (rec)
GRELPHRE Relation to physics (rec)
GRESCHRE Relation to school and education (rec)
GREGASRE Relation to studying gases (rec)
GPRIKNRE Estimation of prior knowledge about gases (rec)
Hobbies and activities:
0 no
1 yes
H1 Full- or part time work
H2 Television and video viewing
H3 Radio listening
H4 Collecting
H5 Languages
H6 Writing
H7 Correspondence
H8 Reading
H9 Social life
H10 Shooting sport

(continues)

APPENDIX 10 (continued)

H11 Animal sport
H12 Skiing
H13 Fishing
H14 Combat sport
H15 Sledding
H16 Sport for all
H17 Skating
H18 Ball games with striking implement
H19 Motor sport
H20 Ball games
H21 Games
H22 Traditional sport
H23 Cycling
H24 Dance
H25 Aeronautical sport
H26 Aquatic sport
H27 Recreation
H28 Weight training
H29 Gymnastics
H30 Mountaineering
H31 Track & field
H32 The visual arts
H33 Music
H34 Theatre/acting/self-expression
H35 Fixing and. building cars and motors
H36 Electronics and radio amateur activities
H37 Model building
H38 Handicrafts
H39 Computers
H40 Science hobbies
H41 Other technical hobbies and driving (cars and motorbikes)
H42 Clubs and, coaching
H43 Church
H44 Scouts
H45 Social activities and charity
H46 Computer- and video games
H47 Other hobbies and activities
H48 (FIN) Orienteering

Main hobby categories - aggregated variables (see appendix 16 for details):

SH1 Full or part-time work
SH2 Radio, television, and video
SH3 Collecting
SH4 Reading, languages, and writing
SH5 Social life
SH6 Sports and recreation
SH7 Art hobbies
SH8 Technical hobbies and handicraft
SH9 Community work and social issues
SH10 Other hobbies and activities

Recoded main hobby categories (aggregated):

0 no
1 yes

SH2REC RADIO, TELEVISION, AND VIDEO
SH4REC READING, LANGUAGES, AND WRITING
SH6REC SPORTS AN RECREATION
SH7REC ART HOBBIES
S118REC TECHNICAL HOBBIES AND HANDICRAFT
SH9REC COMMUNITY WORK AND SOCIAL ISSUES

(continues)

APPENDIX 10 (continued)

LEARNING QUESTIONNAIRE:

1 strongly agree
2 agree
3 sort of agree
4 sort of disagree
5 disagree
6 strongly disagree

LI You have a certain amount of intelligence and you really can't do much to change it.
L2 Your intelligence is something about you that you can't change very much.
L3 You can learn new things, but you can't really change your basic intelligence.

0 no 1 yes

L4 Problems that aren't too hard, so I don't get many wrong.
L5 Problems that I'll learn something from, even if they're so hard that I'll get a lot wrong.
L6 Problems that are fairly easy so I'll do well.
L7 Problems that are hard enough to show that I'm smart.

1 very true for me
2 true for me
3 a little true for me
4 a little true for me
5 true for me
6 very true for me

L8 I usually think I'm intelligent - I wonder if I'm intelligent.
L9 I'm not sure I'm smart enough to be successful - Fra pretty sure I'm smart enough to be successful.
L10 when I get new material, I'm usually sure I will be able to learn it - when I get new material, I often think I may not be able to learn it.
L11 I'm not very confident about my intellectual ability - I feel pretty confident about my intellectual ability.

Learning Questionnaire aggregated variables:

SLENTITY Entity - lncremental Intelligence (range: 1,00 - 6,00; high scores= incremental intelligence)
(Dweck & Henderson leave scores between 3.0 and. 4.0 out of analyse; 1,00-3,00 are entity theorists 4,00-6,00 are incremental theorists)

SLGOAL Goal Choice (problem type)
1 Easy performance goal-1
2 Learning goal
3 Easy performance goal-2
4 Challenging performance goal

SLCONFI Confidence in one's intelligence
(theoretical range: 1,00 - 6,00; high scores= high confidence)

ENTITREC Entity-Incremental Intelligence (CIassified)
1 Entity theorist
2 uncertain
3 lncremental theorist

SLGOALRE Goal Choice /Problem Type (Recoded)
1 Easy performance goal
2 Challenging performance goal
3 Learning goal

SLCONFRE Confidence in Intelligence (Categorized)
2 (1,75 - 2,25)
3 (2,50 - 3,25)
4 (3,50 - 4,25)
5 (4,50 - 5,25)
6 (5,50 - 6,00)

LEARNING PROCESS QUESTIONNAIRE:

1 never true
2 probably true
3 sometimes true
4 usually true
5 always true

(continues)

APPENDIX 10 (continued)

LPQ1 I chose my present subjects mainly because of career prospects when I leave school, not because I'm particularly interested in them.
LPQ2 I find that at times my school work can give me a feeling of deep personal satisfaction.
LPQ3 I try to obtain high marks in all my subjects because of the advantage this gives me in competing with others when I leave school.
LPQ4 I tend to study only what's set; I usually don't do anything extra.
LPQ5 While I am studying, I often try to think of how useful the material that I am learning would be in real life.
LPQ6 I regularly take notes from suggested readings and put them with my class notes on a topic.
LPQ7 I am put off by a poor mark on a test and worry about how I will do on the next test.
LPQ8 While I realize that others sometimes know better than I do, I feel I have to say what I think is right.
LPQ9 I have a strong desire, to do best in all of my studies.
LPQ10 I find that the only way to learn many subjects is to memorize them by heart.
LPQl1 In reading new material, I am often reminded of material I already know and see the latter in a new light.
LPQ12 I try to work solidly throughout the term and revise regularly when the exams are close.
LPQ13 Whether I like or not, I can see that studying is for me a good way to get a well-paid or secure job.
LPQ14 I find that many subjects can become very interesting once you get into them.
LPQ15 I like the results of tests to be put up publicly so that I can see by how much I beat some others in the class.
LPQ16 I prefer subjects in which I have to learn just facts to ones which require a lot of reading and understanding of material.
LPQ17 I find that I have to do enough work on a topic so that I can form my own point of view before I am satisfied.
LPQ18 I always try to do all of my assignments as soon as they are given to me.
LPQ19 Even when I have studied hard for a test, I worry that I may not be able to do well on it.
LPQ20 I find that studying some topics can be really exciting.
LPQ21 I would rather be highly successful in school even though this might make me unpopular with some of my class mates.
LPQ22 In most subjects I try to work things so that I do only enough to make sure I pass, and no more.
LPQ23 1 try to relate what I have learned in one subject to what I already know in other subjects.
LPQ24 Soon after a class or lab, I re-read my notes to make sure I can read them and understand them.
LPQ25 I think that teachers shouldn't expect secondary school students to work on topics that are outside the set course.
LPQ26 I feel that I might one day be able to change things in the world that I see now to be wrong.
LPQ27 I will work for top marks in a subject whether or not I like the subject.
LPQ28 I find it better to learn just the facts and details about a topic rather than try to understand all about it.
LPQ29 I find most new topics interesting and often spend extra time trying to find out more about them.
LPQ30 When a test is returned, I go over it carefully correcting all the errors and trying to understand why I made the original mistakes.
LPQ31 I will continue my studies only for as long as necessary to get a good job.
LPQ32 My main aim in life is to find out what to believe in and then to act accordingly.
LPQ33 I see doing well in school as a sort of game, and I play to win.
LPQ34 I don't spend time on learning things that I know won't be asked in the exams.
LPQ35 I spend a great deal of my free time finding out more about interesting topics which have been discussed in different classes.
LPQ36 I usually try to read all the references and things my teacher says we should.

Learning Process Questionnaire aggregated variables:

Next six variables: theoretical range: 6-36; high scores indicate existence of a motive or a strategy
LPQSM Surface Motive
LPQDM Deep Motive
LPQAM Achievement Motive
LPQSS Surface Strategy
LPQDS Deep Strategy
LPSAS Achievement Strategy

Next three variables: theoretical range: 12 - 72; high scores indicate existence of an approach
LPQSA Surface Approach
LPQDA Deep Approach
LPQAA Achieving Approach

Next variable: theoretical range: 24-144; high scores indicate existence of the approach
LPQDAA Deep-Achieving Approach

(continues)

APPENDIX 10 (continued)

	Next six variables:1 (6-10), 2 (11-15), 3 (16-20), 4 (21-25), 5 (26-30)
LPQSMREC	Surface Motive (Categorized)
LPQDMREC	Deep Motive (Categorized)
LPQAMREC	Achieving Motive (Categorized)
LPQSSREC	Surface Strategy (Categorized)
LPQDSREC	Deep Strategy (Categorized)
LPQASREC	Achieving Strategy (Categorized)
	Next three variables: 1 (12-20), 2 (21-30), 3 (31-40), 4 (41-50), 5 (51-60)
LPQSAREC	Surface Approach (Categorized)
LPQDAREC	Deep Approach (Categorized)
LPQAAREC	Achieving Approach (Categorized)
	Next variable: 1 (24-40), 2 (41-60), 3 (61-80), 4 (81-100), 5 (101-120)
LPQDAARE	Deep-Achieving Approach (Categorized)

MULTIPLE CHOICE QUESTIONS 1:

Correct answers are underlined. Please also note that letter (G) in brackets after the variable name indicates that the content deals with gas laws and letter (K) shows the content is about the Kinetic theory of gases. These two groups of variables were used in forming aggregated variables for a number of statistical analyses. Note that only the correct answering alternative is presented. The other alternatives are presented in appendices 6a (English version) and 6b (Finnish version), where the whole questionnaires can be seen.

0 wrong answer or guess
1 correct guess
3 correct answer

M1 **When a small volume of water is boiled, a large volume of steam is produced. Why?**
<u>A The molecules are further apart in steam than in water.</u>

M2 **An iron container is weighted after the air in it has been pumped out (evacuated). Then it is filled with hydrogen gas and weighed again. What is the weight of the container full of hydrogen compared to the weight of the evacuated container?**
<u>B greater</u>

M3 (K) **A jar of oxygen gas and a jar of hydrogen gas are at the same temperature. Which of the following physical quantities has the same value for the molecules of both gases?**
<u>E the average kinetic energy</u>

M4 (G) **The gas laws are valid for real gases, except ...**
<u>D when temperature is low and pressure high</u>

M5 (G) **When pressure is constant the volume of a gas ...**
<u>A varies directly with its Kelvin temperature</u>

M6 (G) **When temperature is constant the volume of a gas ...**
<u>B increases when the pressure decreases</u>

M7 (G) **When volume is kept constant the pressure of a gas ...**
<u>C varies directly with the temperature</u>

M8 **In a simple mercury barometer (see the figure) the mercury in the tube - whose bottom end is open - stays above the level of mercury in the dish. What makes this possible?**
<u>E the weight of the atmosphere</u>

M9 (K) **Which of the following statements is not part of or cannot be derived from the Kinetic Theory of Gases?**
<u>B at low temperatures and under high pressures gases become liquids</u>

M10 (K) **Which of the following statements is not true: At the zero point of Kelvin Scale ...**
<u>E molecular motion would be very slow and non-linear</u>

M11 **A mole ...**
<u>E is the number of molecules in a 22.4 litres of a gas at standard atmospheric pressure and temperature</u>

M12 **Which statement is not true about pressure. Pressure of a gas ...**
<u>E is caused by particles which increase their mass in elastic collisions</u>

M13 (K) **When a gas is heated, its molecules ...**
<u>D start moving faster</u>

M14 (K) **Which of the following statements is wrong. When the temperature of a gas decreases, the molecules of the gas ...**
<u>D start reducing their volume as the Gas laws predict</u>

(continues)

APPENDIX 10 (continued)

MULTIPLE CHOICE QUESTIONS - 2: Variable names are from MM 1 to MM 14. In all other respects these variables are identical with variables M1 - M14 described above.

Multiple Choice Questionnaire Aggregated variables:

MULTI1	Multiple Choice l Total Score (theoretical range: 0-42; 42 represents the best knowledge)
MULTI2	Multiple Choice-2 Total Score (theoretical range: 0-42; 42 represents the best knowledge)
SMGAIN	Multiple Choice Gain Score (range: -9 - 24)
	Next two variables: 1 (0-4 points), 2 (5-9 points), 3 (10-14 points), 4 (15-19 points), 5 (20-24 points), 6 (25-29 points), 7 (30 points or more)
SMULIREC	Multiple-Choice-I Total Score (categorized)
SMUL2REC	Multiple-Choice-2 Total Score (categorized)
	Next variable: 1 (negative scores), 2 (0-4 points), 3 (5-9 points), 4 (15-19 points), 5 (20 points or more)
SMGAINRE	Multiple-Choice Gain Score (CIassified)

from m1re to m14re and from mm1re to mm14re (recoding: 0 = wrong 1 = correct guess or answer)

from mIgain to m14gain (these are item by item gainscores)

GAININDI	SUM OF ALL INDIVIDUAL ITEM GAIN SCORES
GASGAINI	SUM OF INDIVIDUAL GAS LAW ITEM GAIN SCORES (m4gain + m5 gain + m6gain + m7gain)
KINGAINI	SUM OF INDIVIDUAL KINETIC THEORY ITEM GAIN SCORES (m3gain + m9gain + m10gain + m13gain + m14gain)
y 1	INITIAL SUM SCORES OF THE GAS LAWS (m4 + m5 + m6 + m7)
Y2	FINAL SUM SCORES OF THE GAS LAWS (mm4 + mm5 + mm6 + mm7)
GASGAIN	GAIN SCORE OF THE GAS LAWS BASED ON SUM SCORES (y2 - y1)
KI	INITIAL SUM SCORES ON KINETIC THEORY (m3 + m9 + m10 + m13 + m14)
K2	FINAL SUM SCORES ON KINETIC THEORY (mm3 + mm9 + mm13 + mm14)
KINGAIN	GAIN SCORE ON KINETIC THEORY OF GASES BASED ON SUM SCORES (K2 - K1)

TASK PAPERS 1 - 5: (for coding rules see appendix 11)

	Next variables: scale 0 - 6
TASKP1.1	Task Paper 1 - task 1
TASKP1.2	Task Paper 1 - task 2
TASKP2.1	Task Paper 2 - task 1
TASKP2.2	Task Paper 2 - task 2
TASKP3.1	Task Paper 3 - task 1
TASKP3.2	Task Paper 3 - task 2
TASKP4.1	Task Paper 4 - task 1
TASKP4.2	Task Paper 4 - task 2
TASKP5.1	Task Paper 5 - task 1
TASKP5.2	Task Paper 5 - task 2

Task Papers aggregated variables:

SUMTASKP	Sum score from task papers 1 - 5 (all the above 10 single variable values added together)
TASKPGAS	Task Paper (1-4) gas law items
TASKPKIN	Task Paper (5) Kinetic Theory items

CONCEPT MAPS + ESSAYS 1 - 2: (for coding rules see appendix 12)

	Next two variables: 0 (zero level - no knowledge), 2 (diffused organized knowledge), 4 (partially organized knowledge), 8 (highly organized knowledge)
CMAPOS1	CMAP1: Pretest Overall Structure
CMAPOS2	CMAP2: Post-test Overall Structure
CMAPSSC1	CMAP1: Pretest Specific Structure and Coherence (empirical range: 1 - 11)
CMAPSSC2	CMAP2: Post-test Specific Structure and Coherence (empirical range: 3 - 35)
CMAPC1	CMAP1: Pretest Content (empirical range: 1 - 24)
CMAPC2	CMAP2: Post-test Content (empirical range: 4 - 69)
	The following gain scores were calculated by subtracting the pretest scores from the post-test scores for each student
GAINOS	Gain scores for Overall Structure
GAINSSC	Gain scores for Specific Structure and Coherence
GAINC	Gain scores for Content

(continues)

APPENDIX 10 (continued)

Concept maps + essays aggregated variables:
GAINALL3 Sum Gain Scores (for the three variables above)
SMCMTOT1 Pretest CMAP sum score (CMAPOS1+CMAPSSC1+CMAPC1)
SMCMTOT2 Post-test CMAP sum score (CMAPOS2+CMAPSSC2+CMAPC2)
SMCMGAIN Sum score CMAP gain score
EXPERIENCE QUESTIONNAIRE:
1 strongly disagree
2 disagree
3 uncertain
4 agree
5 strongly agree
EXP1 I found gases and their behaviour as an interesting topic to learn about.
EXP2 I already knew fairly well the things we were taught.
EXP3 I think it was useful to learn about gases and their behaviour.
EXP4 Studying gases and their behaviour did not make sense to me.
EXP5 I knew very little about gases and their behaviour before this course.
EXP6 I could clearly see how the physics information in this course was related to real world.
EXP7 I feel confident that I understand the things we studied in the course.
EXP8 I had big difficulties in understanding the things taught in the course.
EXP9 Hours used for studying topics at home.
EXPIO The content of the textbook was interesting.
EXP11 The workbook and task papers had challenging problems and questions.
EXP12 I wish we had more this kind of courses.
EXP13 The content of the questions and problems in the workbook and task papers was interesting to me.
EXP14 The textbook was easy to understand.
EXP15 The video programme really helped me to understand the gas laws.
EXP16 The video programme really helped me to understand the Kinetic Theory of Matter.
EXP17 The structure of the textbook was unclear.
EXP18 The instruction in this course was not different from lessons we usually have in physics.
EXP19 Some questions and problems in the workbook and task papers made me realize I need to know more about the behaviour of gases.
EXP20 The video programme made the lessons more interesting than usual lessons.
EXP21 I could have well understood all the things without the video programme.
Experience Questionnaire - aggregated variables:
Below each of the following aggregated variables there is a list of the single variables used for making it. Note that the sums of single variable values were divided with the number of variables in order to have clearly interpretable value ranges (strongly disagree 1,00 - 5,00 strongly agree)
ERELCOUR EXPERIENCES ABOUT THE COURSE IN GENERAL:
EXPI I found gases and their behaviours as an interesting topic to learn about.
EXP3 I think it was useful to learn about gases and their behaviour.
EXP12 I wish we had more this kind of courses.
EPRIKNOW ESTIMATION OF PRIOR KNOWLEDGE ABOUT GASES (AFTER COURSE):
EXP2 I already knew fairly well the things we were taught.
EXP5 I knew very little about gases and their behaviour before this course. (original scale was reversed)
EEXPVH EXPERIENCES ABOUT THE VII)EO PROGRAMME:
EXP15 The video programme really helped me to understand the gas laws.
EXP16 The video programme really helped me to understand the Kinetic Theory of Matter.
EXP20 The video programme made the lessons more interesting than usual lessons.
EXP21 I could have understood all the things without the video programme. (original scale was reversed)
EEXPWRI EXPERIENCES ABOUT THE WRITTEN MATERIALS:
EXPIO The content of the textbook was interesting.
EXPI 1 The workbook and task papers had challenging problems and questions.
EXP13 The content of the questions and problems in the workbook and task papers was interesting.
EXP14 The textbook was easy to understand.
EXP17 The structure of the textbook was unclear. (original scale was reversed)
EXP19 Some questions and problems in the workbook and task papers made me realize I need to know more about the behaviour of the gases.

(continues)

APPENDIX 10 (continued)

EUNDERST EXPERIENCES ABOUT UNDERSTANDING:
EXP7 I feel confident that I understand the things we studied in the course.
EXP8 I had big difficulties in understanding the things taught in the course. (original scale was reversed)

Recoded scale for the following aggregated variables:
1(1,00-1,49) strongly disagree
2 (1,50-2,49) disagree
3 (2,50-3,49) uncertain
4 (3,50-4,49) agree
5 (4,50-5,00) strongly agree

ERECOURE Experiences about he course in general (rec)
EPRIKNRE Estimation of prior knowledge about gases (after course) (rec)
EEXPVIRE Experience about the video programme (rec)
EEXPWRRE Experiences about the written materials (rec)
EUNDREC Experiences about understanding (rec)

Aggregated and change variables dealing with relation to studying gases:

Scales of the original variables:
1 strongly disagree
2 disagree
3 uncertain
4 agree
5 strongly agree

Single attitude change variables:
CH1 (EXP1 - G68) I found/find gases and their behaviour as an interesting topic to learn about.
CH2 (EXP3 - G70) I think it was/is useful to know more about gases and their behaviour.
CH3 (EXP4 - G71) Studying gases and their behaviour did/does not make sense to me. (original scales were reversed)
SMCH SUM OF SINGLE VARIABLE CHANGES IN RELATION TO STUDYING GASES
SMRELG1 PRETEST RELATION TO STUDYING GASES (AGGREG.):
G68 + G70 + G71 (original scale of G71 was reversed)
SMRELG2 POST-TEST RELATION TO STUDYING GASES (AGGREG.):
EXP1+ EXP3 + EXP4 (original scale of EXP4 was reversed)
CHSMREL CHANGE IN RELATION TO STUDYING GASES (AGGREG.)

APPENDIX 11 RULES FOR CODING EDUCATION AND OCCUPATIONS IN SOME SPECIAL CASES

Exceptions and modifications used with ISCED (International Standard Classification of Education) and ISCO-88 (International Standard Classification of Occupations).

EDUCATION

Description of education by student (Coding for ISCED level of Education in brackets)

- Grade 1 - 6 (1)
- Primary (2)
- Grade 7 - 11 (2)
- Grade 12 - 13 (3)
- Occupation skill level is 2, education is not mentioned, but is most probably at least 3 (e.g. mechanics usually have at least an occupational school completed) (3)
- Trade + commerce (4)
- Occupational title refers to a job requiring more than senior high school, but the exact required level of education is not known (4)
- Unfinished degree that would be level 5 if completed (4)
- 1 - 2 years of university (degree not mentioned) (4)
- College (5)
- Diploma (5) [diploma was used in connection with "draftsman - (architectural)"].
- Technical school + 2 years university (5)
- Over 2 years but under 4 years of university (degree not mentioned) (5)
- Occupational title "teacher" without information on education (5)
- HuK (Finnish equivalent of Bachelor's degree) (6)
- Master of (something)/Master's degree (6)
- 4 years or more of university (degree not mentioned) (6)
- An implication of a completed university degree (6)
- Academic (without a specific label) (6)
- Bachelor of (something) (6)

If education was not mentioned and could not be inferred from the occupational title, education was coded as 9 (missing) (e.g. roofer without mention of education)

OCCUPATION

- With uncertain occupational titles the lower skill level of the two possible/probable ones was used
- If the same person was given two occupational titles that are at different skill levels, the higher one was used
- If the same occupational title was possible through education in two institutions at different levels and there is no specific information regarding the education, the lower educational level was used (e.g. in Finland the level of education of a dental hygienist can be either 3 or 5)
- If there was a contradiction between an occupational title and education, coding was considered separately for each case and the missing information code 9 was used if no other reasonable solution was found
- Student was generally coded as 9 (missing), if education was nearly completed and the coming occupation was given, the coding was made according to the occupational title mentioned (e.g. a student becoming an optician after 3 months)
- If the occupational title was not found in ISCO, but the level of education was 6 and other resembling occupational titles belong to skill level 4, the occupational title was coded as 6

(continues)

APPENDIX 11 (continued)

Occupational title written by a student (coding for ISCO skill level in brackets)

- Mother/ housewife/ house mother
  - education not mentioned or the level is 3 or less (1)
  - education at least 4 (2)
  - if the previous occupation was mentioned, coding was done according to it

- Electrician - without information on education or the level of education 4 or less (2)
- Sales/ salesman/ salesperson/ sales clerk (2)
- Secretary - without indication of the nature of the job (2)
- Teacher’s aid (2)

- Electrician - level of education at least 5 (3)
- Nurse - helper (3)
- Teacher, without information on education (3)
- Safety specialist (3)
- Building contractor (3)

- Engineer (4)
- Social worker (4)
- Businessman/ manager/ inspector/ supervisor/ owner/ entrepreneur etc. without more specific description of the job
  - if level of education was 4 or less (3)
  - if level of education was at least 5 (4)

Occupational titles coded as 9 (missing):
- Psychology
- Unemployed (also when the preceding occupation was mentioned)
- Retired (if the previous occupation was mentioned, coding was done according it)
- Dead/ deceased (also when the previous occupation was mentioned)

APPENDIX 12. RULES FOR CODING TASK PAPERS 1 - 5

Task Paper 1: Rules for scoring tasks related to Boyle's law

The following item was accepted as a correct one:
The equation was not presented, but the notes implied that the correct equation was applied.

Errors and corresponding minus scores:

Type of error	Minus scores
minor calculation error that slightly changed the final result.	1
major calculation error that significantly changed the final result.	2
mistake in copying the initial values (e.g. 0.12MPa written instead of the correct one, 12 Mpa).	1
incorrect unit conversions (e.g. 1000mbar = 100 bar) that resulted in a significant error in the final result.	2
the value of normal atmospheric pressure was incorrect (e.g. 10.13 bar or 101.3 bar) resulting in a significant error in the final result.	2
wrong unit (e.g. kPa instead of dm^3) in the final answer.	2
initial values and substitutions not written.	2

Task Paper 1: Boyle's Law. Scoring in specific cases:

Description of the case	Scores
basic equation and the solution of the unknown member correct, the rest incomplete or wrong.	2
basic equation and the substitutions correct, wrong method in solving of the unknown variable of the equation.	2
problem 2: 0.11MPa converted to 0.110000 Pa resulting in a very significant error in the final result, otherwise OK. (one case)	3
part of the initial values written, and most of the substitutions written implying the correct equation was probably applied, no calculations made. (one case)	2
correct basic equation written, only some or no initial values written, incompletely written substitutions, correct final answer. (two cases)	4
initial situation incorrectly interpreted: atmospheric pressure (1.013 bar) added to the value (2.20 bar) for p_1, otherwise correct.	4

(continues)

APPENDIX 12 (continued)

Task Paper 2: Rules for scoring tasks related to Charles' law

The following items were accepted as correct:
(1) the equation was not presented, but the notes implied the correct equation was applied
(2) substitutions in the equations were not required if the final answer was correct
(3) missing unit in the final answer was not required if it was noted in the substitution

Errors and corresponding minus scores:

Type of error	Minus scores
problem 1: Temperatures not converted to Kelvin scale (critical error).	3
problem 2: Temperatures not converted to Kelvin scale (critical error). Note! In problem 2 there was more material to be solved. Therefore this error - even though critical - was not emphasized as much as in problem 1.	2
wrong value (373) of the Kelvin scale used for 0 Celsius degrees while converting the temperatures; mechanical errors in temperature conversions that significantly changed the final results.	2
problem 2: the volumes of the initial samples were summed up (at the beginning or at the end) and treated as one sample, even though the idea was to consider each sample separately. Because this error had to do with the "laboratory setting" and not with understanding of Charles' Law, it was interpreted as a minor error, thus only 1 minus point. However, if the answer regarding the number and sizes of the bottles was inconsistent with the summed up volume answer (or was completely missing), one extra minus point was given.	1
minor mechanical errors in temperature conversions that did not significantly change the final results.	1
incorrect unit conversions (e.g. 566 cm^3 = 5,7m^3) that resulted in significant errors in the final results.	2
T_1 and T_2 had changed their places while substituting the values. As a result of this the final volume was smaller than the initial one even though the temperature increased. This should have been noticed.	2
incorrect initial value for V_1 was given, causing a considerable change in the final results.	2

(continues)

APPENDIX 12 (continued)

Task Paper 2: Charles' Law. Scoring in specific cases:

Description of the situation	Scores
problem 2: Only the final answer (number and size of bottles) written - even if correct.	0
problem 2: Basic equation correct, temperatures correctly converted and values correctly substituted in the basic equation, but the unknown member in the basic equation not solved.	2
problem 1: totally wrong initial value (200 cm^3 instead of 566 cm^3) used in calculations, otherwise correct. (one case)	4
problem 1: temperature coefficient for gas volume applied, but the volumes were not compared to volumes at 0 °C. (two cases)	2
problem 2: the initial situation incorrectly interpreted: Boyle's law first used for calculating the volume for the gas samples and only then Charles'/Gay-Lussac's law applied. (two cases)	0
problem 2: basic equation correct, V_2 in the equation correctly solved, temperature conversions correct, V_1 incorrectly substituted (instead of the original value for V_1 a value from the list of bottle sizes was used), final answer regarding the size of bottles missing; problem 1 correctly solved.	3
problem 2: basic equation and its solution correct, but volume incorrect - separately calculated - indicating a serious misunderstanding of the described situation.	1

(continues)

APPENDIX 12 (continued)

Task Paper 3: Rules for scoring tasks related to Gay-Lussac's Law

The following items were accepted as correct:
(1) unit was missing in the final result, but present in the substitutions
(2) the equation was not presented, but the notes implied the correct equation was applied
(3) one initial value converted to bars and rounded off using only one decimal

Errors and corresponding minus scores:

Type of error	Minus scores
minor calculation error that slightly changed the final result.	1
major calculation error that significantly changed the final result.	2
writing error (e.g. 14.0 marked as 140).	1
unit of pressure not presented in the substitutions, nor in the final result, OR the following incorrect units were used: cm, mm, and no written answers, such as 400 cm as measured in the height of the mercury.	1
error in order of magnitude (e.g. 1,5 N instead of 1,5kN).	1
problem 1: temperatures not converted to Kelvin scale (critical error).	3
accidental mistake in temperature conversions (the other value correct, small mistake in the other one).	1
one temperature value correctly converted to Kelvin's, the other incorrectly.	1
both temperature values incorrectly converted to Kelvin's.	2
problem 2: temperatures not converted to Kelvin scale (critical error). Note! In problem 2 there was more material to be solved. Therefore this error - even though critical - was not emphasized as much as in problem 1.	2
incorrect unit conversions (e.g. 505 Hgcm = 6731 mbar, 400 Hgcm = 400 kPa) that resulted in a significant error in the final result.	2
wrong value (-30) accidentally used instead of the correct one (-33).	0,5
all the equations missing and no substitutions written.	2
problem 2: unit missing in the final answer (for each phase separately).	1
incorrect unit of pressure used: Pa instead of Hgcm.	1
505 Hgcm marked as 505 mmHg in the equation.	1
problem 2: units omitted in substitutions and in the final result (for both sections of the problem separately).	1
minor mistake in copying the values (e.g. 40.4 dm^3 written instead of the correct one - 40.0dm^3).	0,5

(continues)

APPENDIX 12 (continued)

Task Paper 3: Gay-Lussac's Law. Scoring in specific cases:

Description of the situation	**Scores**
basic equation and the solution of the unknown member correct, the rest incomplete or wrong.	2
basic equation and the substitutions correct, wrong method in solving of the unknown variable of the equation.	2
problem 2: all the other parts correct, except for the value for the p while calculating the force exerted on the door; wrong value (96,5 kPa) used instead of 3,5kPa.	4
problem 2: first section of the problem otherwise correct, except the equation solved for a wrong member (p_1 instead of p_2), the force exerted on the door correctly calculated (using the incorrect value for p obtained from the first section).	4
correct final result (400 Hgcm) incorrectly converted to kilopascals or Torrs; otherwise correct.	5
problem 1: equation correctly solved and calculated, but for wrong member (p_1 instead p_2)..	1
problem 2: instead of one force, two forces (outside and inside) calculated, otherwise correct.	4
problem 2: for <u>each</u> of the two phases, if only the final result was written (even if a correct one).	0,5
inaccurate value (100 kPa) for NTP pressure used for converting Hgcm's to kPa resulting in an error in the final result, otherwise correct.	5
problem 2: the first half OK, pressure difference correctly calculated and F correctly solved from the equation, but two values for pressure used instead of one.	4
otherwise correct, except the unit of the force F was J instead of N.	5

(continues)

APPENDIX 12 (continued)

Task Paper 4: Rules for scoring tasks related to General Gas Law

The following items were accepted as correct:
(1) unit was missing in the final result (if otherwise correct and the units were present in the substitutions), J/m^3 accepted as well
(2) the equation was not presented, but the notes implied the correct equation was applied

Errors and corresponding minus scores:

Type of error	Minus scores
minor calculation error that slightly changed the final result.	1
major calculation error that significantly changed the final result.	2
mistake in copying the initial values (e.g. correct=0.020m^3, marked=0.20m^3), also: value 6,31 used instead of the correct one, 8,31 J/mol K.	1
incorrect unit conversions (e.g. problem one the final result was marked as 1,22 Pa) that resulted in a significant error in the final result.	2
correct unit (Pa) used in the calculation result, incorrect conversion to Mpa/kPa in the final answer.	1
units not marked in the substitutions and not in the final result; otherwise correct. Equation pV=RT used and the units not cancelled in the substitutions, and not presented in the final answer. If the unit was marked with a question mark, interpretation was that unit is missing.	2
problem 2: correct basic equation, correct initial values written, equation correctly solved and correct substitutions to the basic (not the solved) equation including the units; no calculations.	2
incorrect unit used in the final result (m^3 instead of Pa).	2
value for p_1 used also for p_2.	2
all other stages correct, except V_1 and V_2 mixed in the initial values.	3
wrong value (293K) used instead of the correct one (294K).	0,5

(continues)

APPENDIX 12 (continued)

Task Paper 4: General Gas Law. Scoring in specific cases:

Description of the situation	Scores
basic equation and the solution of the unknown member correct, the rest incomplete or wrong.	2
basic equation and the substitutions correct, wrong method in solving of the unknown variable of the equation, calculations OK..	3
problem 1: equation correctly solved and calculated, but for wrong member (p_1 instead p_2).	2
basic equation and initial values correct.	2
only the final answer (correct one) written.	1
one substitution missing, otherwise correct.	3
one inital value missing, equation correctly solved and substitutions are made, no calculations.	3
problem 2: value for V_1 obtained by adding up the values V_1 and V_2 (a serious misinterpretation of the initial situation), otherwise correct. (a few cases).	3
mole mass (M) used instead of mole (n), basic equation OK, substitutions OK, except the incorrect M, correct unit in the calculation result, incorrect unit conversion in the final answer.	2
problem 2: correct basic equation, correct initial values written, equation correctly solved and correct substitutions to the basic (not the solved) equation including the units, no calculations. (a few cases)	4
basic equation, solving of the unknown member OK, substitutions OK, but without units, no calculations made.	4

(continues)

APPENDIX 12 (continued)

Task Paper 5: Rules for scoring tasks related to real gases and the Kinetic Theory of Gases

Prototype answers and their scoring: Task 1 (Maximum points = 6)

Why does the behavior of a highly compressed real gas deviate considerably from that of an ideal gas?

A) *As the pressure increases* and the particles approach each other, the forces of attraction between the particles draw the particles together. At this point, the volume shrinks faster than the gas laws predict. (scoring: 3 points if only this item A is mentioned)

B) *If the pressure continues to increase*, the actual volume of gas particles begins to make up a larger part of the total gas volume: it is more and more difficult to compress the gas. Therefore, when the pressure is increased by a large amount, the volume shrinks more slowly than the gas laws predict. (scoring: 6 points if this item B is mentioned; no extra points from point A if item B is mentioned)

Exception: If a respondent has described the phase changes (from a gaseous state to a liquid state and finally to a solid state) caused by an increased pressure, 2 points were given supposing that the phase changes were explained using a molecular explanation.

Prototype answers and their scoring: Task 2 (Maximum points = 6)

A rigid container has n molecules of gas A in it. An equal number of molecules of gas B is then introduced into it. If average kinetic energies of the molecules in the two gases were equal before the gases were mixed, what change, if any, has taken place in (A) temperature; (B) the pressure inside the container. Explain.

A) The temperature remains the same (scoring: 1 point for this statement), because the kinetic energy of the gases was the same before mixing. Therefore, the kinetic energy remains the same also after mixing. (scoring: 2 point for this explanation)

B) The pressure doubles (scoring: 1 point for this statement) because the number of gas molecules doubles and the volume remains the same. Accordingly, collisions of the gas molecules with the walls of the container double, as well. (scoring: 2 point for this explanation)

(continues)

APPENDIX 12 (continued)

Samples of students' answers and their scoring:

For each sample answer, an original Finnish answer and corresponding English translation are given. The Finnish answer is in *italics.*

Task 1:

Example 1) *Molekyylit lähenevät toisiaan ja niiden väliset vetovoimat vetävät molekyylit yhteen tällöin tilavuus alkaa pienentyä oletettua nopeammin*. (2 points) **Translation**: Molecules approach each other and the attraction forces between them draw the molecules together and the volume starts decreasing faster than expected.

Example 2) *Siinä kaasumolekyylit siirtyvät lähemmäksi toisiaan ja niiden välinen vetovoima alkaa kasvaa. Silloin kaasun tilavuus pienenee enemmän kuin ideaalikaasun, ja ne jopa muuttuvat nesteeksi tai kiinteäksi, jos lämpötila on tarpeeksi pieni*. (4 points). **Translation**: There the gas molecules move closer to each other and the attraction force between them starts increasing. Then the volume of a gas decreases more than that of the ideal gas, and they even change into a liquid or into a solid form if the temperature is low enough.

Example 3) *Ideaalikaasu noudattaa Boylen lakia* $V_1/V_2 = p_2/p_1$*, jossa tilavuus on kääntäen verrannollinen paineeseen lämpötilan ollessa vakio. Kun paine kasvaa kaasumolekyylit vievät vähitellen yhä suuremman osan kaasun kokonaistilavuudesta ja sitä on yhä vaikeampi puristaa kokoon. Tilavuus pienenee hitaammin*. (6 points) **Translation**: An ideal gas follows Boyle's law $V_1/V_2 = p_2/p_1$ where the volume varies inversely with the pressure, temperature being constant. When the pressure increases the gas molecules take gradually a larger part of the total volume of the gas and it is increasingly difficult to compress it. The volume decreases more slowly.

Task 2:

Example 1): Question a) *Lämpötila nousee, koska kineettistä energiaa tulee lisää molekyylien lisääntyessä* (0 points). **Translation**: The temperature increases because more kinetic energy comes as the molecules multiply. **Question b)** *Paine suurenee koska tilavuus on sama ja säiliöön laitetaan lisää kaasua*. (2 points). **Translation**: The pressure increases because the volume is the same and more gas is added into the container.

(continues)

APPENDIX 12 (continued)

Example 2): Question a) *Lämpötila ei nouse, koska kaasujen keskimääräiset kineettiset energiat ovat samat*. (3 points). **Translation**: The temperature does not increase because the average kinetic energies of the gases are the same. **Question b)** *Paine nousee, koska säiliössä on enemmän molekyylejä ja molekyylit törmäilevät siksi useammin säiliön seinämiin*. (2 points). **Translation**: The pressure increases because there are more molecules in the container and therefore the molecules collide with the walls of the container more frequently.

Example 3): Question a) *Lämpötila pysyy samana, koska kaasujen kineettinen energia on sama*. (3 points) **Translation**: The temperature remains the same, because the kinetic energy of the gases is the same. **Question b)** *Paine kasvaa kaksinkertaiseksi, koska molekyylien määrä kaksinkertaistuu vakiotilavuudessa*. (3 points) **Translation**: The pressure doubles, because the number of molecules doubles in a constant volume.

APPENDIX 13 RULES FOR CODING CONCEPT MAPS + ESSAYS

(A) Concept Maps + Essays : Scores for Overall Structure (OS)

The following three levels of prior knowledge (see Langer, 1980) supplemented by an additional "zero level" were used in scoring the overall structure of students' concept maps:

(0) *"Zero level"*. At this level learners do not provide any notions whatsoever or all the notions are irrelevant or false (0 points given)

(1) *Diffused organized knowledge* (lowest level). At this level learners can only report personal experience or tangential cognitive links. (2 points given). *Application in the present study:* presentations not meeting the minimum requirements of the next level (partially organized knowledge) and exceeding the zero level were given two points.

(2) *Partially organized knowledge*. At this level learners can provide examples of a concept and define it in terms of its main characteristics. (4 points given). *Application in the present study:* Minimum requirements: Molecular structure of gases was identified and a notion was presented indicating that gas behaviour can be defined by temperature, volume and pressure, all of which are interdependent + at least some of the gas laws were presented. Four point were given also if all the gas laws and the definition of an ideal gas (a gas that behaves according to Boyle's law at all temperatures and pressures) were well presented. If the molecular nature of gases was correctly noted in the essay but not included in the concept map, a maximum of four points was given. Note that if the presentation of the molecular structure of gases/Kinetic theory of gases contained serious errors (e.g. "At high temperatures particles move closer to each other"), only two points were given.

(3) *Highly organized knowledge*. At this level elaborations of the concept are provided to its superordinate and related concepts, and the concept is defined precisely. (8 points given). *Application in the present study:* A minimum requirement for 8 points is that both the gas laws and the Kinetic theory of gases are correctly and widely explained and a connection between the Kinetic theory and the gas laws was indicated.

Note that only papers with both the concept map and the essay in both measurement phases (1 and 2) were included in the final analyses. There were 13 missing concept maps in Concept Map + Essay 1 and 7 in Concept Map + Essay 2.

Examples of students' concept maps + essays for each level (category) are given below:

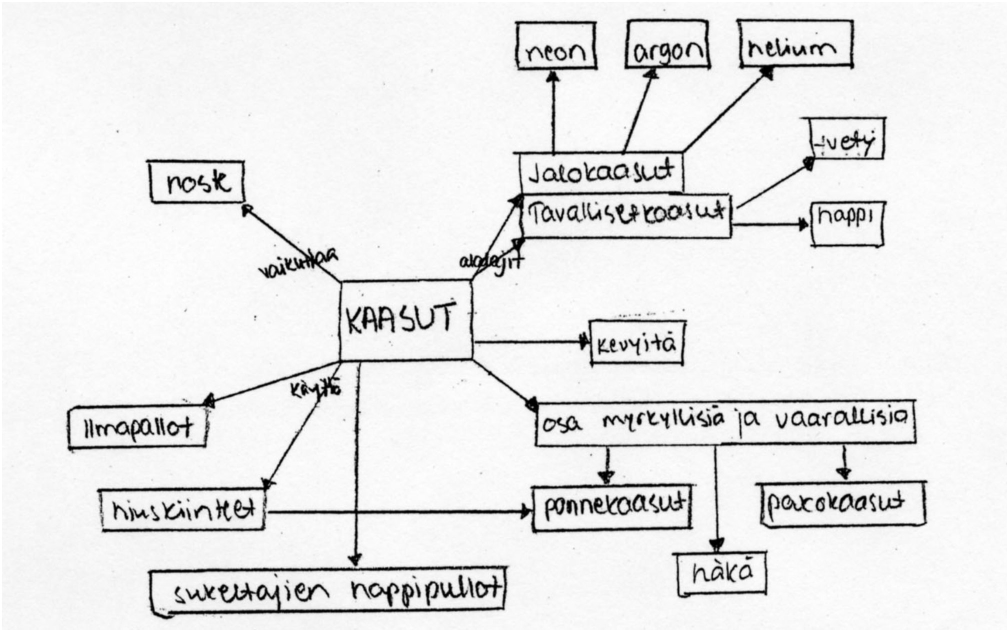
"Zero level" (0 points)

(There were no concept maps which were given zero points)

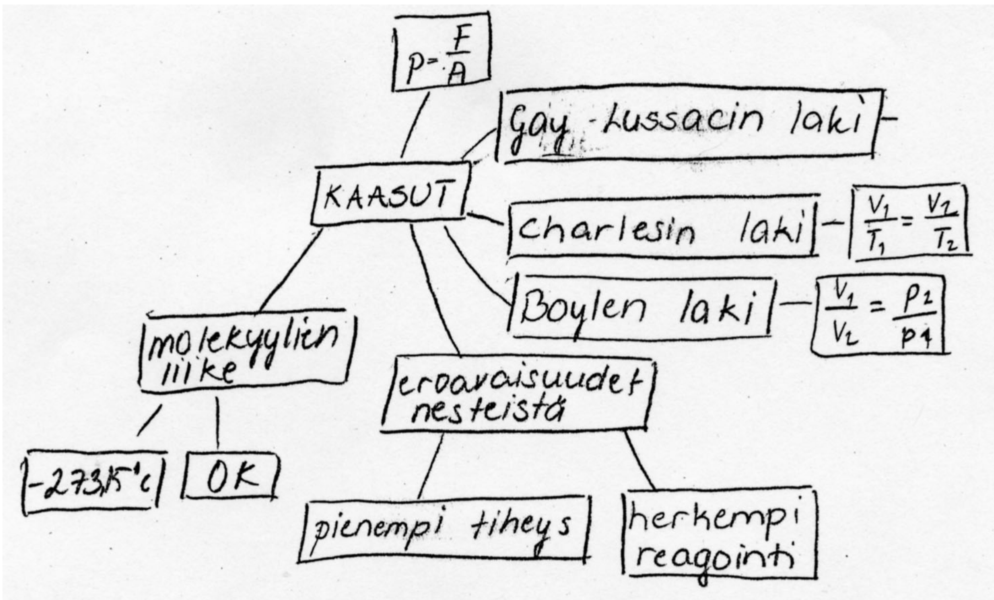
(continues)

APPENDIX 13 (continued)

Diffused organized knowledge (2 points)



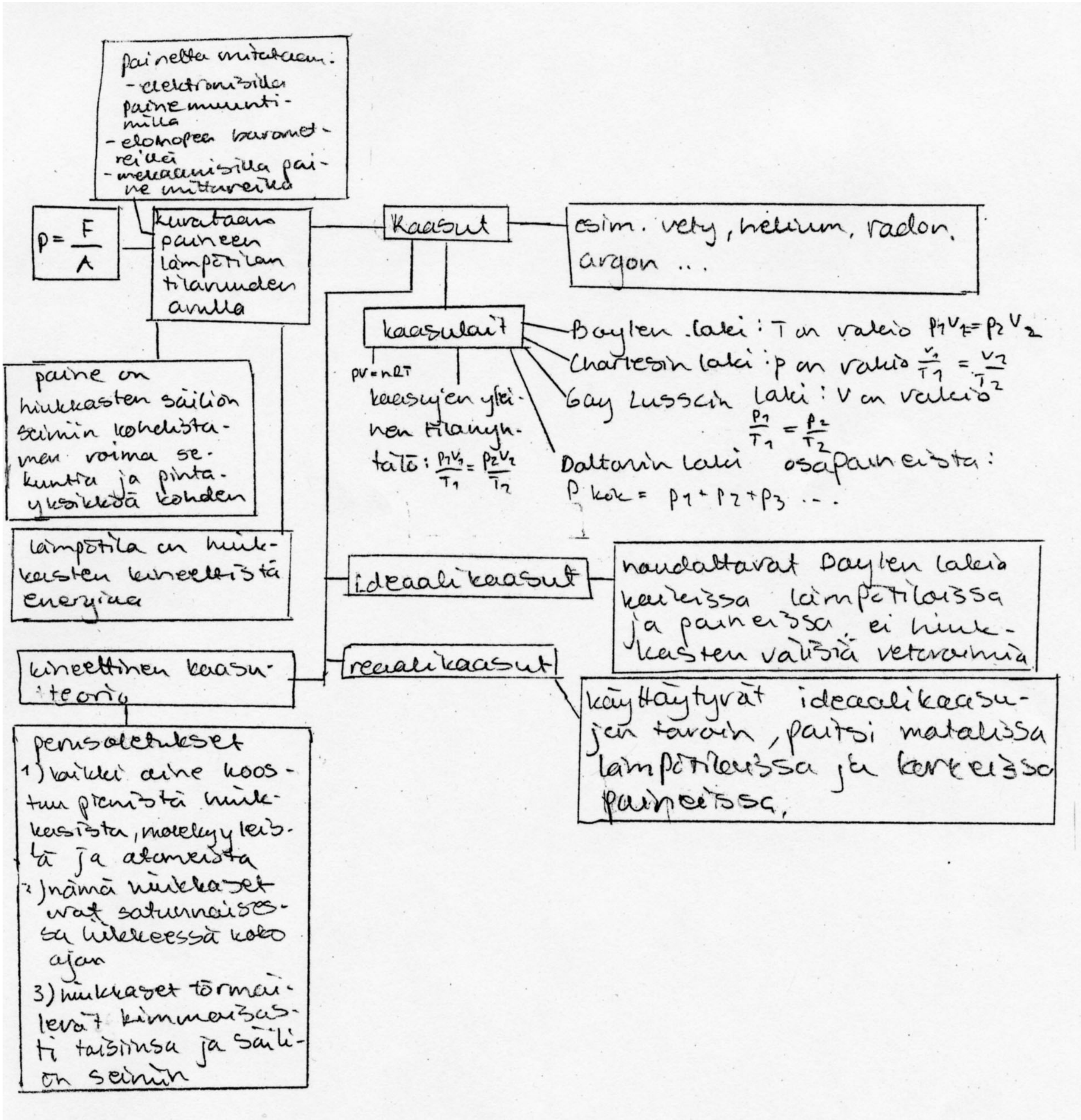
Partially organized knowledge (4 points)



(continues)

APPENDIX 13 (continued)

Highly organized knowledge (8 points)



APPENDIX 13 (continued)

(B) Concept Maps + Essays: Scores for Specific Structure and Coherence (SSC)

The following ideas developed by Cronin et. al. (1982, 29) were used in giving scores for specific structure and coherence of students' concept maps + essays. The final score was obtained as follows: The individual scores were added together and the sum was rounded to the nearest larger whole number. Note that one of the criteria applied by Cronin et al., "hierarchy" was omitted from the table below; it was not used in this study because the hierarchy in students' concept maps was not as specified as needed for scoring it according to the system developed by Cronin et al. Note that the concept maps and essays were evaluated together with the main emphasis being on the concept map. While scoring the Specific Structure and Coherence only scientific concepts and statements were accepted. Therefore, general remarks concerning the application of gases in real life and general notions on "observable" features of gases, such as odour and lightness, were not given any scores. These notions were taken into consideration while scoring the Content - see scoring criteria for content later in this appendix.

Criteria	**Definition**	**Scoring Procedure**
Concept Recognition (CR)	Concepts are objects, events, situations or properties of things that are designated by a label or symbol	*Original*: Count all concepts that are connected to other concepts by propositions. Score 1 point for each concept. *Application in this study*: 1 point for each scientific concept or equation <u>used in a relevant context</u> in a manner that shows a respondent has understood the meaning of it . Note that even if the name of the concept was correct, but it was incorrectly explained in the essay , no points were given. Scores were given also for concepts presented in the essay.
Grouping (G)	Groupings are the ways concepts can be linked or joined together. The three types of groupings are: Point grouping: a number of single concepts emanate from one concept. Open grouping: Three or more concepts are linked in a single chain. Closed grouping: Concepts from a closed system are linked together. *Application in this study*: Note that the concepts used in the groupings must be scientific concepts not just notions of separate characteristics of gases, such as "invisible" or "light".	*Original* scoring of groupings: Point grouping: 1 point for each concept in the group. Open grouping: 2 points for each concept in the group. Closed groupings: 3 points for each concept in the group. *Application in this study*: one point for each grouping that forms a logical entity consisting of scientific concepts/statements; two points for each relevant link indicated - and explained - between these groupings. Note that only groupings in the concept map were accepted.

(continues)

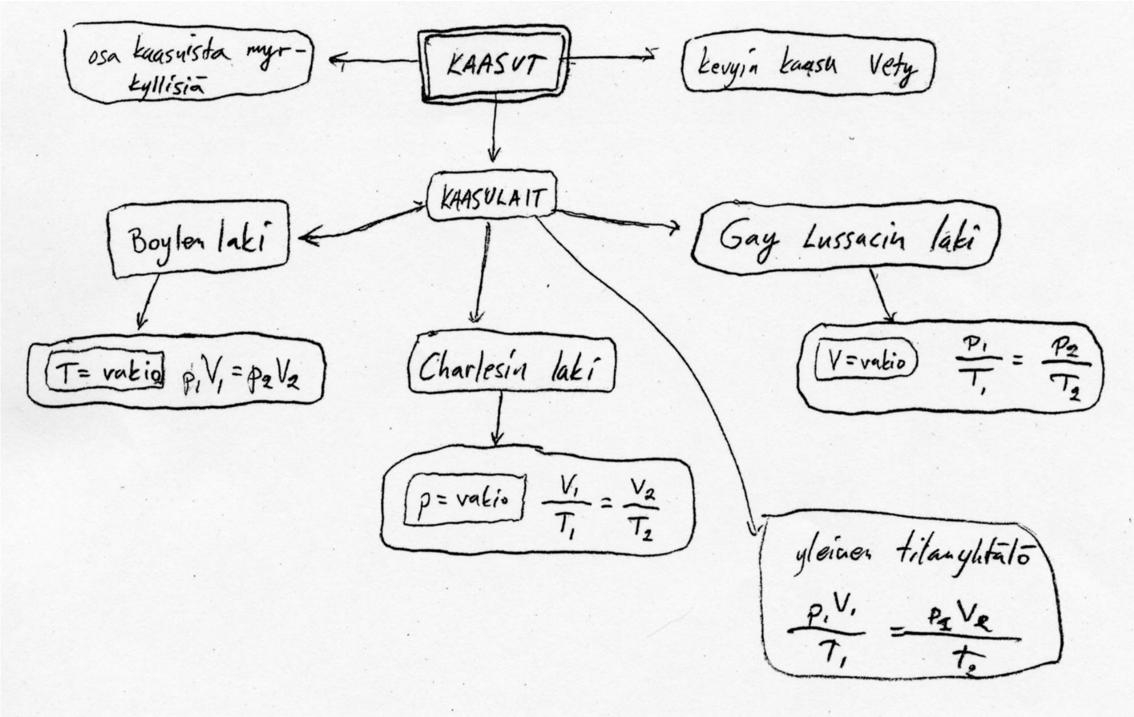
Bran-ching (B)	Branching of concepts refers to the level of differentiation among concepts, that is, the extent the more specific concepts are connected to more general con-cepts.	Score one point for each branching point which has at least two statement lines. *Appli-cation in this study*: one point given for each branching point where a connection between a general and a specific concept is correctly indicated by lines. Note that scores were given only if the branching was pre-sented in the concept map. Also a branching point between the ideal/general gas law and more specific gas laws was accepted.
Proposi-tion (P)	Concepts acquire meaning thro-ugh the relationships between concepts. The relationships are represented by connecting word(s)/phrases written on the line joining any two concepts. Simple proposition is a simple English [Finnish] word or phrase. Scientific propositions. This is a phrase or statement that is com-posed of technical or scientific word(s).	Simple propositions score one point for each word or phrase; give half a point for repeated use of simple propositions. *Applica-tion in this study*: half a point given for each simple proposition used in a relevant con-text. Scientific propositions score two points for each proposition; give one point for repeated use of scientific propositions. *Ap-plication in this study*: one point given for each scientific proposition used in a relevant context. Note that propositions must be presented in the concept map (using a line and an ex-planation) or both in the concept map (using a line) and in the essay (explanation)

Exceptions and special situations: *Concept Recognition*: each name of a gas or a mixture of gases was given one point - a maximum score for naming gases was 3. Each name of a gas law scored 1 point and 2 points were given for each gas law if also the equation or verbal explanation was presented. 1 point was given for each gas law equation (without name) derived from the Combined gas laws. Temperature, pressure, and volume each scored 1 point only if their interdependence was noted either in the concept map or in the essay. *Proposition:* a graphic presentation of 3 phases of gas, where temperature and pressure explain the phase changes, was also accepted and points were given for correct propositions.

(continues)

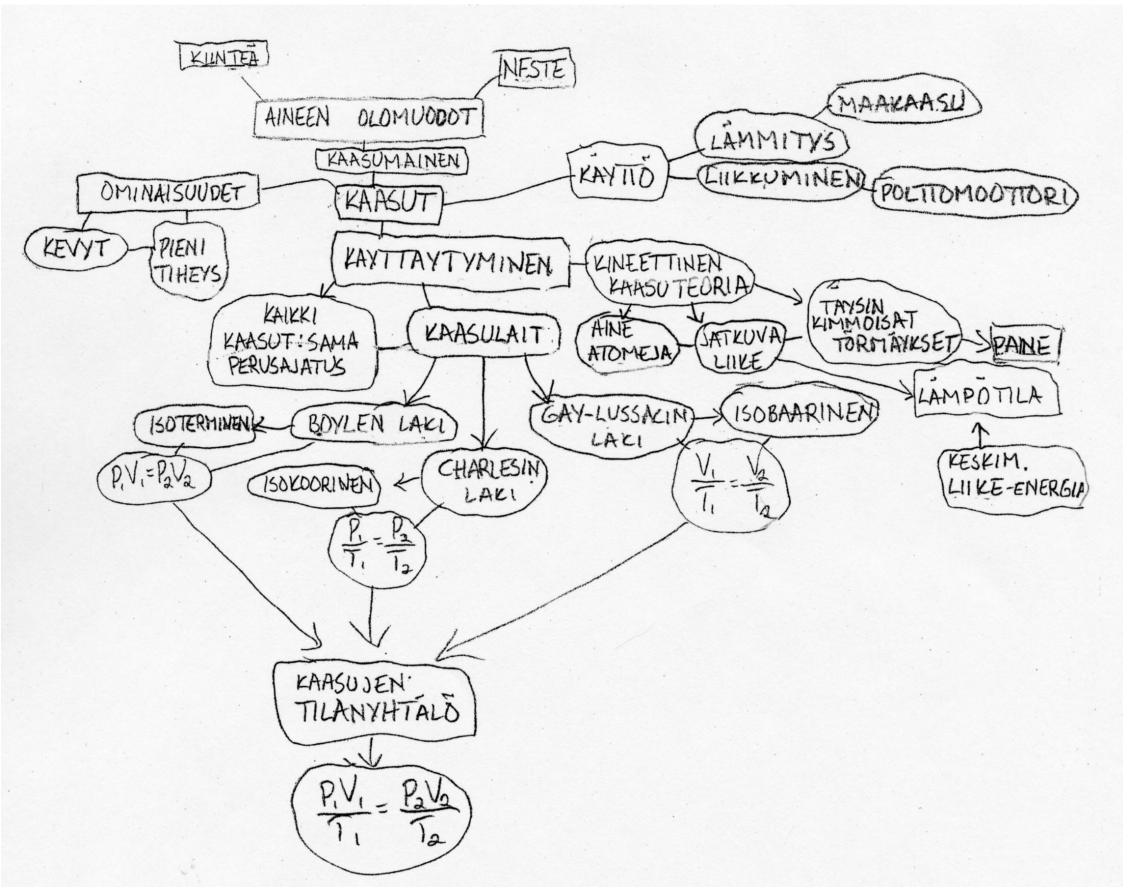
APPENDIX 13 (continued)

Example 1 of Scores for Specific Structure and Coherence (SSC): 11 points



APPENDIX 13 (continued)

Example 2 of Scores for Specific Structure and Coherence (SSC): 21 points



(continues)

APPENDIX 13 (continued)

(C) Concept Maps + Essays: Scores for Content (C)

The following category of topics (from A to L) was drawn from the "textbook" used by students during the teaching period. The topics were categorised by the researcher. The listing was given to five physics teachers working in senior high schools in Jyväskylä, Finland. The teachers were asked to determine how important/essential they consider each topic to be in senior high school physics using a 1-6 scale, where 1 is the most important and 6 is the least important; 0 stands for "no scores were given". Topic L "Other relevant notions of gases and their behaviour" was not scored by the teachers; it was included as a category for possible miscellaneous aspects presented by the students. The original scores given by teachers are in brackets. Based on these scores the researcher calculated average "importance scores" for each topic in the category; note that the score 0 was not used in calculating the average. Finally, the scores were reversed (1=6, 2=5, 3=4, 4=3, 5=2, 6=1) and categories E "Combined Gas Law / Ideal Gas Law" 1and G "Kinetic Theory of Gases" were given score 6 by the researcher, even though these scores slightly differed from the ones given by some of the teachers. These two categories were considered to be the most essential ones and therefore they were given the highest score. ***The final score was used as a coefficient (****referred to as final coefficient below****) to multiply the sum of individual points students were given for presenting each relevant notion under each category of the topics*** (A - L). Notions both in concept maps and essays were taken into consideration. If a notion was correct, but incomplete or vague, 0.5 point was given.

A. Differences compared to liquids and solids

(3,3,5,5,0; mean= 4) final coefficient = **3**

- gases move more easily and expand without forming a definite shape or boundary
- gases (while in equilibrium) exert the same pressure everywhere in the gas
- gases have lower density than other forms of matter

B. 11 gaseous elements in the Periodic Table of Elements

(4,4,5,6,0; mean= 4,75) final coefficient = **2**

- 1 point was given for each correct name of gases or mixture of gases, such as butane. A maximum of 5 points was given even when more than five gas names were mentioned. 2 points were given for a notion that the Periodic Table of Elements contains 11 gaseous elements.

C. The condition of a gas can be described using three quantities:

(1,2,2,3,4; mean= 2,4) final coefficient = **5**

- pressure (p), volume (V), and temperature (T)
- One point was given if all the three quantities were mentioned, thus - given the coefficient - the total score was 5; one point was taken off the total score if the volume was not mentioned.

D. The empirically detected gas laws describe and predict how gases behave as these quantities vary

(2,2,2,2,4; mean= 2,4) final coefficient = **5**

Each of the following gas laws was given one point:

- T is constant -> Boyle's (and Mariotte's) Law $V_1p_1=V_2p_2$ (or other form of the equation or verbal or graphical description of the law)
- p is constant -> Charles'/Gay-Lussac's Law $V_1T_2=V_2T_1$ (or other form of the equation or verbal or graphical description of the law)
- V is constant ->"Third gas law"/Gay-Lussac's Law $p_1T_2=p_2T_1$ (or other form of the equation or verbal or graphical description of the law)

(continues)

APPENDIX 13 (continued)

Exceptions here: In the following cases no coefficients were used. 2 points were given for each name of a gas law, and 1 point per gas law was given if the presentation included an incorrect explanation of the relations of temperature, pressure and volume. Equation or verbal explanation of a gas law (without a name) scored 3 points if the constant (P, V or T) was noted and 2 points if the constant was not noted. If the Combined gas law was fully presented and it was explained that the other gas laws can be derived from it, each name of the single gas laws was given 3 points provided that the correct constant (T, P, or V) was noted in each case.

These specific gas laws can be derived from ....

E. Combined Gas Law / Ideal Gas Law

(1,1,2,2,3; mean=1,8) final coefficient = **6**

One point was given for either the combined gas law or the ideal gas law:

- pV=cT (or pV=RT)
- pV=nRT (describes interrelations among volume, pressure, temperature, and the number of moles of a gas)

  Note that if the ideal gas law was presented and it was clearly indicated that the individual gas laws, such as Boyle's law, can be derived from the ideal gas law, a total of 21 points were given and the coefficient was not used.

Exceptions here: In the following cases no coefficients were used. 2 points were given for a correct name and 3 points for an equation without the name.

F. Dalton's Law of Partial Pressures (for a mixture of non-reacting gases)

(3,3,4,5,0; mean=3,75) final coefficient = **3**

- $p_{total} = p_1 + p_2 + p_3 + \cdots p_n$

Exception here: In the following case the coefficients was not used. 1 point was given if only the name was presented.

G. Kinetic Theory of Gases

(1,1,1,3,4; mean= 2) final coefficient = **6**

- relevant historical aspects of the development of the Kinetic Theory of Gases

  One point given for each of the following notions related to the basic assumptions of the Kinetic Theory of Gases:
- all matter is made of small particles (molecules, atoms); particles are in constant, rapid, linear, random motion.
- higher temperature -> more rapid motion
- particles experience elastic collisions (with each other and the walls of the container), where the momentum and kinetic energy of the particles is conserved

H. Molecular explanation of temperature and pressure

(1,3,3,4,5,; mean=3,2) final coefficient = **4**

One point given for each of the following two notions:

- temperature is a measure of the average kinetic energy of the molecules
- pressure is a measure of the momentum exchange of the particles with the sides of the container per second per unit area - ... the force exerted by the particles on a unit area of surface

I. Differences between real gases and the Ideal gas

(1,2,3,3,6; mean=3) final coefficient = **4**

One point given for each of the following three notions:

- in normal conditions (NTP) most real gases behave like the ideal gas, which is defined as a gas that obeys Boyle's law at all temperatures and pressures. differences appear at low temperatures and high pressures, because ...at low temperatures gas molecules move slower
- under high pressures gas molecules move closer to each other ->attraction forces increase, and volume shrinks faster than the gas laws predict
- under very high pressures molecules make up a larger part of the total gas volume -> volume shrinks more slowly than the ideal gas law predicts

(continues)

APPENDIX 13 (continued)

J. The phase behaviour of real gases

(3,4,4,5,0; mean=4) final coefficient = **3**

One point given for each of the following three notions:

- each real gas changes to a liquid phase and eventually into a solid phase at certain combinations of low temperatures and high pressures
- these combinations of low temperatures and high pressures are specific for each real gas
- other relevant notions of the phase behaviour of real gases, such as a description of the critical point

K. Research and utilization of gases

(5,5,6,6,0; mean= 5,5,) final coefficient = **1**

- One point for each relevant notion regarding research and utilization of gases

L. Other relevant notions of gases and their behaviour

Coefficient = **1**

(each case determined separately)

APPENDIX 14 RULES USED IN CODING NUMERIC ANSWERS IN SOME QUESTIONNAIRES

GENERAL QUESTIONNAIRE

Variable 012 Working during school term (in hours a week) - coding rules:
(1) This variable included only one exception where a coding rule had to be used: 15 - 20, where a mean was calculated and brought up to the nearest whole number, 18 in this case.

Variable 015 How many hours do you usually sleep a day? - coding rules:
(1) in case of two consecutive numbers (e.g. 8 - 9) the larger was used (9 in this example) (e.g. 2: if 6.5 - 7, then 7 is used)
(2) in case of one fraction or a decimal number (e.g. 7.5) the nearest larger whole number is used (8 in this example)
(3) in case of two whole numbers with one whole number between them (e.g. 7 - 9) the mean is calculated = the whole number between two numbers is used (8 in this example)

All the other answers included just one whole number.

EXPERIENCE QUESTIONNAIRE

Variable 010 Did you study the topics of the course at home? (In hours) coding rules:
(1) in case of one fraction or a decimal number (e.g. 0.5) the nearest larger whole number is used (1 in this example)
(2) one answer was written 1/4 hours/each day, this was coded to 1 hour.

APPENDIX 15 Inter-correlations of the LPQ-items for factor analysis

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1	1,00	-,018	,104	,021	-,050	,014	,151	,008	,013	,223	-,097	,044	,192	-,041	,017	,123	-,054	-,008	,129	-,095	,064	,014	-,113	,034	,087	-,007	,168	,175	-,077	,005	,139	,002	,040	,203	-,057	,066
2	-,018	1,000	,141	-,250	,059	,111	,052	,019	,226	-,061	,185	,236	,197	,342	-,031	-,147	,216	,110	,094	,442	,238	-,231	,201	,171	-,201	,226	,171	-,154	,277	,181	-,242	,115	,109	-,282	,270	,277
3	,104	,141	1,000	,100	-,027	,096	,062	,038	,192	,108	,080	,250	,214	,065	,101	-,055	,033	,086	,082	,108	,235	-,202	,116	,074	-,003	,064	,389	-,024	,046	,261	-,009	,016	,288	,034	,079	,175
4	,021	-,250	,100	1,000	-,072	-,193	,066	,029	-,145	,141	-,153	-,121	-,037	-,178	,101	,124	-,203	-,090	,013	-,243	-,009	,189	-,259	-,276	,241	-,167	,024	,123	-,308	-,062	,279	-,075	,003	,329	-,243	-,111
5	-,050	,059	-,027	-,072	1,000	,132	,128	-,012	-,005	-,051	,186	,000	,124	,073	,066	,015	,081	-,063	,015	,162	,100	-,020	,141	,026	-,017	,091	-,032	,011	,109	,116	-,039	,116	-,025	,027	,109	-,015
6	,014	,111	,096	-,193	,132	1,000	,107	,035	,206	,121	,201	,203	-,006	,056	-,029	,071	,169	,159	,120	,030	,105	-,110	,244	,360	-,128	,212	,148	,060	,253	,203	-,147	,084	,147	-,045	,283	,245
7	,151	,052	,062	,066	,128	,107	1,000	-,004	,036	,151	-,059	,007	,079	-,024	,033	,036	-,049	,012	,373	-,005	,094	,065	-,164	,110	,040	,075	,112	,173	,025	,073	,070	,016	,075	,115	,093	,077
8	,008	,019	,038	,029	-,012	,035	-,004	1,000	-,054	,081	,024	-,094	,002	,028	,099	,011	,126	-,069	,058	-,031	,039	,125	,115	-,056	-,042	,122	-,021	-,045	,093	-,008	,035	,113	,047	-,029	,062	-,101
9	,013	,226	,192	-,145	-,005	,206	,036	-,054	1,000	,125	,230	,442	,266	,152	-,097	-,140	,246	,288	,036	,218	,248	-,367	,124	,319	,006	,191	,437	-,004	,206	,226	-,084	,024	,255	-,217	,195	,298
10	,223	-,061	,108	,141	-,051	,121	,151	,081	,125	1,000	-,121	,111	,068	-,101	,147	,205	-,010	,225	,190	-,197	-,010	,133	-,144	,072	,037	,038	,260	,340	-,042	,018	,166	,087	,158	,040	,086	,139
11	-,097	,185	,080	-,153	,186	,201	-,059	,024	,230	-,121	1,000	,237	,110	,259	-,080	-,191	,286	,067	,014	,270	,185	-,158	,455	,285	-,118	,256	,147	-,205	,261	,238	-,180	,119	,143	-,193	,179	,128
12	,044	,236	,250	-,121	,000	,203	,007	-,094	,442	,111	,237	1,000	,273	,140	-,074	-,176	,142	,361	,118	,201	,132	-,315	,111	,286	-,043	,108	,448	-,096	,221	,251	,013	,045	,212	-,119	,124	,299
13	,192	,197	,214	-,037	,124	-,006	,079	,002	,266	,068	,110	,273	1,000	,146	,007	-,040	,081	,062	,130	,175	,191	-,130	,102	,148	-,023	,185	,238	-,020	,084	,219	,098	,042	,183	-,085	,042	,122
14	-,041	,342	,065	-,178	,073	,056	-,024	,028	,152	-,101	,259	,140	,146	1,000	-,071	-,162	,211	,026	,049	,514	,146	-,123	,175	,095	-,174	,258	,072	-,159	,412	,072	-,120	,197	,062	-,168	,188	,141
15	,017	-,031	,101	,101	,066	-,029	,033	,099	-,097	,147	-,080	-,074	,007	-,071	1,000	,169	-,081	-,061	-,059	-,090	,063	,177	,012	-,152	,143	-,014	-,029	,147	-,016	-,058	,114	-,036	,167	,152	-,009	,054
16	,123	-,147	-,055	,124	,015	,071	,036	,011	-,140	,205	-,191	-,176	-,040	-,162	,169	1,000	-,167	,030	,113	-,184	-,021	,196	-,072	-,076	,179	-,142	-,104	,274	-,121	-,108	,171	-,073	,041	,192	-,078	-,080
17	-,054	,216	,033	-,203	,081	,169	-,049	,126	,246	-,010	,286	,142	,081	,211	-,081	-,167	1,000	,156	,007	,184	,127	-,118	,256	,225	-,149	,337	,086	-,211	,318	,231	-,136	,187	,094	-,224	,229	,111
18	-,008	,110	,086	-,090	-,063	,159	,012	-,069	,288	,225	,067	,361	,062	,026	-,061	,030	,156	1,000	,108	,001	,007	-,091	,105	,267	,028	,130	,278	,076	,120	,160	-,057	,117	,186	-,121	,223	,339
19	,129	,094	,082	,013	,015	,120	,373	,058	,036	,190	,014	,118	,130	,049	-,059	,113	,007	,108	1,000	,011	,099	-,002	,001	,183	,017	,019	,237	,123	,067	,076	,097	,077	,115	,038	,098	,178
20	-,095	,442	,108	-,243	,162	,030	-,005	-,031	,218	-,197	,270	,201	,175	,514	-,090	-,184	,184	,001	,011	1,000	,131	-,083	,248	,076	-,146	,227	,080	-,216	,374	,180	-,137	,114	,027	-,256	,211	,111
21	,064	,238	,235	-,009	,100	,105	,094	,039	,248	-,010	,185	,132	,191	,146	,063	-,021	,127	,007	,099	,131	1,000	-,159	,163	,126	,016	,143	,175	-,082	,083	,224	-,063	,097	,165	-,029	,105	,204
22	,014	-,231	-,202	,189	-,020	-,110	,065	,125	-,367	,133	-,158	-,315	-,130	-,123	,177	,196	-,118	-,091	-,002	-,083	-,159	1,000	-,075	-,187	,002	-,070	-,341	,211	-,089	-,204	,121	-,013	-,098	,103	-,045	-,212
23	-,113	,201	,116	-,259	,141	,244	-,164	,115	,124	-,144	,455	,111	,102	,175	,012	-,072	,256	,105	,001	,248	,163	-,075	1,000	,223	-,197	,213	,083	-,260	,244	,174	-,186	,100	,086	-,176	,206	,152
24	,034	,171	,074	-,276	,026	,360	,110	-,056	,319	,072	,285	,286	,148	,095	-,152	-,076	,225	,267	,183	,076	,126	-,187	,223	1,000	-,188	,214	,228	,037	,279	,383	-,121	,143	,169	-,217	,402	,330
25	,087	-,201	-,003	,241	-,017	-,128	,040	-,042	,006	,037	-,118	-,043	-,023	-,174	,143	,179	-,149	,028	,017	-,146	,016	,002	-,197	-,188	1,000	-,070	,033	,085	-,209	-,152	,223	-,124	-,008	,182	-,219	-,035
26	-,007	,226	,064	-,167	,091	,212	,075	,122	,191	,038	,256	,108	,185	,258	-,014	-,142	,337	,130	,019	,227	,143	-,070	,213	,214	-,070	1,000	,054	-,066	,257	,112	-,162	,152	,096	-,174	,248	,096
27	,168	,171	,389	,024	-,032	,148	,112	-,021	,437	,260	,147	,448	,238	,072	-,029	-,104	,086	,278	,237	,080	,175	-,341	,083	,228	,033	,054	1,000	-,024	,097	,193	,069	,025	,347	-,084	,150	,351
28	,175	-,154	-,024	,123	,011	,060	,173	-,045	-,004	,340	-,205	-,096	-,020	-,159	,147	,274	-,211	,076	,123	-,216	-,082	,211	-,260	,037	,085	-,066	-,024	1,000	-,090	-,111	,160	,002	,050	,112	,031	,060
29	-,077	,277	,046	-,308	,109	,253	,025	,093	,206	-,042	,261	,221	,084	,412	-,016	-,121	,318	,120	,067	,374	,083	-,089	,244	,279	-,209	,257	,097	-,090	1,000	,190	-,198	,167	,161	-,209	,436	,179
30	,005	,181	,261	-,062	,116	,203	,073	-,008	,226	,018	,238	,251	,219	,072	-,058	-,108	,231	,160	,076	,180	,224	-,204	,174	,383	-,152	,112	,193	-,111	,190	1,000	-,083	,201	,131	-,118	,242	,316
31	,139	-,242	-,009	,279	-,039	-,147	,070	,035	-,084	,166	-,180	,013	,098	-,120	,114	,171	-,136	-,057	,097	-,137	-,063	,121	-,186	-,121	,223	-,162	,069	,160	-,198	-,083	1,000	-,016	,078	,256	-,237	-,052
32	,002	,115	,016	-,075	,116	,084	,016	,113	,024	,087	,119	,045	,042	,197	-,036	-,073	,187	,117	,077	,114	,097	-,013	,100	,143	-,124	,152	,025	,002	,167	,201	-,016	1,000	,094	-,089	,142	,122
33	,040	,109	,288	,003	-,025	,147	,075	,047	,255	,158	,143	,212	,183	,062	,167	,041	,094	,186	,115	,027	,165	-,098	,086	,169	-,008	,096	,347	,050	,161	,131	,078	,094	1,000	,033	,117	,144
34	,203	-,282	,034	,329	,027	-,045	,115	-,029	-,217	,040	-,193	-,119	-,085	-,168	,152	,192	-,224	-,121	,038	-,256	-,029	,103	-,176	-,217	,182	-,174	-,084	,112	-,209	-,118	,256	-,089	,033	1,000	-,142	-,046
35	-,057	,270	,079	-,243	,109	,283	,093	,062	,195	,086	,179	,124	,042	,188	-,009	-,078	,229	,223	,098	,211	,105	-,045	,206	,402	-,219	,248	,150	,031	,436	,242	-,237	,142	,117	-,142	1,000	,310
36	,066	,277	,175	-,111	-,015	,245	,077	-,101	,298	,139	,128	,299	,122	,141	,054	-,080	,111	,339	,178	,111	,204	-,212	,152	,330	-,035	,096	,351	,060	,179	,316	-,052	,122	,144	-,046	,310	1,000

APPENDIX 16 ROTATED FACTOR MATRIX OF LPQ-ITEMS (N = 341)

LPQ Scale*	LPQ Items	Factors						h^2
		1	2	3	4	5	6	
AM	27	76	38	49	14	-01	-66	60
AS	12	66	15	15	-01	-15	-08	52
AM	9	64	18	21	-04	-10	-09	51
AM	3	57	01	-09	03	17	22	41
SS	22	-51	-06	-05	18	43	-13	50
AM	33	49	02	08	04	38	02	39
AS	36	46	06	37	18	-07	-13	39
SM	13	42	28	-13	21	04	20	36
AS	18	41	-03	38	03	05	-39	47
AS	30	36	05	36	02	-07	34	40
DM	20	09	74	-01	-05	-09	19	60
DM	14	07	73	00	00	03	08	55
DM	2	23	61	13	04	-10	08	46
DS	29	06	54	41	-02	12	02	48
SS	34	-06	-43	-25	26	15	26	40
DM	26	10	41	28	-04	23	08	32
SS	16	-15	-32	02	29	31	-03	31
DM	32	01	26	23	07	22	04	18
AS	24	29	05	67	17	-15	04	57
AS	6	14	-09	64	09	07	17	48
DS	35	07	28	61	11	08	-01	48
SS	4	06	-35	-44	14	24	06	39
DS	23	12	17	39	-39	19	36	52
SM	31	19	-21	38	27	23	-04	33
DS	17	15	34	35	-25	17	05	35
SM	25	14	30	-34	09	10	01	24
SM	7	-01	05	08	68	-07	21	52
SM	19	13	08	13	59	-03	08	40
SS	28	-09	-23	10	53	19	-28	47
SM	1	16	-04	-13	45	05	01	25
SS	10	23	-14	13	41	39	-38	55
AM	15	02	-12	-12	04	58	10	37
DM	8	-09	15	01	-09	55	01	34
DS	5	-13	07	17	14	03	56	38
AM	21	34	13	03	06	10	46	36
DS	11	23	22	33	-30	05	39	46
Eigenvalue		57	31	20	17	14	13	1.53
Pct of Variance		15.8	8.6	5.5	4.8	4.0	3.7	42.4

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. a Rotation converged in 21 iterations. Kaiser-Meyer-Olkin Measure of Sampling Adequacy 0,810; Bartlett's Test of Sphericity Approx.Chi-Square 2741,908, Sig.,000.

* SM=Surface Motive, SS=Surface Strategy, DM=Deep Motive, DS=Deep Strategy, AM=Achieving Motive, AS=Achieving Strategy

APPENDIX 17 FREQUENCIES FOR DETAILED CATEGORIES OF STUDENTS' HOBBIES AND ACTIVITIES (Finland n = 358; Canada n = 143)

HOBBY OR ACTIVITY	Finland		Canada	
	f	%	f	%
FULL- OR PART TIME WORK (sh1)	18	5.0	4	2.8
RADIO, TELEVISION, AND VIDEO (sh2)				
- Television/video viewing	13	3.6	8	5.6
- Radio listening	1	0.3	2	1.4
COLLECTING (sh3)	3	0.8	10	7.0
READING, LANGUAGES, AND WRITING (sh4)				
- Languages	2	0.6	-	-
- Writing	5	1.4	2	1.4
- Correspondence	5	1.4	-	-
- Reading	67	18.7	19	13.3
SOCIAL LIFE (sh5)	15	4.2	35	24.5
SPORTS AND RECREATION (sh6)				
- Shooting sport	18	5.0	2	1.4
- Animal sport	9	2.5	2	1.4
- Skiing	55	15.4	10	7.0
- Fishing	18	5.0	2	1.4
- Combat sport	18	5.0	3	2.1
- Sport for all	102	28.5	27	18.9
- Skating	12	3.4	1	0.7
- Ball games with striking implement	70	19.6	25	17.5
- Motor sport	4	1.1	2	1.4
- Ball games	42	11.7	33	23.1
- Games	3	0.8	2	1.4
- Cycling	5	1.4	6	4.2
- Dance	11	3.1	3	2.1
- Aeronautical sport	-	-	3	2.1
- Aquatic sport	7	2.0	12	8.4
- Recreation	17	4.7	-	-
- Weight training	21	5.9	6	4.2
- Gymnastics	1	0.3	-	-

(continues)

APPENDIX 17 (continued)

HOBBY OR ACTIVITY	**Finland**		**Canada**	
	f	**%**	**f**	**%**
SPORTS AND RECREATION (sh6) continues ...				
- Track & Field	8	2.2	2	1.4
- Orienteering	15	4.2	-	-
ART HOBBIES (sh7)				
- The visual arts	13	3.6	7	4.9
- Music	98	27.4	33	23.1
- Theatre/acting/self-expression	6	1.7	-	-
TECHNICAL HOBBIES AND HANDICRAFT (sh8)				
- Fixing and building cars and motors	5	1.4	2	1.4
- Electronics and radio amateur activities	3	0.8	1	0.7
- Model building	2	0.6	3	2.1
- Handicrafts	12	3.4	1	0.7
- Computers	56	15.6	8	5.6
- Science hobbies	2	0.6	2	1.4
- Computer- and video games	5	1.4	8	5.6
- Other technical hobbies / car and motorbike driving	3	0.8	13	2.1
COMMUNITY WORK AND SOCIAL ISSUES (sh9)				
- Club- and coaching activities	7	2.0	4	2.8
- Church	9	2.5	2	1.4
- Scouts	26	7.3	13	9.1
- Social activities and charity	11	3.1	8	5.6
OTHER HOBBIES AND ACTIVITIES (sh10)	32	8.9	13	9.1

APPENDIX 18 FORMS OF VIDEO USE IN PHYSICS IN TREATMENT GROUPS A - H

TABLE 1. Forms of video use in physics in senior high school according to students in treatment groups A - H (Percentage distributions)

Video use: Summarizing the content studied	**n**	**never (1)**	**sometimes (2)**	**rather often (3)**	**often (4)**	**very often (5)**	**M**	**SD**
Treatment group A	49	69	27	2	2	-	1.33	0.60
Treatment group B	48	96	4	-	-	-	1.04	0.20
Treatment group C	35	94	6	-	-	-	1.06	0.24
Treatment group D	59	93	7	-	-	-	1.05	0.23
Treatment group E	36	69	25	-	6	-	1.41	0.78
Treatment group F	37	92	5	-	3	-	1.11	0.52
Treatment group G	43	100	-	-	-	-	1.00	-
Treatment group H	37	68	27	3	3	-	1.42	0.69

F-test for differences in means (M) between the treatment groups: F-value = 5.94; p = .000
Significant pairwise differences between the treatment groups based on Dunnett T3: A-B .031; A-G .005; G-H .025

TABLE 2. Forms of video use in physics in senior high school according to students in treatment groups A - H (Percentage distributions)

Video use: Filling up time	**n**	**never (1)**	**sometimes (2)**	**rather often (3)**	**often (4)**	**very often (5)**	**M**	**SD**
Treatment group A	49	86	14	-	-	-	1.13	0.33
Treatment group B	48	85	13	2	-	-	1.17	0.43
Treatment group C	35	100	-	-	-	-	1.00	-
Treatment group D	59	75	24	-	2	-	1.29	0.57
Treatment group E	36	89	8	3	-	-	1.12	0.41
Treatment group F	37	86	6	5	-	-	1.14	0.42
Treatment group G	43	100	-	-	-	-	1.00	-
Treatment group H	39	82	15	3	-	-	1.19	0.47

F-test for differences in means (M) between the treatment groups: F-value = 2.60; p = .013
Significant pairwise differences between the treatment groups based on Dunnett T3: C-D .006; D-G .006

TABLE 3. Forms of video use in physics in senior high school according to students in treatment groups A - H (Percentage distributions)

Video use: Tasks used in viewing videos	**n**	**never (1)**	**sometimes (2)**	**rather often (3)**	**often (4)**	**very often (5)**	**M**	**SD**
Treatment group A	49	86	14	-	-	-	1.15	0.36
Treatment group B	48	94	4	2	-	-	1.09	0.35
Treatment group C	35	94	-	-	6	-	1.17	0.71
Treatment group D	59	92	7	2	-	-	1.09	0.35
Treatment group E	36	89	11	-	-	-	1.12	0.33
Treatment group F	37	95	-	3	3	-	1.08	0.50
Treatment group G	43	100	-	-	-	-	1.00	-
Treatment group H	38	63	34	3-	-	-	1.42	0.55

F-test for differences in means (M) between the treatment groups: F-value = 2.73; p = .009
Significant pairwise differences between the treatment groups based on Dunnett T: G-H .002

(continues)

APPENDIX 18 (continued)

TABLE 4. Forms of video use in physics in senior high school according to students in treatment groups A - H (Percentage distributions)

Video use: Videotaped feedback about performance in lab	**n**	**never (1)**	**sometimes (2)**	**rather often (3)**	**often (4)**	**very often (5)**	**M**	**SD**
Treatment group A	49	100	-	-	-	-	1.00	-
Treatment group B	48	10	-	-	-	-	1.00	-
Treatment group C	35	100	-	-	-	-	1.00	-
Treatment group D	59	100	-	-	-	-	1.00	-
Treatment group E	36	94	6	-	-	-	1.06	0.24
Treatment group F	37	97	3	-	-	-	1.03	0.17
Treatment group G	43	100	-	-	-	-	1.00	-
Treatment group H	38	92	8	-	-	-	1.08	0.28

F-test for differences in means (M) between the treatment groups: F-value = 2.31; p = .026
Significant pairwise differences between the treatment groups based on Dunnett T: -

TABLE 5. Forms of video use in physics in senior high school according to students in treatment groups A - H (Percentage distributions)

Video use: Providing a basis for discussion	**n**	**never (1)**	**sometimes (2)**	**rather often (3)**	**often (4)**	**very often (5)**	**M**	**SD**
Treatment group A	49	71	27	2	-	-	1.31	0.51
Treatment group B	48	94	6	-	-	-	1.04	0.20
Treatment group C	35	94	6	-	-	-	1.06	0.24
Treatment group D	59	81	18	2	-	-	1.20	0.45
Treatment group E	36	72	22	3	3	-	1.38	0.70
Treatment group F	37	92	3	5	-	-	1.08	0.37
Treatment group G	43	100	-	-	-	-	1.00	-
Treatment group H	38	71	24	5	-	-	1.36	0.59

F-test for differences in means (M) between the treatment groups: F-value = 4.12; p = .000
Significant pairwise differences between the treatment groups based on Dunnett T: A-G .003; D-G .024; G-H .023

TABLE 6. Forms of video use in physics in senior high school according to students in treatment groups A - H (Percentage distributions)

Video use: Giving instructions for working	**n**	**never (1)**	**sometimes (2)**	**rather often (3)**	**often (4)**	**very often (5)**	**M**	**SD**
Treatment group A	49	94	4	2	-	-	1.08	0.35
Treatment group B	48	96	4	-	-	-	1.04	0.20
Treatment group C	35	94	-	6	-	-	1.11	0.47
Treatment group D	59	97	3	-	-	-	1.02	0.13
Treatment group E	36	97	-	3	-	-	1.06	0.34
Treatment group F	37	92	3	-	5	-	1.11	0.52
Treatment group G	43	100	-	-	-	-	1.00	-
Treatment group H	39	90	10	-	-	-	1.08	0.31

F-test for differences in means (M) between the treatment groups: F-value = 1.11 p = .357
Significant pairwise differences between the treatment groups based on Dunnett T:

(continues)

APPENDIX 18 (continued)

TABLE 7. Forms of video use in physics in senior high school according to students in treatment groups A - H (Percentage distributions)

Video use: Introducing new concepts	**n**	**never (1)**	**sometimes (2)**	**rather often (3)**	**often (4)**	**very often (5)**	**M**	**SD**
Treatment group A	48	65	29	2	4	-	1.46	0.74
Treatment group B	48	85	13	2	-	-	1.15	0.42
Treatment group C	35	94	3	-	3	-	1.11	0.53
Treatment group D	59	72	25	4	-	-	1.29	0.53
Treatment group E	36	36	56	6	3	-	1.74	0.71
Treatment group F	37	92	5	-	-	3	1.06	0.23
Treatment group G	43	100	-	-	-	-	1.00	-
Treatment group H	39	51	28	13	8	-	1.75	1.00

F-test for differences in means (M) between the treatment groups: F-value = 8.64; p = .000
Significant pairwise differences between the treatment groups based on Dunnett T: A-G .003; B-E .001; B-H .018; C-E .001; C-H .014; D-G .001; E-F .014; E-G .000; G-H .000;

TABLE 8. Forms of video use in physics in senior high school according to students in treatment groups A - H (Percentage distributions)

Video use: Giving cameras for data gathering	**n**	**never (1)**	**sometimes (2)**	**rather often (3)**	**often (4)**	**very often (5)**	**M**	**SD**
Treatment group A	49	100	-	-	-	-	1.00	-
Treatment group B	48	100	-	-	-	-	1.00	-
Treatment group C	35	100	-	-	-	-	1.00	-
Treatment group D	59	98	2	-	-	-	1.02	0.13
Treatment group E	36	100	-	-	-	-	1.00	-
Treatment group F	37	94	3	3	-	-	1.06	0.33
Treatment group G	43	100	-	-	-	-	1.00	-
Treatment group H	38	100	-	-	-	-	1.00	-

F-test for differences in means (M) between the treatment groups: F-value = 1.49; p = ..169
Significant pairwise differences between the treatment groups based on Dunnett T:

TABLE 9. Forms of video use in physics in senior high school according to students in treatment groups A - H (Percentage distributions)

Video use: Making a video programme	**n**	**never (1)**	**sometimes (2)**	**rather often (3)**	**often (4)**	**very often (5)**	**M**	**SD**
Treatment group A	49	100	-	-	-	-	1.00	-
Treatment group B	48	100	-	-	-	-	1.00	-
Treatment group C	35	100	-	-	-	-	1.00	-
Treatment group D	59	100	-	-	-	-	1.00	-
Treatment group E	36	100	-	-	-	-	1.00	-
Treatment group F	37	95	-	5	-	-	1.06	0.33
Treatment group G	43	100	-	-	-	-	1.00	-
Treatment group H	38	100	-	-	-	-	1.00	-

F-test for differences in means (M) between the treatment groups: F-value = 2.46; p = .018
Significant pairwise differences between the treatment groups based on Dunnett T: -

(continues)

APPENDIX 18 (continued)

TABLE 10. Forms of video use in physics in senior high school according to students in treatment groups A - H (Percentage distributions)

Video use: Showing how theory applies to practice	**n**	**never (1)**	**sometimes (2)**	**rather often (3)**	**often (4)**	**very often (5)**	**M**	**SD**
Treatment group A	49	49	45	2	2	2	1.63	0.82
Treatment group B	48	88	12	-	-	-	1.15	0.36
Treatment group C	35	94	-	6	-	-	1.11	0.47
Treatment group D	59	83	14	2	2	-	1.20	0.56
Treatment group E	36	58	36	-	6	-	1.53	0.79
Treatment group F	37	91	3	3	-	3	1.14	0.68
Treatment group G	43	100	-	-	-	-	1.00	-
Treatment group H	39	54	36	5	5	-	1.61	0.84

F-test for differences in means (M) between the treatment groups: F-value = 6.80; p = .000
Significant pairwise differences between the treatment groups based on Dunnett T: A-B .007; A-C .011; A-G .000; B-H .041; C-H .046; E-G .007; G-H .001

APPENDIX 19 T-TESTS: DIFFERENCES BETWEEN FEMALE AND MALE STUDENTS IN AGGREGATED VARIABLES

Note: See appendix 10 for how the aggregated variables were constructed. The decimals of means and standard deviations were rounded to the nearest whole number.
* t-test for nonequal variances used; ** Four physics student groups did not use the video programme and four physics student groups did not use Task Papers

Variable	female			male			t-test	
	n	M	SD	n	M	SD	t	p
Entity vs. incremental intelligence	123	10.2	6	225	13.7	6.9	1.47	.143
Confidence in intelligence	120	4.1	0.7	230	4.4	0.8	-3.67	.000
LPQ Surface Motive	121	19.2	3.2	230	19	3.3	0.47	.642
LPQ Deep Motive	118	19.8	2.6	230	19.1	3.5	1.96*	.051
LPQ Achieving Motive	121	18.9	3.2	228	18.2	3.7	1.77	.078
LPQ Surface Strategy	120	14.4	3.2	229	15.7	3.5	-3.35	.000
LPQ Deep Strategy	119	17.7	3.1	228	17.8	3.1	-0.37	.712
LPQ Achieving Strategy	121	17.2	3.2	230	15.8	3.7	3.66	.000
LPQ Surface Approach	120	33.7	5.3	229	34.8	5.6	-1.78	.076
LPQ Deep Approach	116	37.4	5	228	36.9	5.8	0.82*	.416
LPQ Achieving Approach	121	36.1	5.3	228	34	6.3	3.16	.000
LPQ Deep-Achieving Approach	116	73.5	8.5	226	70.8	10.2	2.43	.016
Visuality in physics	119	3.4	0.5	223	3.34	0.5	0.77	.438
Connection of science to real life	120	3.5	0.4	227	3.5	0.5	-0.13*	.895
Difficulties in physics	117	3.1	0.5	227	2.9	0.6	2.42	.016
Relation to physics	123	3.6	0.5	223	3.6	0.5	-0.85	.394
Relation to school and education	123	3.7	0.5	226	3.4	0.5	5.4	.000
Relation to studying gases	121	3.5	0.5	229	3.5	0.7	-0.08	.936
Estimation of prior knowledge about gases (pretest)	122	2.5	0.7	230	2.7	0.8	-1.82	.070
Estimation of prior knowledge about gases (post-test)	114	1.8	0.6	215	2.2	0.8	-4.79*	.000
Relation to course	112	3.7	0.7	208	3.4	0.7	-0.21	.833
Experiences of the video programme **	78	3.2	0.8	159	3.1	0.8	0.98	.329
Experiences of the written materi-als	110	3.3	0.6	208	3.2	0.6	0.68	.496

(continues)

APPENDIX 19 (continued)

Variable	female			male			t-test	
	n	M	SD	n	M	SD	t	p
Experiences of understanding	114	2.8	0.3	215	2.8	0.3	-0.83	.409
Multiple-Choice Questionnaire 1 total scores (pretest)	123	10.2	6.0	225	13.7	6.9	-4.76	.000
Multiple-Choice Questionnaire 2 total scores (post-test)	116	23.0	8.5	218	24.9	8.2	-2.01	.046
Multiple-Choice Questionnaire total gain scores	116	12.8	8.0	209	11.3	7.7	1.70	.091
Gas law items from Multiple-Choice Questionnaire (gain scores)	116	5.8	4.4	209	5.2	4.2	1.05	.293
Kinetic Theory items from Multiple-Choice Questionnaire (gain scores)	116	3.5	3.7	209	3.4	3.6	0.29	.771
Total scores from Task Papers 1-5**	99	40.5	9.6	188	38.5	9.6	1.71	.090
Concept Map + Essay 1 total scores (pretest)	86	17.4	7.4	157	14.7	5.3	3.03*	.003
Concept Map + Essay 2 total scores (post-test)	86	35.7	18.3	157	29.3	12.4	2.89*	.004
Concept Map + Essay 2 - 1 total gain scores	86	18.28	15.8	157	14.6	11.9	1.87*	.063

APPENDIX 20 F-TESTS: DIFFERENCES BETWEEN SOCIOECONOMIC GROUPS IN AGGREGATED VARIABLES

Note: See appendix 10 for how the aggregated variables were constructed. The decimals of means and standard deviations were rounded to the nearest whole number. According to the Levene test of homogeneity of variances there were no significant differences, except for Video usage in physics (p=.002), Experiences in understanding (p=.030), and Kinetic Theory items from Multiple-Choice Questionnaire (gain scores) (p=.036)

Variables	SES group means				F-value	p
	low	lower middle	higher middle	high		
Entity vs. incremental intelligence	3.5	3.6	3.5	3.6	0.18	.912
Confidence in intelligence	4.3	4.1	4.6	4.3	3.44	.018*
LPQ Surface Motive	18.7	19.7	19.1	19.0	0.65	.584
LPQ Deep Motive	19.9	19.0	20.2	19.2	1.77	.155
LPQ Achieving Motive	18.6	18.5	19.5	18.0	1.98	.119
LPQ Surface Strategy	16.0	15.1	14.6	15.0	0.93	.425
LPQ Deep Strategy	17.3	17.6	18.6	17.7	1.53	.209
LPQ Achieving Strategy	16.0	16.1	16.9	15.9	0.96	.411
LPQ Surface Approach	34.8	34.8	33.7	34.0	0.50	.682
LPQ Deep Approach	37.2	36.6	38.7	36.9	1.72	.165
LPQ Achieving Approach	34.6	34.6	36.4	33.8	1.97	.120
LPQ Deep-Achieving Approach	71.8	71.2	75.1	70.7	2.37	.072
Visuality in physics	3.3	3.3	3.4	3.4	0.96	.413
Connection of science to real life	3.5	3.5	3.6	3.6	1.12	.342
Difficulties in physics	3.0	3.0	2.9	2.9	1.02	.384
Relation to physics	3.6	3.5	3.7	3.6	1.36	.256
Relation to school and education	3.5	3.5	3.7	3.5	2.25	.084
Relation to studying gases	3.5	3.5	3.5	3.4	0.50	.683
Estimation of prior knowledge about gases (pretest)	2.4	2.5	2.7	2.7	1.80	.148
Estimation of prior knowledge about gases (post-test)	2.1	1.9	2.2	2.1	1.49	.218
Relation to course	3.6	3.4	3.4	3.4	0.68	.566

(continues)

APPENDIX 20 (continued)

Variables	SES group means				F-value	p
	low	lower middle	higher middle	high		
Experiences of the video programme	2.8	3.1	3.0	3.1	0.35	.791
Experiences of the written materi-als	3.4	3.2	3.2	3.1	0.57	.634
Experiences of understanding	2.9	2.8	2.8	2.7	1.19	.314
Multiple-Choice Questionnaire 1 total scores (pretest)	12.3	11.0	13.2	12.4	1.04	.375
Multiple-Choice Questionnaire 2 total scores (post-test)	21.3	23.6	25.9	25.7	2.37	.072
Multiple-Choice Questionnaire total gain scores	9.4	12.4	12.9	13.4	1.40	.245
Gas law items from Multiple-Choi-ce Questionnaire (gain scores)	3.9	5.9	5.8	5.6	1.33	.267
Kinetic Theory items from Multiple-Choice Questionnaire (gain scores)	3.5	3.1	3.9	4.1	0.73	.533
Total scores from Task Papers 1-5	39.9	38.1	40.3	37.7	0.73	.538
Concept Map + Essay 1 total scores (pretest)	15.7	15.2	16.6	15.5	0.34	.799
Concept Map + Essay 2 total scores (post-test)	30.2	32.9	31.0	32.8	0.25	.860
Concept Map + Essay 2 - 1 total gain scores	14.7	17.1	15.8	16.2	0.15	.933

* Upper middle SES group was significantly different (Sheffe: p=.022) from lower middle SES group.

APPENDIX 21 T-TESTS: DIFFERENCES BETWEEN STRONGLY[1)] AND WEAKLY GOAL-CENTERED[2)] STUDENTS IN AGGREGATED VARIABLES

Notes: See appendix 10 for how the aggregated variables were constructed. The decimals of means and standard deviations were rounded to the nearest whole number.
* t-test for non-equal variances used; ** Four physics student groups did not use the video programme and four physics student groups did not use Task Papers
1) students planning to include science subjects as part of their future education. 2) students not planning to include science subjects... or who have not decided yet or do not plan to continue education; 1-way significance was used for LPQ-variables and Relation to physics.

Variable	weak goal			strong goal			t-test	
	n	M	SD	n	M	SD	t	p
Entity vs. incremental intelligence	168	3.6	1.1	183	3.5	1.1	1.41	.160
Confidence in intelligence	166	4.2	0.8	182	4.5	0.7	-3.21	.000
LPQ Surface Motive	166	19.3	3.1	183	18.9	3.5	1.27	.204
LPQ Deep Motive	165	18.4	3.0	181	20.2	3.1	-5.59	.000
LPQ Achieving Motive	165	17.8	3.3	182	19.1	3.7	-3.32	.000
LPQ Surface Strategy	166	15.8	3.4	181	14.8	3.5	2.59	.010
LPQ Deep Strategy	166	16.9	3.0	179	18.5	3	-4.79	.000
LPQ Achieving Strategy	166	15.5	3.4	183	17.0	3.6	-4.05	.000
LPQ Surface Approach	166	35.1	5.2	181	33.8	5.7	2.31	.021
LPQ Deep Approach	165	35.3	5.2	177	38.7	5.3	-5.98	.000
LPQ Achieving Approach	165	33.3	5.8	182	36.1	6.0	-4.41	.000
LPQ Deep-Achieving Approach	164	68.7	9.1	176	74.7	9.4	-6.03	.000
Visuality in physics	161	3.2	0.5	180	3.5	0.5	-4.37	.000
Connection of science to real life	165	3.4	0.4	181	3.7	0.5	-7.55*	.000
Difficulties in physics	164	3.1	0.5	179	2.8	0.6	4.83	.000
Relation to physics	165	3.4	0.5	180	3.8	0.5	-7.08	.000
Relation to school and education	166	3.3	0.5	182	3.7	0.5	-5.9	.000
Relation to studying gases	166	3.3	0.6	183	3.7	0.5	-6.21*	.000
Estimation of prior knowledge about gases (pretest)	168	2.6	0.8	183	2.7	0.8	-1.91	.057
Estimation of prior knowledge about gases (post-test)	151	2.0	0.7	175	2.1	0.8	-1.44*	.150
Relation to course	147	3.2	0.7	170	3.5	0.6	-4.41	.000

(continues)

APPENDIX 21 (continued)								
Variable	weak goal			strong goal			t-test	
	n	M	SD	n	M	SD	t	p
Experiences of the video programme **	109	3.1	0.8	126	3.1	0.8	0.09	.930
Experiences of the written materials	144	3.1	0.6	171	3.3	0.6	-2.33	.021
Experiences of understanding	151	2.8	0.3	175	2.8	0.4	-0.21	.832
Multiple-Choice Questionnaire 1 total scores (pretest)	161	11.6	6.8	182	13.0	6.5	-1.90	.058
Multiple-Choice Questionnaire 2 total scores (post-test)	155	22.9	8.7	177	25.4	7.7	-2.83*	.005
Multiple-Choice Questionnaire 2 -1 total gain scores	148	11.2	8.05	175	12.4	7.7	-1.31	.192
Gas law items from Multiple-Choice Questionnaire (gain scores)	148	5.3	4.4	175	5.5	4.2	-0.36	.721
Kinetic Theory items from Multiple-Choice Questionnaire (gain scores)	148	3.0	3.5	175	3.8	3.7	-2.00	.047
Total sum scores from Task Papers 1-5**	134	37.5	10.5	152	40.6	8.6	-2.72*	.010
Concept Map + Essay 1 total scores (pretest)	107	15.2	6.1	135	16.0	6.4	-0.97	.332
Concept Map + Essay 2 total scores (post-test)	107	30.6	16.3	135	32.4	14.1	-0.96	.339
Concept Map + Essay 2 - 1 total gain scores	107	15.4	14.5	135	16.4	12.6	-0.62	.538

APPENDIX 22 T-TESTS: DIFFERENCES BETWEEN CANADIAN AND FINNISH STUDENTS IN AGGREGATED VARIABLES

Notes: See appendix 10 for how the aggregated variables were constructed. The decimals of means and standard deviations were rounded to the nearest whole number.
* t-test for non-equal variances used; ** Four physics student groups did not use the video programme and four physics student groups did not use Task Papers

Variable	Canada			Finland			t-test	
	n	M	SD	n	M	SD	t	p
Entity vs. incremental intelligence	141	4.3	1.2	353	3.6	1.1	6.67	.000
Confidence in intelligence	129	4.5	0.9	350	4.3	0.8	1.46*	.147
LPQ Surface Motive	141	20.0	3.2	351	19.1	3.3	2.87	.004
LPQ Deep Motive	139	20.3	3.6	348	19.4	3.2	2.76*	.006
LPQ Achieving Motive	140	20.8	4.1	349	18.5	3.6	6.12	.000
LPQ Surface Strategy	139	16.3	3.2	349	15.3	3.4	2.93	.004
LPQ Deep Strategy	140	17.8	3.4	347	17.7	3.1	0.03	.977
LPQ Achieving Strategy	140	17.6	4.4	351	16.3	3.6	3.30*	.001
LPQ Surface Approach	139	36.3	5.3	349	34.4	5.5	3.53	.000
LPQ Deep Approach	139	38.1	6.1	344	37.1	5.5	1.75	.081
LPQ Achieving Approach	139	38.4	7.5	349	34.7	6.1	5.06*	.000
LPQ Deep-Achieving Approach	138	76.4	12.0	342	71.7	9.7	4.08*	.000
Visuality in physics	139	3.5	0.6	342	3.4	0.5	1.55*	.124
Connection of science to real life	140	3.7	0.7	347	3.5	0.5	3.08*	.002
Difficulties in physics	136	2.8	0.6	344	3.0	0.6	-2.84	.005
Relation to physics	139	3.8	0.6	346	3.6	0.5	2.80*	.006
Relation to school and education	138	3.6	0.7	349	3.5	0.5	1.53*	.128
Relation to studying gases	139	3.4	0.7	350	3.5	0.6	-1.60	.110
Estimation of prior knowledge about gases (pretest)	140	2.9	1.0	352	2.6	0.8	2.27*	.024
Estimation of prior knowledge about gases (post-test)	97	2.7	0.9	329	2.1	0.8	5.67*	.000
Relation to course	95	3.1	0.7	320	3.4	0.7	-3.27	.001
Experiences about the video programme **	65	3.2	0.8	237	3.1	0.8	1.08	.281

(continues)

APPENDIX 22 (continued)								
Variable	**Canada**			**Finland**			**t-test**	
	n	**M**	**SD**	**n**	**M**	**SD**	**t**	**p**
Experiences about the written materials	92	3.4	0.6	318	3.2	0.6	1.95	.052
Experiences about understanding	96	2.9	0.5	329	2.8	0.3	2.03*	.045
Multiple-Choice Questionnaire 1 total scores (pretest)	136	11.2	6.5	348	12.5	6.8	-1.92	.055
Multiple-Choice Questionnaire 2 total scores (post-test)	112	18.8	8.8	334	24.3	8.3	-5.97	.000
Multiple-Choice Questionnaire 2 -1 total gain scores	98	9.2	6.4	325	11.8	7.8	-3.36*	.001
Gas law items from Multiple-Choice Questionnaire (gain scores)	101	3.9	3.8	325	5.4	4.3	-3.30	.001
Kinetic Theory items from Multiple-Choice Questionnaire (gain scores)	99	1.5	3.6	325	3.5	3.6	-4.83	.000

APPENDIX 23 LEARNING PROCESS QUESTIONNAIRE SUB-SCALES: DISTRIBUTIONS

TABLE A Surface Motive: Percentage distributions of individual items and the aggregate values (n=355)

Item	never true (1)	probably not true (2)	sometimes true (3)	usually true (4)	always true (5)	M	SD
I chose my present subjects mainly because of career prospects when I leave school, not because I'm particularly interested in them. (1)	7	19	34	33	7	3.1	1.02
I am put off by a poor mark on a test and worry about how I will do on the next test. (7)	14	30	29	19	8	2.8	1.15
Whether I like or not, I can see that studying is for me a good way to get a well-paid or secure job. (13)	1	3	17	41	38	4.1	0.87
When I have studied hard for a test, I worry that I may not be able to do well on it. (19)	10	30	28	25	7	2.9	1.12
I think that teachers shouldn't expect secondary school students to work on topics that are outside the set course. (25)**	4	20	38	28	10	3.2	1.01
I will continue my studies only for as long as necessary to get a good job. (31)**	9	27	26	29	9	3.0	1.13
AGGREGATE *	1	13	54	29	3	19.1	3.27

* classification: 1 (6-10), 2 (11-15), 3 (16-20), 4 (21-25), 5 (26-30); n = 351; the mean and the std dev are based on the raw values, not on the classified values (1-5). ** n= 351

TABLE B Surface Strategy: Percentage distributions of individual items and the aggregate values (n=351)

Item	never true (1)	probably not true (2)	sometimes true (3)	usually true (4)	always true (5)	M	SD
I tend to study only what's set; I usually don't do anything extra. (4)**	7	27	30	31	5	3.0	1.04
I find that the only way to learn many subjects is to memorize them by heart. (10)**	27	35	27	9	2	2.2	1.01
I prefer subjects in which I have to learn just facts to ones which require a lot of reading and understanding of material. (16)***	9	27	38	17	9	2.9	1.07
In most subjects I try to work things so that I do only enough to make sure I pass, and no more. (22)	25	39	25	8	3	2.3	1.03
I find it better to learn just the facts and details about a topic rather than try to understand all about it. (28)	34	39	19	7	1	2.0	0.96
I don't spend time on learning things that I know won't be asked in the exams. (34)	8	30	35	21	6	2.9	1.03
AGGREGATE *	8	44	41	7	0	15.3	3.44

* classification:1 (6-10), 2 (11-15), 3 (16-20), 4 (21-25), 5 (26-30); n = 349; the mean and the std dev are based on the raw values, not on the classified values (1-5); ** n = 354; *** n = 355

(continues)

APPENDIX 23 (continued)

TABLE C Deep Motive: Percentage distributions of individual items and the aggregate values (n=354)

Item	never true (1)	probably not true (2)	sometimes true (3)	usually true (4)	always true (5)	M	SD
I find that at times my school work can give me a feeling of deep personal satisfaction. (2)	8	27	42	18	5	2.9	0.98
While I realize that others sometimes know better than I do, I feel I have to say what I think is right. (8)	12	45	30	11	2	2.5	0.93
I find that many subjects can become very inter-esting once you get into them. (14)**	0	4	23	51	22	3.9	0.78
I find that studying some topics can be really ex-citing. (20)**	1	4	16	38	41	4.2	0.87
I feel that I might one day be able to change thin-gs in the world that I see now to be wrong. (26)*-**	8	35	34	16	7	2.8	1.04
My main aim in life is to find out what to believe in and then to act accordingly. (32)****	4	19	38	31	8	3.2	0.98
AGGREGATE *	0	9	57	30	4	19.4	3.20

* classification:1 (6-10), 2 (11-15), 3 (16-20), 4 (21-25), 5 (26-30); n = 348; the mean and the std dev are based on raw values, not on the classified values (1-5); ** n = 355; *** n = 351; **** n = 350

TABLE D Deep Strategy: Percentage distributions of individual items and the aggregate values (n= 351)

Item	never true (1)	probably not true (2)	sometimes true (3)	usually true (4)	always true (5)	M	SD
While I am studying, I often try to think how use-ful the material that I am learning would be in real life.(5)**	4	21	39	29	7	3.2	0.97
In reading new material, I am often reminded of material already know and see the latter in a new light. (11)**	2	13	44	32	9	3.3	0.88
I find that I have to do enough work on a topic so that can form my own point of view before I am satisfied. (17)***	1	20	40	33	6	3.2	0.87
I try to relate what I have learned in one subject to what I already know in other subjects. (23)	0	11	42	39	8	3.4	0.81
I find most new topics interesting and often spend extra time trying to find out more about them. (29)****	8	39	36	14	3	2.6	0.92
I spend a great deal of my free time finding out more about interesting topics which have been discussed in different classes. (35)	28	54	15	3	0	1.9	0.77
AGGREGATE *	1	20	62	16	1	17.7	3.10

* classification:1 (6-10), 2 (11-15), 3 (16-20), 4 (21-25), 5 (26-30); n = 347; the mean and the std dev are based on the raw values, not on the classified values (1-5); ** n = 353; *** n = 355; *** n = 354; **** n = 350

(continues)

APPENDIX 23 (continued)

TABLE E Achievement Motive: Percentage distributions of individual items and the aggregate values (n= 355)

Item	never true (1)	probably not true (2)	sometimes true (3)	usually true (4)	always true (5)	M	SD
I try to obtain high marks in all my subjects because of the advantage this gives me in competing with others when I leave school. (3)**	7	21	33	31	8	3.1	1.05
I have a strong desire to do best in all of my studies (9)	2	10	29	43	16	3.6	0.94
I like the results of tests to be put up publicly so that I can see by how much I beat some others in the class. (15)	42	34	13	9	2	2.0	1.05
I would rather be highly successful in school even though this might make me unpopular with some of my class mates. (21)**	4	13	23	34	26	3.7	1.11
I will work for top marks in a subject whether or not like the subject. (27)***	4	20	28	38	10	3.3	1.03
I see doing well in school as a sort of game, and I play to win. (33)***	11	30	32	22	5	2.8	1.06
AGGREGATE *	1	17	52	28	2	18.5	3.56

* classification:1 (6-10), 2 (11-15), 3 (16-20), 4 (21-25), 5 (26-30); n = 349; the mean and the std dev are based on the raw values, not on the classified values (1-5); ** n = 354; *** n = 351

TABLE F Achieving Strategy: Percentage distributions of individual items and the aggregate values (n=355)

Item	never true (1)	probably not true (2)	sometimes true (3)	usually true (4)	always true (5)	M	SD
I regularly take notes from suggested readings and put them with my class notes on a topic. (6)	25	49	18	7	1	2.1	0.88
I try to work solidly throughout the term and revise regularly when the exams are close. (12)	4	14	32	38	12	3.4	0.99
I always try to do all of my assignments as soon as they are given to me. (18)	7	31	36	22	4	2.9	0.97
Soon after a class or lab, I re-read my notes to make sure I can read them and understand them. (24)**	18	46	28	7	1	2.3	0.89
When a test is returned, I go over it carefully correcting all the errors and trying to understand why I made the original mistakes. (30)**	9	29	34	22	6	2.9	1.04
I usually try to read all the references and things my teacher says we should. (36)**	8	35	35	20	2	2.7	0.94
AGGREGATE *	6	36	45	13	0	16.3	3.57

* classification:1 (6-10), 2 (11-15), 3 (16-20), 4 (21-25), 5 (26-30); n = 351; the mean and the std dev are based on the raw values, not on the classified values (1-5); ** n = 351

APPENDIX 24 SIGNIFICANT T-TEST DIFFERENCES BETWEEN CANADIAN AND FINNISH STUDENTS IN SINGLE ITEMS OF MULTIPLE-CHOICE QUESTIONNAIRE

The decimals of means and standard deviations were rounded to one decimal

Variable	Canada			Finland			t-test	
	n	M	SD	n	M	SD	t	p
(M1) When a small volume of water..	136	1.7	1.4	348	2.0	1.3	-2.13*	.034
(M2) An iron container is weighted after..	135	1.1	1.4	348	0.7	1.2	2.72*	.007
(M3) A jar of oxygen gas and a jar of...	135	0.5	0.9	348	0.2	0.7	2.48*	.014
(M5) When pressure is constant the ...	135	0.8	1.1	348	1.3	1.2	-4.32*	.000
(M6) When temperature is constant the ...	134	0.7	1.2	348	0.9	1.3	-2.09	.037
(M11) A mole ...	136	0.3	0.8	348	1.0	1.3	-7.37*	.000
(M13) When a gas is heated, its molecules...	136	2.1	1.3	348	1.6	1.3	3.74	.000
(MM1) When a small volume of water..	111	2.1	1.4	334	2.5	1.1	-2.99*	.003
(MM2) An iron container is weighted after..	110	1.5	1.5	334	1.0	1.3	3.17*	.002
(MM3) A jar of oxygen gas and a jar of...	108	1.1	1.3	334	1.4	1.4	-2.37*	.019
(MM4) The gas laws are valid for real ...	107	1.5	1.5	334	2.1	1.4	-3.40*	.001
(MM5) When pressure is constant the ...	107	1.8	1.4	334	2.3	1.2	-3.53*	-001
(MM6) When temperature is constant ...	105	1.1	1.4	334	1.8	1.5	-4.21	.000
(MM8) In a simple mercury barometer ...	107	1.6	1.4	334	2.2	1.3	-3.48*	.001
(MM10) Which of the following ...	106	1.4	1.5	334	1.8	1.4	-2.13*	.035
(MM11) A mole ...	107	1.0	1.4	334	2.1	1.3	-7.55	.000
(MM12) Which statement is not true ...	107	1.1	1.4	334	1.9	1.4	-5.31	.000

* t-test for non-equal variances used

APPENDIX 25. T-TESTS FOR ATTITUDE CHANGES IN TREATMENT GROUPS

TABLE A T-tests for attitude changes in treatment groups; attitude item: I find ("found" in post-test) gases and their behaviour an interesting topic to learn about[1] (g68 - exp1)

Treatment Group	n	r	Pretest		Post-test		t-test	
			M	SD	M	SD	t-value	p
A: tasks/preview section + basic sections	47	.46[3]	3.1	0.7	3.5	0.8	-3.95	.000
B: tasks/basic sections + application section	44	.44[2]	3.2	0.7	3.3	1.0	-0.82	.417
C: tasks/basic sections	32	.18	3.2	0.6	3.3	0.8	-0.78	.442
D: tasks/no video	51	.45[3]	3.3	0.7	3.7	0.8	-4.12	.000
E: no tasks/preview section + basic sections	35	.27	3.3	0.6	3.6	0.8	-2.51	.017
F: no tasks/basic sections +application sec.	37	.13	3.3	0.8	3.5	1.1	-0.94	.352
G: no tasks/basics sections	41	.42[2]	3.1	0.9	3.0	1.2	0.70	.491
H: no tasks/no video	37	.23	3.3	0.7	3.1	0.8	1.06	.295

1) Scale: 1 strongly disagree, 2 disagree, 3 uncertain, 4 agree, 5 strongly agree; 2) $p < .01$; 3) $p < .001$

TABLE B T-tests for attitude changes in treatment groups; attitude item: I think it is ("was" in post-test) useful to know more about gases and their behaviour[1] (g70 - exp3)

Treatment Group	n	r	Pretest		Post-test		t-test	
			M	SD	M	SD	t-value	p
A: tasks/preview section + basic sections	46	.28	3.5	0.8	3.7	0.8	-1.07	.291
B: tasks/basic sections + application section	44	.33[2]	3.6	0.8	3.6	0.7	0.52	.607
C: tasks/basic sections	32	.44[3]	3.6	0.7	3.8	0.7	-1.65	.109
D: tasks/no video	51	.37[3]	3.7	0.7	3.8	0.8	-0.84	.403
E: no tasks/preview section + basic sections	35	.18	3.7	0.7	4.0	0.5	-2.65	.012
F: no tasks/basic sections +application sec.	38	.31	3.5	0.8	3.6	0.8	-0.68	.500
G: no tasks/basics sections	42	.53[4]	3.3	1.0	3.3	0.9	0.00	1.00
H: no tasks/no video	36	.10	3.5	0.7	3.4	0.8	0.33	.744

1)Scale:1 strongly disagree, 2 disagree, 3 uncertain, 4 agree, 5 strongly agree; 2) $p < .05$; 3) $p < .01$; 4) $p < .001$

(continues)

APPENDIX 25 (continued)

TABLE C T-tests for attitude changes in treatment groups; attitude item: Studying gases and their behaviour does ("did" in post-test) not make sense to me[1] (g71-exp4)

Treatment Group	n	r	Pretest		Post-test		t-test	
			M	SD	M	SD	t-value	p
A: tasks/preview section + basic sections	46	.16	2.5	0.8	2.1	0.9	2.58	.013
B: tasks/basic sections + application section	43	.35[2]	2.3	0.7	2.1	0.7	1.31	.197
C: tasks/basic sections	32	.16	2.2	0.8	2.2	1.0	0.00	1.00
D: tasks/no video	51	.46[3]	2.3	0.7	1.9	0.9	2.99	.004
E: no tasks/preview section + basic sections	35	-.03	2.4	0.7	1.8	0.6	-2.51	.017
F: no tasks/basic sections +application sec.	38	.27	2.4	0.7	2.0	0.8	2.66	.012
G: no tasks/basics sections	42	.56[3]	2.5	0.9	2.4	1.0	0.66	.512
H: no tasks/no video	37	.11	2.41	0.7	2.4	0.8	0.16	.872

1)Scale: 1 strongly disagree, 2 disagree, 3 uncertain, 4 agree, 5 strongly agree; 2) $p < .05$ 3) $p < .001$

APPENDIX 26 NORMALITY ASSUMPTION TESTING FOR RESIDUALS IN COVARIANCE ANALYSES

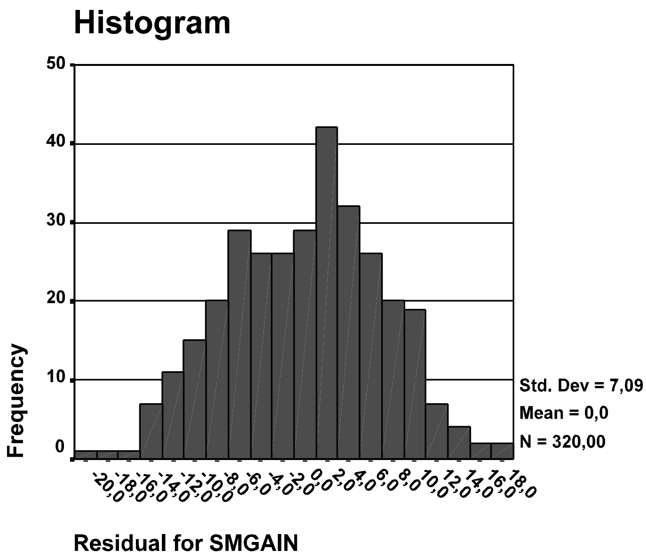
Section 1. Normality assumption testing for residuals in a covariance analysis (table 48 - sub-chapter 8.5.2)

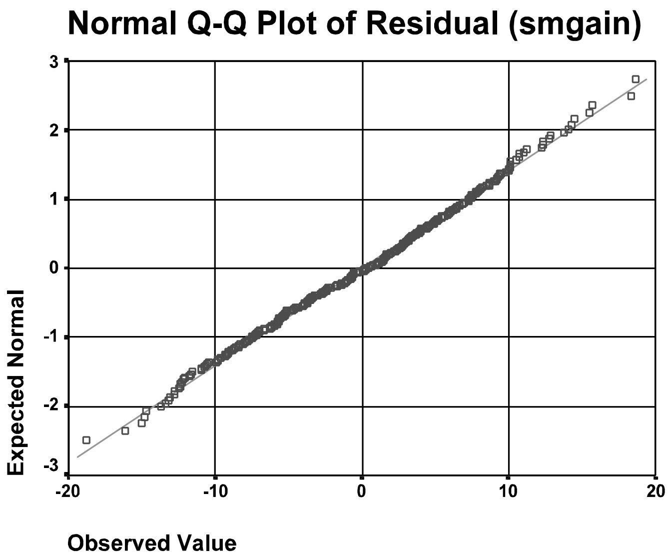
Tests of Normality

	Kolmogorov-Smirnov[a]		
	Statistic	df	Sig.
RES_1 Residual for SMGAIN	,040	320	,200*

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction





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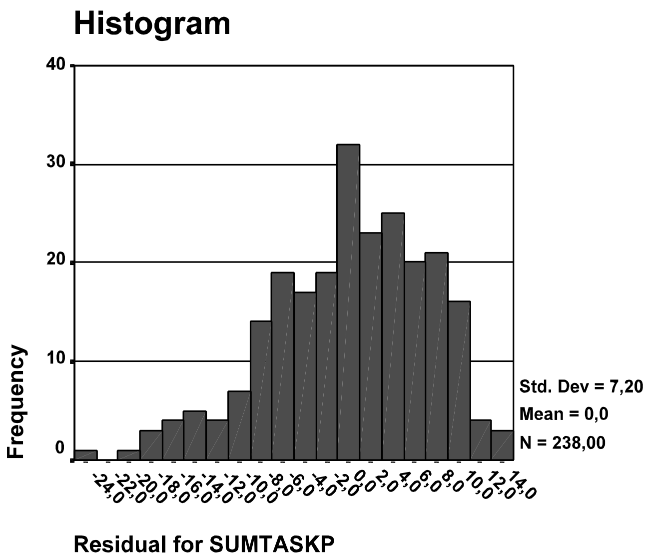
APPENDIX 26 (continued)

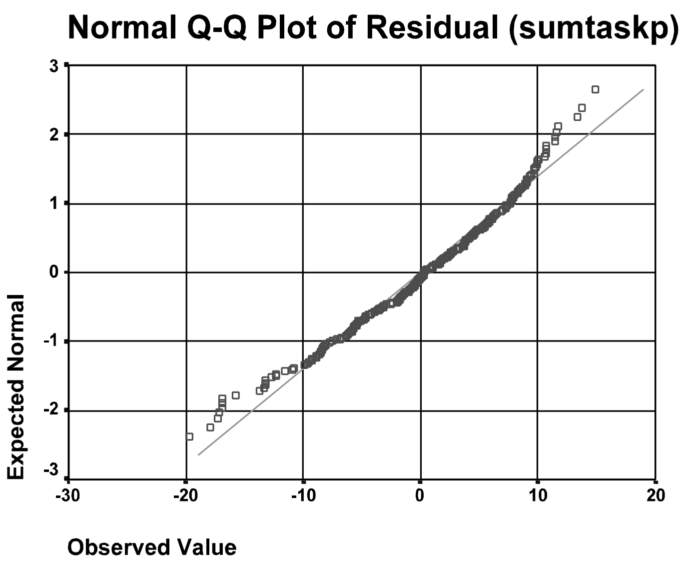
Section 2. Normality assumption testing for residuals in a covariance analysis (table 50 - sub-chapter 8.5.2)

Tests of Normality

	Kolmogorov-Smirnov[a]		
	Statistic	df	Sig.
RES_2 Residual for SUMTASKP	,062	238	,029

a. Lilliefors Significance Correction





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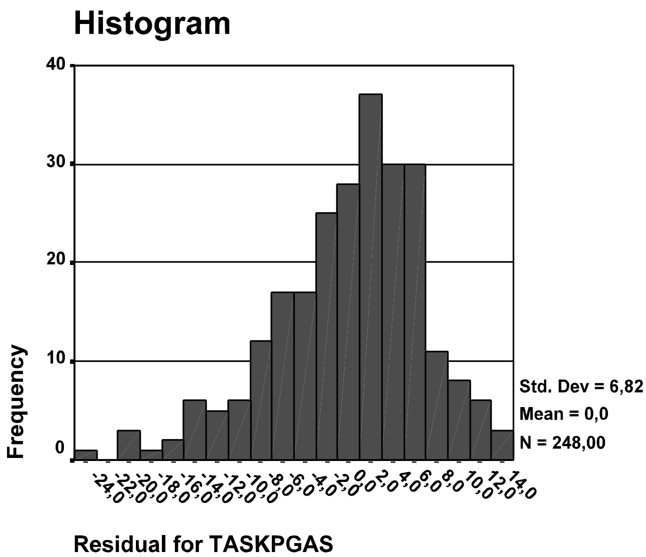
APPENDIX 26 (continued)

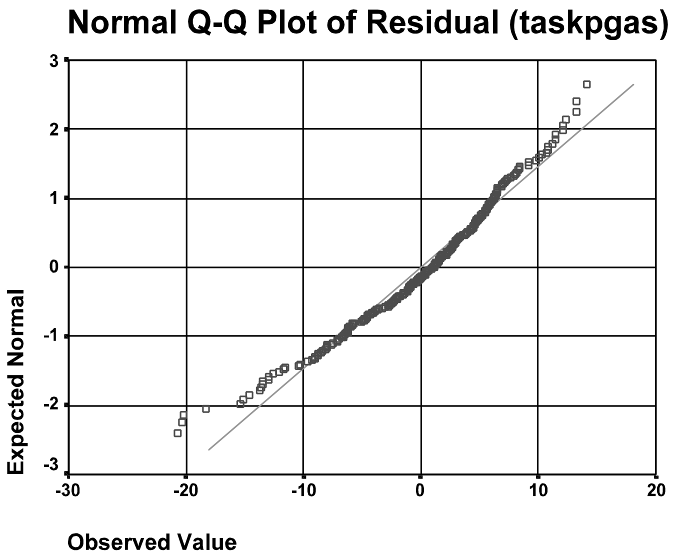
Section 3. Normality assumption testing for residuals in a covariance analysis (table 51 - sub-chapter 8.5.2)

Tests of Normality

	Kolmogorov-Smirnov[a]		
	Statistic	df	Sig.
RES_3 Residual for TASKPGAS	,073	248	,002

a. Lilliefors Significance Correction





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APPENDIX 26 (continued)

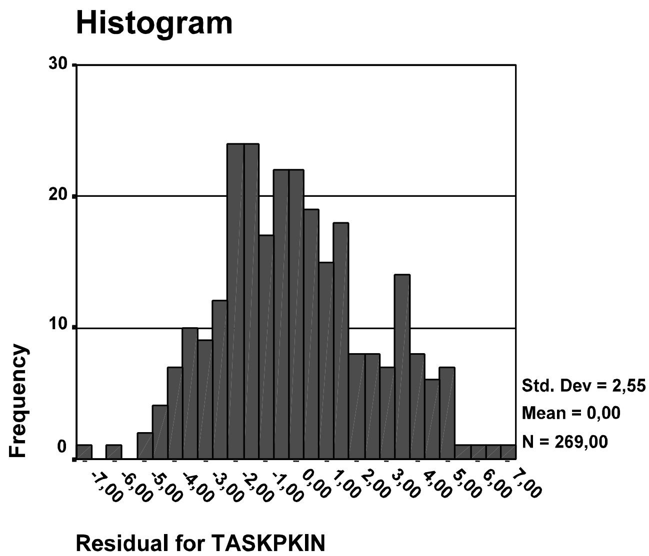
Section 4. Normality assumption testing for residuals in a covariance analysis (table 52 - sub-chapter 8.5.2)

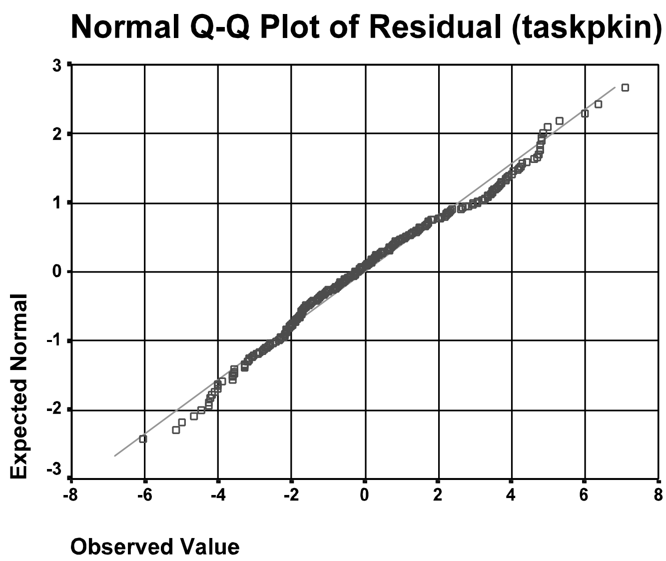
Tests of Normality

	Kolmogorov-Smirnov[a]		
	Statistic	df	Sig.
RES_4 Residual for TASKPKIN	,049	269	,200*

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction





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APPENDIX 26 (continued)

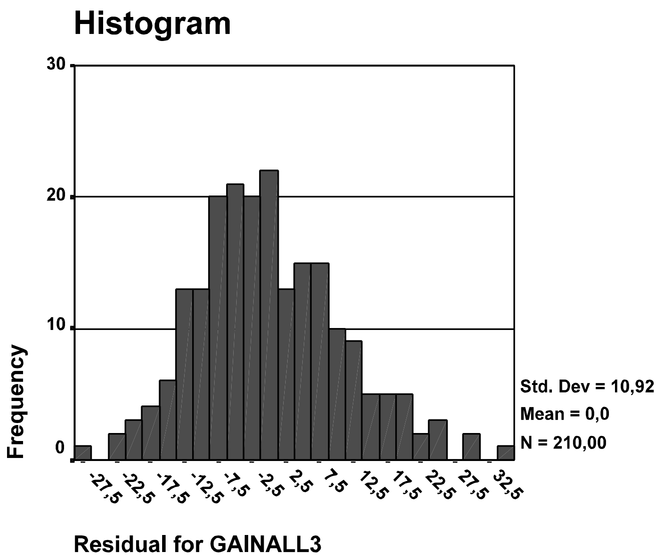
Section 5. Normality assumption testing for residuals in a covariance analysis (table 53 - sub-chapter 8.5.2)

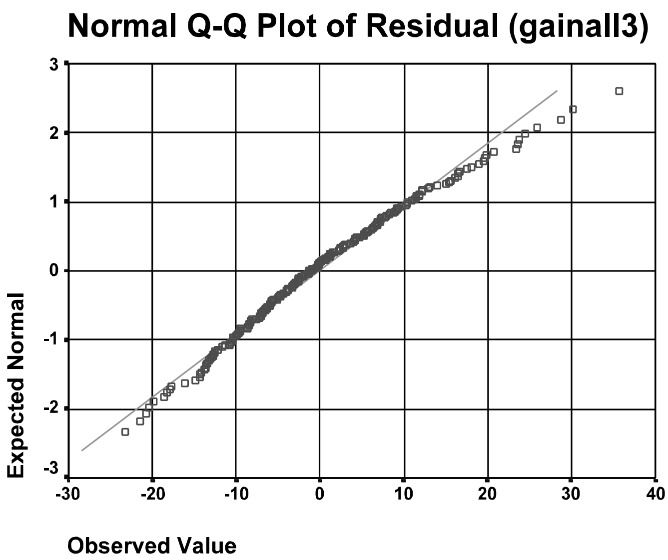
Tests of Normality

	Kolmogorov-Smirnov[a]		
	Statistic	df	Sig.
RES_5 Residual for GAINALL3	,053	210	,200*

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction





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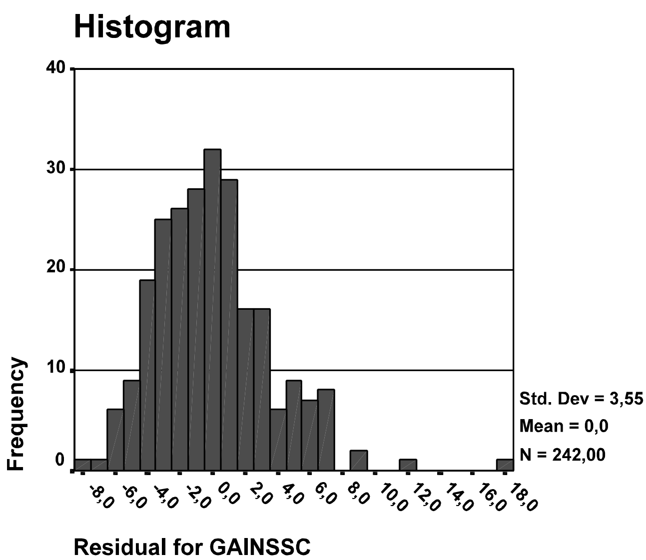
APPENDIX 26 (continued)

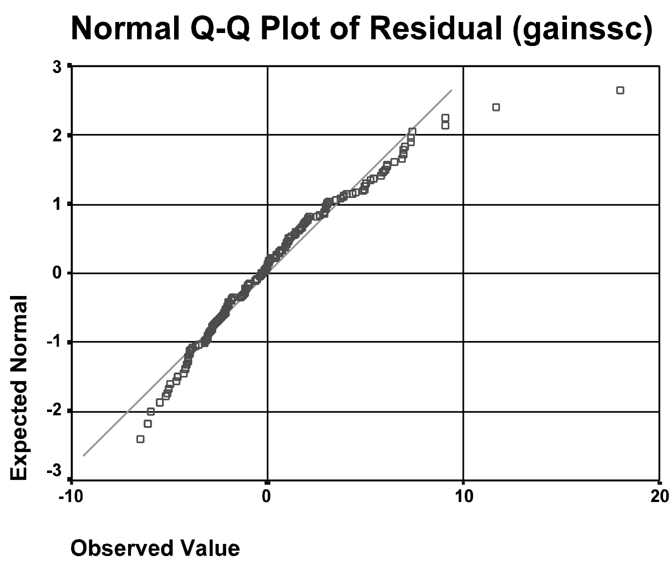
Section 6. Normality assumption testing for residuals in a covariance analysis (table 54 - sub-chapter 8.5.2)

Tests of Normality

	Kolmogorov-Smirnov[a]		
	Statistic	df	Sig.
RES_7 Residual for GAINSSC	,076	242	,002

a. Lilliefors Significance Correction





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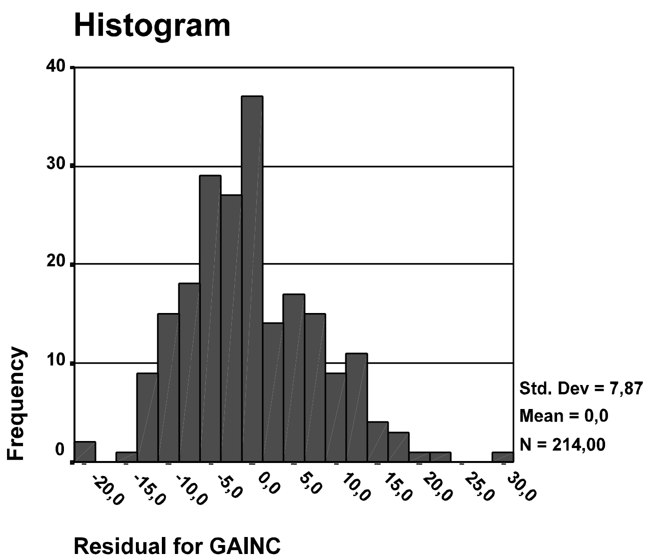
APPENDIX 26 (continued)

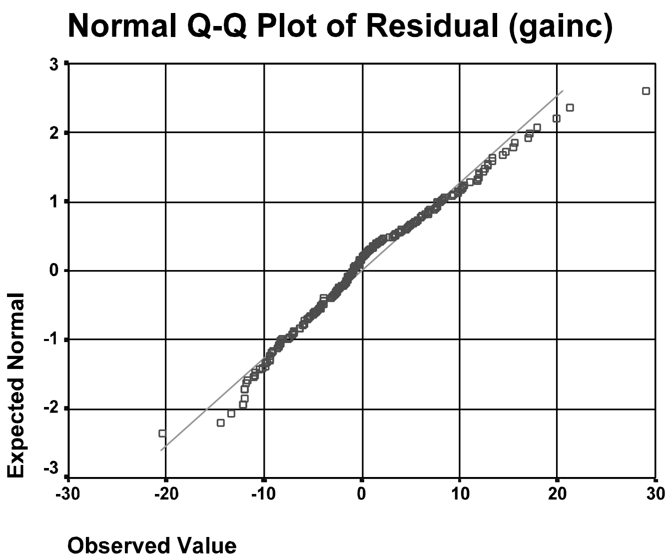
Section 7. Normality assumption testing for residuals in a covariance analysis (table 55 - sub-chapter 8.5.2)

Tests of Normality

	Kolmogorov-Smirnov[a]		
	Statistic	df	Sig.
RES_8 Residual for GAINC	,086	214	,001

a. Lilliefors Significance Correction





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APPENDIX 26 (continued)

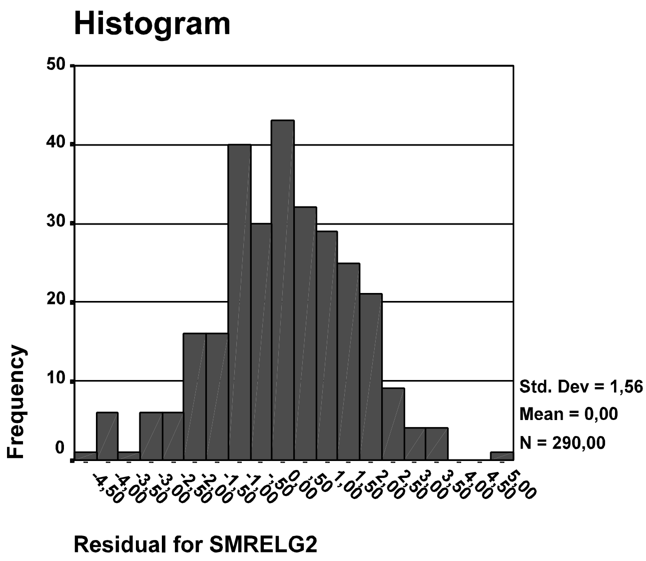
Section 8. Normality assumption testing for residuals in a covariance analysis (table 37 - sub-chapter 8.4.3)

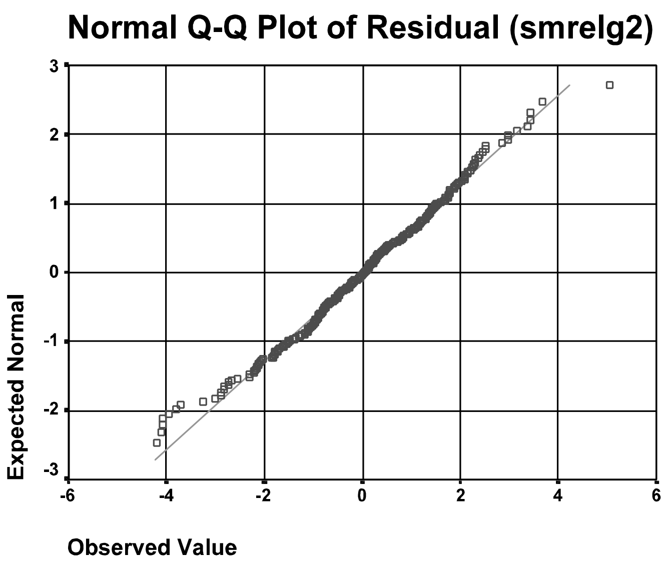
Tests of Normality

	Kolmogorov-Smirnov[a]		
	Statistic	df	Sig.
RES_9 Residual for SMRELG2	,045	290	,200*

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction





APPENDIX 27 STUDENTS' RESPONSES TO OPEN-ENDED QUESTIONS REGARDING THEIR EXPERIENCES OF THE MINICOURSE

TABLE 1 Categories of students' answers to the question: "What was best in this course?"

Categories of students' answers*	**f**
(1) The video programme	78
(2) It was something new/change to studying	58
(3) The textbook and other written materials	45
(4) Learning new thing about gases	20
(5) The minicourse was clear/easy/understandable	18
(6) Clear/illustrative/sufficient learning materials	16
(7) There was no homework/it was not too demanding	12
(8) Learning about the connection of gases to the real world	11
(9) The formulas, equations were clearly presented	10
(10) Had to follow the instruction because of revision and testing	9
(11) The gas laws	8
(12) The minicourse formed a clear whole	7
(13) Interesting topic	6
(14) Miscellaneous positive experiences	22
(15) Miscellaneous negative experiences [1)]	17

* Answers of an individual student may have been classified into more than one category
1) examples of responses: "Didn't like", "boring", "too many questionnaires", etc.

(continues)

APPENDIX 27 (continued)

TABLE 2. Categories of students' answers to the question: "What was worst in this course?"

Categories of students' answers*	f
(1) Too much paperwork [1)]	117
(2) Errors in the textbook	71
(3) Too tight timetable for learning	43
(4) The video programme [2)]	25
(5) Essays and concept maps	12
(6) Correct answers to the problems/task were not available	8
(7) Problems/tasks too much alike	7
(11) Miscellaneous	40
(12) Nothing wrong	5

* Answers of an individual student may have been classified into more than one category
1) of these responses 35 mentioned that there was too little time to fill in the papers;
2) Separate comments: video sections too short 9, bad music 9, too difficult 4, boring 3; note also that four control groups had no videos

TABLE 3 Categories of students' answers to the sentence completion task: "My best insight during the course appeared when..."

Categories of students' answers*	f
(1) I was studying and understood the gas laws	23
(2) I was solving the problems	21
(3) I realized how the general gas law combines the individual gas laws	18
(4) I was studying/understood the Kinetic theory/pressure/temperature	16
(5) I watched the video programme	14
(6) I noticed I had learned something about gases	11
(7) I understood the formulas	9
(8) I noticed how gas laws can be applied in real life	5
(9) Miscellaneous	21
(10) No insights or uncertain	10
(11) Negative experiences	14

* Answers of an individual student may have been classified into more than one category

(continues)

APPENDIX 27 (continued)

TABLE 4 Categories of students' answers to the sentence completion task: "During the course it was really interesting to..."

Categories of students' answers*	f
(1) Learn new things about the gases and gas laws	57
(2) Watch the video	48
(3) Work on problems/equations/tests	25
(4) See how things related to real life	9
(7) Miscellaneous positive experiences	26
(8) Nothing interesting or negative experiences [1)] 33	

* Answers of an individual student may have been classified into more than one category
1) the majority of these comments noted about the errors in the "textbook"

TABLE 5 Categories of students' answers to the sentence completion task: "During the course I often felt..."

Categories of students' answers*	f
(1) Confused or uncertain about understanding	36
(2) I understood/learned the things	35
(3) There was too much paperwork/too little time for the paperwork	35
(4) Tired/frustrated/stressed/nervous	30
(5) Bored/unmotivated	19
(6) There was a hurry	13
(7) How stupid I am	12
(8) Interested/content	10
(9) I knew just a little about gases	7
(10) It was easy/I already knew a lot about gases	6
(11) Miscellaneous negative experiences	15
(12) Miscellaneous positive experiences	6

* Answers of an individual student may have been classified into more than one category

(continues)

APPENDIX 27 (continued)

TABLE 6 Categories of students'comments on the "textbook"

Categories of students' answers*	f
(1) There were errors in the textbook	180
(2) Clear/well organized/easy to understand	97
(3) Good/fine/nice/OK	48
(4) Not good/occasionally unclear/difficult to understand	28
(5) Concise and to the point	17
(6) Interesting	13
(7) Finnish translation did not work well	13
(8) Not enough examples	7
(9) Too much information/too long partly or the whole text	7
(12) Miscellaneous negative comments	18
(13) Miscellaneous positive comments	8

* Answers of an individual student may have been classified into more than one category

TABLE 7 Categories of students' comments about the video programme

Categories of students' answers*	f
(1) OK/fine/good/great/funny	47
(2) Clarifying/well-developed/explained simply	33
(3) Made understanding and learning things or main aspects easier/better	32
(4) Irritating/bad music	21
(5) Too simple/too much repetition	18
(6) Fairly good	16
(7) Too short sections	16
(8) Not useful/could have learned without	16
(9) Interesting/somewhat more interesting than normal instruction	14
(10) Illustrative/helped in visualizing things	14
(11) Visual aspects/animation too simple/clumsy	11
(12) Miscellaneous negative comments	18
(13) Miscellaneous positive comments	19

* Answers of an individual student may have been classified into more than one category

(continues)

APPENDIX 27 (continued)

TABLE 8 Categories of students' comments about the workbook and Task Papers

Categories of students' answers*	f
(1) Clear/nice/good/fine/well-made task/problems	71
(2) Some too difficult (given the time available)	26
(3) Understandable/sufficiently easy or difficult	24
(4) Some/all tasks/problems too simple or easy	24
(5) Fairly good/proper/normal	21
(6)Too few problems/tasks available or too few problems requiring calculations	21
(7) Too little time available for task papers/problems	20
(8) Too many task papers/too much work	18
(9) Correct answers were not available	16
(10) Positive that both easy and more difficult tasks/problems were available	12
(11) Interesting tasks	10
(12) Boring/useless	9
(13) Miscellaneous negative comments	33
(14) Miscellaneous positive comments	16

* Answers of an individual student may have been classified into more than one category

(continues)

APPENDIX 27 (continued)

TABLE 9 Categories of students' comments about the minicourse, in general

Categories of students' answers*	**f**
(1) Refreshing/different for a change	59
(2) Good/OK/well done	58
(3) Interesting	36
(4) Fairly good/I learned fairly well	35
(5) There should have been more time for learning	26
(6) Too much paperwork/questionnaires	24
(7) Prefers "normal" physics lessons	21
(8) Not beneficial/unclear/confusing	16
(9) Would be nice to learn in a similar way in the future	15
(10) Too easy/slow	8
(11) I understood things better than usually	6
(12) Miscellaneous positive experiences	16
(13) Miscellaneous negative experiences	15

* Answers of an individual student may have been classified into more than one category

APPENDIX 28 TEACHERS' (N=16) EXPERIENCES OF THE MINICOURSE BASED ON THEIR RESPONSES TO OPEN-ENDED QUESTIONS

Note that figures in brackets after statements indicate how many of the teachers responded in that way; only frequencies of 2 or more are marked. Also note that a slash (/) separates responses given by different teachers.

TABLE 1 Teachers' (n=16) answers to the question: "What was best in this course?"

Categories of answers	f
The video programme [1]	10
Change compared to normal activities [2]	3
Compared to the textbook used in the school the text was better organized	1
The topic is rather easy and therefore nice to teach	1
No answers	1

1) More detailed: video programme was good (clear/illustrative) or facilitated learning (8) video programme provided change to regular classes (2)
2) More detailed: testing of new material and essay assignments to students, different order of presenting the topic and more "chalk and talk" physic than normally, therefore made to consider the strengths of this way of teaching, changes compared to normal activities.

TABLE 2 Teachers' (n = 16)* answers to the question: "What was worst in this course?"

Categories of answers	f
Too many tests and too much paperwork for students/lack of time	11
Errors in the materials	6
Tasks and assignments were given too soon	2
The tasks of the workbook were either in wrong order (application tasks first) or too repetitive	1
The course was not challenging enough for some students	1
Forgot to mention about using the 2. concept map and multiple-choice questions in evaluation	1
No response	1

* Some teachers gave more than one response. Therefore, the total sum of column f is more than 16.

(continues)

APPENDIX 28 (continued)

TABLE 3 Teachers' (n=16) answers to the sentence completion task: "The best moment during the course appeared when ..."

- The first video section began/ The video was viewed/ The video presentation was dealt with by discussing/ Boyle's law was presented by the animation/ The class went silent to concentrate on watching the video - The first concept map was created - The students said they found contradictions after comparing the text to their textbook; critical readers - The students found the absolute zero point by studying the isobars - One had the students think and discuss the topic - I found how easy it is to teach with ready-made material - The beginning of the course/ We started the course and the end of the course/ It was over, because also students found it heavy - No response (3)

TABLE 4 Teachers' (n=16) answers to the sentence completion task "During the course it was really interesting to ..."

- To observe students working actively/ To see that students at least try to understand the topic in question/ That students worked intensively/ To see students attending to filling in the papers seriously/ To notice that the class concentrates on viewing the video - To observe students' reactions in new situations/ To observe students getting interested in and later getting bored with the same type of questionnaires - Give students problems to be solved - Read students' answers - To notice how remarkable an impact evaluation has on students - Compare the tasks and the video text - Application of gases - To notice efforts in the field of teaching - No response (3)

TABLE 5. Teachers' (n=16) answers to the sentence completion task: "During the course I often felt..."

- Shortage of time (because of many tests) and a need to summarize verbally/ There was too little time for tasks/ There is not enough time/ Anxiety due to the use of time/ Getting nervous when there is not enough time/ The time is too short/ - Competing with the clock - Reading part of the text was the responsibility of the students - Students' role remained little - The laws were presented logically yet the discussion was merely stated facts - That hands are not enough, I would have liked to use our demonstration equipment more - Too large a proportion of the age population has selected the extended course in physics - No response (4)

(continues)

APPENDIX 28 (continued)

TABLE 6 Teachers' (n=16) comments about the textbook

- To the point/ To the point and clear/ Simple and clear enough/ The basic structure of the text fairly clear/ Good order of topics, although students' comment in their experience questionnaires are sometimes not appropriate/ Normal - The beginning of the text (sections 1-4) was pleasantly concise, in sections 5-6 the text sometimes discussed unnecessary areas/ Interesting but too expansive. The text can provide a basis for a separate gas physics course/ The texts are clear, though compared to the physics books [used in school] the content is rather brief - Good text as such. Numerous errors disturbed somewhat/ Too many errors/ Some troublesome errors created confusion/ Errors that also students noted, which may have caused the students to lose their confidence in the text - Occasionally the text is not logical - Far too few examples/ More discussion about everyday situations - A lot of fact-stating text - More deep knowledge/ Challenging tasks were missing - Rather clear, but partly repetitive - No response (1)

TABLE 7 Teachers' (n=12)[1] comments about the video programme

- Good (2)/ A video programme is suitable to the topic like this/ General picture quite nice - Programmes were clear and not too long - General presentation and the laboratory situations were good - The presentation of the gas laws in the video programmes was good and many-sided, I was a little disappointed at the presentation of the kinetic theory of gases/ Illustration of the gas laws good (though some verbal mistakes were present), the possibilities in illustrating the kinetic theory of gases also very good, here it did not quite work/ Wrong presentation of Brown's movement disturbed - Good idea, realization could be better - Partly repetitive, but somewhat illustrative - Quite OK, but a lot of practice is needed to get results - Too much self-evident aspects - Graphical presentations are very easy to do on board (are even more clarifying) - No response (5) including four teachers from control groups that did not have a video programme

1) Four physics groups did not use videos

(continues)

APPENDIX 28 (continued)

TABLE 8 Teachers' (n=16) comments about the workbook and the task papers

Positive comments: - Tasks good, not too hard/ Good/ Feasible/ Quite variable/ Support teaching process - Good discussion questions. there could be more of them. I mean that it would be good to discuss the gas laws qualitatively so that one would be more capable of estimating the result/ Some interesting verbal questions - The tasks of the workbook were generally good, though solving some of them required extra attention to the matter/ With a slower timetable the tasks are suitable - The task papers were in line with other texts **Negative comments:** - Too few tasks/ Hard tasks missing/ Tasks were fairly easy. There could have been more demanding tasks had there been a lot of time to use - I would have placed the tasks of the workbook in a different order and made them more diverse/ The order of the tasks was bad - The gas law tasks repeated the same aspects tautologically/ Tasks of the task papers were of the same type - Answers to the workbook tasks should be provided **Miscellaneous:** - Generally the tasks of the task papers were good. The 2nd task of the 2nd task paper was a little confusing - Task papers were labourious and time consuming; idea good, but the timetable too tight - There were some "cunning" tasks among the tasks. More of them. One hardly needs formula-substitution tasks - Some students confronted the concept of mole for the first time *The following two comments may refer to the text*: Printing errors/ Errors in the workbook changed students'attitudes, but not disturbingly

TABLE 9 Teachers' (n = 16) comments about the course in general

Comments	f
Positive comments about the video programme [1]	4
Works with sufficient time and without too much paperwork [2]	5
Too little time, too much paperwork [3]	4
Miscellaneous responses [4]	3

1) Positive comments about the video programme:
- Good videos have a positive effect on students' attitudes and learning outcomes/ An interesting teaching period. Video programmes are surely suitable also in discussing many other topics that are difficult to illustrate
- Presenting practical applications in the opening and ending sections deserves thanks, though a Canadian emphasis was apparent
- Positive, I will utilize the material in future instruction in my own applied way

(continues)

APPENDIX 28 (continued)

2) Works with sufficient time and without too much paper work:

- The total period was confused due to the continuous tests. During "real teaching" the system works well. There was not much time for discussions/ The extensive rush ruined a good instructional idea. The use of videos in this field of physics is quite reasonable, but the written feedback on every occasion took so much time that there was not enough time for in-depth discussions and physical considerations that in my mind are more important. Also there was not enough time for developing computing readiness, though tasks would have been available/ The study took more time than I would have thought (restricted), later on it is nice to utilize the video programme in teaching the gas laws
- Quite good; the real teaching period does not include inquiries and filling of papers that created aggression and "unnecessary load" on lessons/ Due to the lack of time the teacher felt a little restrained, as he could not really have influence on but had to leave room for the video. However, without question forms the total idea would work

3) Too little time, too much paper work:

- My planned timetable did not work. The topic maybe too broad to be taught in 5 hours if one desires to affect the thought structures. Students got tired of filling in the papers, particularly writing essays was not liked/ The tests took a major part of the total time so that the proportion of in-depth discussion was very little. So an impression was left that students learned qualitatively, but not quantitatively (can describe, but accuracy is missing)
- An interesting experiment, though I do not believe the matter was discussed more deeply than in a normal situation. Perhaps I was not able to get oriented, perhaps the tests messed up the learning situation. Yet I will try it again next year without the extensive questionnaires that are too great a strain on the atmosphere.
- The idea good, but division into periods and use of time must be carefully planned. Not such a fast pace. Could work well, if all the students had the same video tape at home

4) Miscellaneous:

- The teaching period was gone through in a week: in dealing with the kinetic theory, we turned back to our own textbook. Later on we will utilize the information about the phase changes
- I am always ready to try new methods
- We will come to see your oral defence

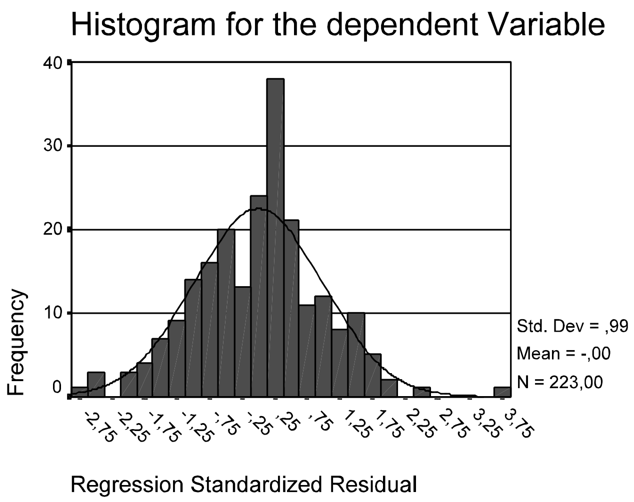
(continues)

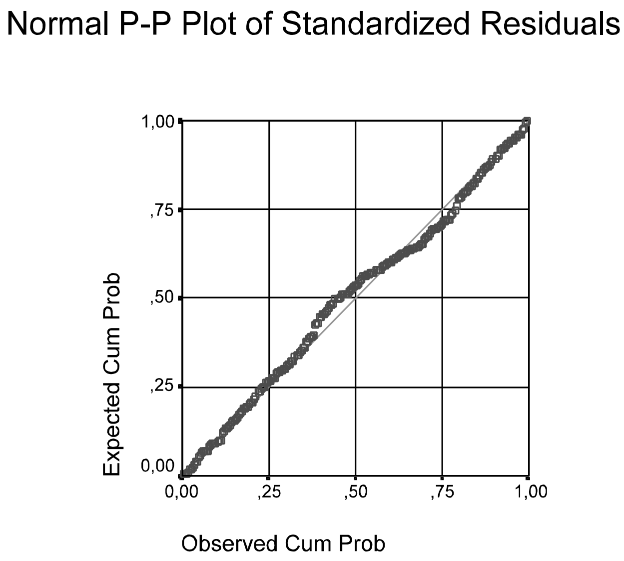
APPENDIX 28 (continued)

TABLE 10 Teachers' (n=16) suggestions for developing the instructional text, the tasks and the video programme

Suggestions regarding the instructional text
- Correct the errors (3)/ Checking the language
- Use the gas law names that have become standard in Finland/ Present Boyle's law in another form (P1V1 = P2V2)/ Emphasize the use of thermodynamic temperature (Kelvin scale) in the gas laws/Teach the general gas law first and derive the specific gas laws (Boyle, Charles, Gay-Lussac) from it
- The mole concept should be presented more precisely
- The discussion of gases should take no more than 3-4 one hour lessons
- The phase behaviour of gases is dealt with in another connection in current textbooks
- Some sections could be more concise/ Instructional text is extensive: the core content could be marked and text that goes beyond the actual course can then be read if one is interested in it/ Some parts of the text could be left out, e.g. from the units on pressure atm and torr could be left out
- The content of the text could be more extensive (e.g. measuring volume, temperature and pressure)
Suggestions regarding the tasks:
- Correct some printing errors and terms/ Check the language of tasks, e.g. the sentence in task no. 38 is too long/ One figure is missing/ Use SI units
- Present basic problems first and application-related problems after/ Increase the number of challenging tasks/ More tasks regarding everyday life
- Increase the number of activity ideas in the workbook
- Correct answers to the problems should be included so that students could check the answers themselves
Suggestions regarding the video programme:
- More molecules in the animation of the kinetic theory of gases, direct and random motion of the molecules (2)/ The basic assumptions of the Kinetic theory should be better presented/ The illustration of the critical point could be better/ More precise presentation of phase diagrams
- Select better music (more variable, not such pounding piano music)
- Leave out unnecessary repetition
- The sections presented at one time could be longer (picking up video equipment for the classroom for the sake of five minutes feels hard)
- A little bit longer blanks between the video sections to have enough time to stop the VCR before the next section
General comments:
- The best students got bored, because they did not feel challenged. The study kit was best for an average and below average student
- Short video programmes can make studying interesting particularly with regard to topics that are otherwise hard to illustrate/ Videos can make theoretically oriented teaching more illustrative
- Suggestions for dividing the topic into lessons could be considered
- No rushing! Spending time accordingly
No suggestions (5)

APPENDIX 29 CHECKING THE ASSUMPTIONS OF THE STEPWISE REGRESSION ANALYSIS (in table 62 - sub-chapter 8.6.4)





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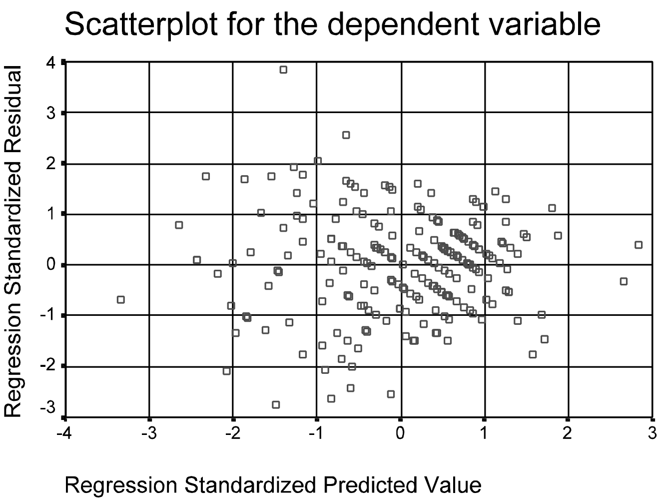
APPENDIX 29 (continued)



APPENDIX 30 VARIANCE COMPONENTS ESTIMATES OF PHYSICS GROUPS (CLASS) FOR THE DEPENDENT VARIABLES IN COVARIANCE ANALYSES (Tables 48, 50-55 in chapter 8.5.2)

Table nro	Dependent variable	Variance (class)	Variance (Error)
48	smgain	2.2	50.7
50	sumtaskp	8.4	50.8
51	taskpgas	10.5	44.5
52	taskpkin	1.2	6.0
53	gainall3	9.0	120.9
54	gainssc	1.3	12.3
55	gainc	1.5	63.6

APPENDIX 31 ESSAYS OF THE CONCEPT MAPS IN FIGURES 8 AND 9

Essay related to the concept map in figure 8:

Kaasut ovat yleensä kevyempiä kuin ilma. Ilmassa on eniten vetyä. Maailma koostuu kaasuista. Jalokaasuja on esim. Radon. Kaasuista pystyy myös tekemään nestettä ja kiinteää ainetta. (esseessä lueteltuja kaasujen nimiä): Vety, Helium, Radon, Arkon, Xenon.

Translation: Gases are usually lighter than the air. Hydrogen is the most common gas in the air. The world is composed of gases. Radon is one of the noble gases. It is possible to make liquid and solid out of gases. (names of gases listed in the essay): Hydrogen, Helium, Radon, Argon, Xenon.

Essay related to the concept map in figure 9:

Kaasuja on satoja erilaisia ja kaasuja voidaan valmistaa. Kaasuja löytyy luonnosta mutta joitain on vain muilla planeetoilla. Kaasua voi mitata ja ne on luokiteltu. Kaasua voi käyttää moniin tarkoituksiin (esim. lämmitys ja valaisu). Kaasut ovat yleensä kevyempiä kuin ilma ja värittömiä. Kaasuja voidaan mitata ja laskea kaasulaeilla (Charles-, Boyle- ja Gay-Lussacin -lait). Kaasut käyttäytyvät hyvin erilailla, kun esimerkiksi lämpötilaa muutetaan. Laskuissa lämpötila esitetään aina Kelvineinä. Kaasuja laskiessa on tärkeä ideaalikaasulaki. Se tarkoittaa, että kaasu käyttäytyisi kaikissa paineissa ja lämpötiloissa samalla lailla. Käytännössä tällaista kaasua ei ole. Kun säilön tilavuutta missä kaasu on muuttaa kaasun painetta. Kaasujen laskemisessa on 3 perussuuretta: lämpötila, tilavuus ja paine. Normaali ilmanpaine on 1.013 bar.

Translation: There are hundreds of different gases and it is possible to make gases. Gases are found in nature, but there are some to be found only on other planets. It is possible to measure gases and they are categorized. Gases can be used for many purposes (e.g. heating and illumination). Gases are usually lighter than the air and colourless. Gases can be measured and calculated with gas laws (the laws of Charles, Boyle and Gay-Lussac). Gases behave very differently when, for instance the temperature is changed. In calculations the temperature is always expressed by using Kelvins. The ideal gas law is important when calculating the gases. It means that a gas would behave in the same way at all pressures and temperatures. In practice a gas like this does not exist. When the volume of a container where the gas is is changed it (changes) the pressure. There are 3 basic quantities when calculating gases: temperature, volume and pressure. Normal air pressure is 1.013 bar.

Note that these essays and related concept maps were produced by the same person, the first ones during the pretest and the second one during the post-test.