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Antti-Jussi Lakanen

On the Impact of Computer Science Outreach Events on K-12 Students

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ABSTRACT

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Many countries have begun to adopt computer science (CS) and computational thinking (CT) into national curricula of compulsory education and upper secondary education. It is argued that learning rigorous CS concepts not only secures a workforce for the future's digital industries but also benefits all students by improving their problem-solving and logical reasoning skills. However, the popularity of CS as a university major declined in the beginning of the 21st century, resulting in the development of a range of student outreach activities to engage young students in the study of computing.

This thesis originated from this need to attract and retain students in the CS field. The focus of this research is in understanding how the outreach impacts student's development of an interest in computer science and engineering studies. The impact is considered from both long-term (from 3 months to 3–5 years) and short-term (ca. 1 week) perspectives. There were two contexts in this study: game programming workshops organized during summer holidays, and technology and programming club events. This dissertation comprises six articles that consider the impact using mixed methods: while qualitative methods were dominant, quantitative methods were also used.

The impact of outreach seems to be two-fold. On one hand, this study indicates that the outreach indeed impacts positively on students' interest towards computer science and engineering studies from the long-term perspective. This positive impact was either "confirmatory" (confirms earlier career aspirations) or "emergent" (individual interest emerges due to participation). On the other hand, there were students whose plans were not affected by the outreach, or, moreover, were disengaged from CS due to the workshop. This latter finding can also be seen as a positive result as the students can make better informed choices due to these experiences. The results suggest that to be able to affect student interest in pursuing CS degrees, it is important to expose students to rigorous CS concepts in a hands-on manner. It is also important for the content to be engaging but at the same time comprehensible to all students. The results also call for more long-term evaluation of student outreach impact on interest development.

Keywords: computer science education, outreach, game programming, K-12

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Antti-Jussi Lakanen

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1 INTRODUCTION

This thesis provides insight into how computer science outreach impacts students. In particular, this study investigates how outreach activities contribute to the development of students' interest in computer science and engineering studies from the short-term as well as long-term perspective. Mixed methods were used as a methodological framework to compose an overall view of the phenomenon. However, the emphasis in this study was on qualitative methods.

There is an increasing tendency to include computer science (CS) and computing skills in compulsory education (Tenenberg and McCartney, 2014; Brown et al., 2014; Hubwieser et al., 2015). This development is also underway in Finland, where computing skills such as programming are clearly articulated in the core curriculum (Opetushallitus, 2014). One of the underlying assumptions of building CS into national curricula is the need for new workforce participants to support the growth prospects of the future's digital industries (Brown et al., 2014; Livingstone and Hope, 2011). More importantly, recent research suggests that learning computing and *computational thinking* (for the initial conceptualization see Wing, 2006; for a more thorough elaboration, see Selby and Woollard, 2014) in compulsory education (years 1–9) and upper secondary education (years 10–12)[1] is beneficial for students in many ways. First, students who learn CS topics in the middle and high school level have a predisposition to more quickly learning more advanced computing topics (Armoni et al., 2015). Second, CS incorporates fundamental concepts of computational thinking, such as problem representation, prediction, and abstraction (Kafai et al., 2014; Sengupta et al., 2013; Comer et al., 1989), and these skills have been claimed to be important skills for the future (Harel Caperton, 2010).

While there is still uncertainty about what computer science education (CSE) really is and how CSE should be implemented in the compulsory and upper secondary education levels (Hubwieser et al., 2015), there is a growing base of evi-

1 The sum of compulsory and upper secondary education is sometimes referred to as K-12, "from kindergarten to 12th grade." Even though the term is typically used in the United States and Canada, I have used it in this thesis to refer to students within the above-mentioned educational level. The term is also used in the articles included in this thesis.

dence suggesting that learning CS also yields transferable skills that are seen as important building blocks of general problem-solving skills (Brown et al., 2014; Akcaoglu and Koehler, 2014). These skills include, for instance, higher-order and algorithmic thinking skills, logical reasoning, and debugging strategies (Wing, 2006; Seehorn et al., 2011; Fessakis et al., 2013; Kafai et al., 2014; Sengupta et al., 2013; Israel et al., 2015; Brown et al., 2014).

Despite the call for more CS professionals, and the arguments that second the position of CS as an important skill both now and in the future, the popularity of CS among incoming university students declined radically during the first decade of the 21st century (Carter, 2006; Vegso, 2005; Huggard and Goldrick, 2006). The downward trend of students majoring in computer science was also present within the local context of the present work, at the Department of Mathematical Information Technology, University of Jyväskylä, Finland. The concern about how to attract more students triggered a project comprising different activities targeted for students 12–18 years of age to engage students towards CS. The project was initiated in the summer of 2009. The current research project was also started during this period.

Efforts to develop strategies, learning environments and activities that aim to engage young students in studying CS, increase their interest in CS careers, and improve their understanding of CS concepts are often referred to as *outreach* (Barr and Stephenson, 2011; Bell et al., 2011; Lambert and Guiffre, 2009; Scragg and Smith, 1998). Outreach programs and activities to raise the interest and engagement of young students in CS have been carried out since the dawn of modern computers (Buchman, 1956). Even though many of the studies investigating CS outreach interventions report, for instance, increased motivation towards learning computer science concepts (Papastergiou, 2009), the data is typically collected prior to and shortly after the outreach events. However, the long-term impact of these interventions has not been intensively studied. This leads to open questions, such as, how does students' interest develop during the three months, one year, or four years following the intervention? Do students independently reengage with CS content, do they persevere when confronted with difficulties when working with the content, and are their career aspirations affected?

Even though this thesis originated from the need to attract and retain students in the CS field, the need for research to investigate the long-term impacts of outreach programs motivated this work. Thus, this work seeks to shape a deeper understanding of the role of student outreach in developing interest in computer science and engineering studies. Additionally, this research focuses on understanding student populations (that is, groups within the student cohort and characteristics of these groups) to be able to conceptualize the factors related to student engagement and interest development. To summarize, the overall main goal of this thesis is to provide both short-term and long-term perspective on the impact of computer science outreach. The exact research questions are elaborated in Section 3.2.

As the present study comprises several individual articles, it covers the role and impact of student outreach from multiple angles. I have included two particular educational contexts: game programming summer workshops and an extracurricular "coding and technology club." As game design has appeared to be a promising approach to interest students in CS (Repenning et al., 2010), we employed that approach in the outreach, using games as a "real-world context" in the assignments and projects. All the individual articles are written in collaboration with other authors. I will present my contribution to these articles in Chapter 4. In article PI, we evaluated the student feedback and highlighted students' interest towards computing and engineering careers, as well as perceptions of the CS field. In article PII, using a follow-up survey, we investigated post-course CS activities. In article PIII, we concentrated on coding club participants' interest development in computing through students' orientation and attitudes towards CS. In article PIV, we differentiated student cohorts using statistical cluster analysis to understand students' motives to participate in the outreach. In article PV, we focused on workshop participants' conceptions of programming. In article PVI, we investigated the impact of outreach on students' educational paths using in-depth retrospective interviews.

In the original articles, we employed both quantitative and qualitative methods. Therefore, I used mixed methods (Johnson and Onwuegbuzie, 2004; Teddlie and Tashakkori, 2009; Venkatesh et al., 2013) as the research approach in this study. The qualitative methods were, however, dominant for several reasons. First, using qualitative methods enabled the participants to express themselves more broadly rather than only filling out numbers in questionnaires. Second, using the qualitative material and multiple methods (questionnaire data, interviews, etc.) it was possible to provide more in-depth perspective on the development of student interest (Renninger and Hidi, 2016, p. 62) along with other perspectives on outreach impact. Third, in several of the individual articles, the number of respondents was too low for reliable statistical analyses; however, statistical analyses were also used where appropriate to complement the qualitative analyses. More in-depth discussion about the methodological approach is presented in Section 3.3.

The following chapters are organized as follows. Chapter 2 provides the theoretical foundation of this work. Chapter 3 presents the context of this study and presents the research questions as well as the methodological framework. Chapter 4 gives an overview of the original articles included in this thesis. Finally, in Chapter 5 the results are discussed and limitations, conclusions, and directions for future research are given.

2 BACKGROUND OF THE RESEARCH

This chapter presents the theoretical foundation that brings together the concepts of interest, interest development, and (student) engagement. Additionally, I discuss related theories that are relevant to this work. Each of these theories is presented on a general level and the linkage to this thesis is discussed. The results of this thesis are also discussed in Chapter 5 through the lens of these theories to describe and weave the aspects of the phenomena emerging from the original articles.

2.1 Interest and interest development

Interest is a powerful driver. In everyday language, the concept of interest is widely used and it often refers to something that makes people get involved, become engaged, move into action, and *do* things. Interest as a psychological variable was being investigated as early as 1897 by Baldwin and through the 20th century by Dewey (1913), Piaget (1968), and Strong (1951), among others. However, as a scientific concept, interest has been elaborated upon in the last thirty years as a result of a range of systematic studies (Renninger and Hidi, 2011, p. 169). The importance of motivation in education, arising from genuine interest wherein a “person has identified himself with” a topic (Dewey, 1913, p. 43), has been underlined by educational theorists. Herbart and Benner (1986) and Dewey (1913), among others, have “demanded to foster the development of lasting (educationally valuable) interests in school, which are seen as a supraordinate goal of education” (Krapp, 2002, p. 389).

In their *four-phase model of interest development*, Hidi and Renninger (2006) propose that the development of interest can be conceptually integrated into a model consisting of four separate phases: (1) triggered situational interest, (2) maintained situational interest, (3) emerging individual interest, and (4) well-developed individual interest. In their model, interest is described as a driver that makes people do things; we are more inclined to commit ourselves to things in which we find ourselves interested. According to Hidi and Renninger, interest has dual meaning: on one hand, interest is defined as a motivational variable, which "refers to the ... predisposition to reengage with particular [content] over time" (2006, p. 112). In other words, interest holds motivational qualities; it is a motivational predisposition. The content with which a person can engage can be abstract or concrete, such as classes of objects, events, activities, or ideas (Hidi and Renninger, 2006; Renninger and Hidi, 2016).

On the other hand, interest also refers to a psychological state of engaging (Hidi and Renninger, 2006), which "is characterized by increased attention, effort, concentration, and affect during engagement" (Renninger and Hidi, 2016, p. 9). It is important to make the distinction between these two meanings. According to Renninger and Hidi (2016), the psychological state is grounded in our physiological and neurological reactions to objects, such as people or tasks. The motivational variable of interest, however, is responsible for the processes that determine how we act, feel, engage, and learn. This is illustrated in the following example (Renninger and Hidi, 2016, p. 9).

> Two children who are playing chess and are in different phases of interest may be in the same psychological state but may differ in their predisposition to return to playing chess another time. The child with less developed interest (triggered or maintained situational interest), may or may not continue to seek opportunities to play, depending on available and competing opportunities; on the other hand, the child with more developed interest in chess (emerging individual or well-developed individual interest) will be motivated to return to play: he will not want to be called away from the game, and, if he is, he is likely to seek opportunities to play chess again just as soon as he can.

According to Renninger and Hidi (2016), there are two common misunderstandings about interest. The first misunderstanding is that it is static (Renninger and Hidi, 2016). In everyday language, it seems very usual to talk about and conceptualize interest as something that either is present or absent. However, recent studies on interest show that while conceptualizations of interest vary (Renninger and Hidi, 2011), many researchers agree that interest does indeed have the ability to develop (Hidi and Renninger, 2006; Krapp and Prenzel, 2011; Silvia, 2005; Schiefele, 2009). The second misunderstanding, related to the first one, is seeing interest as a characteristic of a person, a trait, or something that a person is born with (Renninger and Hidi, 2016). However, interest is not "cemented" or built into a person. Instead, the person together with the environment defines the direction of interest and contributes to its development (Hidi and Renninger, 2006, p. 112). This second misunderstanding is particularly serious when a teacher or educator believes that a student either has or does not have interest towards certain content, such as technology or engineering fields. In such cases, the teacher can refrain from providing the student with a learning environment or instructional conditions that would support the development of the student's situational or (emerging) individual interest. Naturally, this can have major implications on the student's career aspirations. Indeed, Hidi and Renninger suggest that educators are in a position to make a significant contribution to students' academic interest, emphasizing that interest is the outcome of an "*interaction* between a person and a particular content" (emphasis added) (2006, p. 112).

In an educational context, interest has been studied to predict choice of academic major of college students (Harackiewicz et al., 2002). Interest-triggered learning activities have been alleged to yield better learning results and a higher degree of deep-level learning. According to Singh et al. (2002), there is research evidence suggesting that interest, along with motivation, attitudes, and academic engagement (active involvement, commitment, and attention), seems to be a critical construct related to learning. Interest also plays an important role in choosing a career. Interest has been found to have an influence on student's educational aspirations and the choices he or she makes regarding his or her career (Krapp, 2000). For instance, exposing children early to science correlates with choosing a science-related career (Tai et al., 2006). In their study about attrition among science, mathematics, and engineering majors (SME), Seymour and Hewitt (1997, p. 66) state that "the best foundation for survival and success is to have chosen one's major because of an intrinsic interest in the discipline and/or in the career fields to which it is leading." Their findings suggest that it is very important that students who choose to pursue engineering degree choose to do so for the right reasons. That is, the students who persist in SME fields have likely chosen to pursue that field based on intrinsic interest rather than influence of family members, high school teachers, or materialistic reasons.

Basing one's perception of a future career solely upon good grades or success in a particular school subject may result in negative ramifications on self-confidence and persistence. In the study by Seymour and Hewitt (1997), students' that too narrowly based their mathematics or science career choices upon experiences and good scores in high school were disappointed when they realized that studying in college can be different from what they had expected. Seymour and Hewitt (1997) call these "uninformed choices" based on students' "blindness" to the realization that they had chosen a science-based major because it seemed like a logical extension of high school science or mathematics. In the context of this thesis, this phenomenon is also pronounced in computer science, although rather than being a distinct school subject, CS learning has been designed to penetrate the whole curriculum. From this perspective, to minimize the possibility of uninformed choices, it is important to provide the students with opportunities to "try out" working with computer science content to determine whether they see value in that for themselves. This was one of the goals of conducting our outreach program in addition to developing (increasing) student interest towards CS. To make informed career choices about CS, it is important to understand what computer science is about and, in particular, build an understanding that computer science is more than just programming (Denning and McGettrick, 2005). At the same time, CS outreach programs can raise awareness of the academic environment, learning goals, and contents of the CS field to relieve the tension between middle and high school curricula and university "expectations."

The previous findings from recent research underline the need for the concept of interest in this thesis. As this work seeks to gain understanding of the role and impact of student outreach, it is important to look at the *actions* of the students. These actions are certain "turning points" and can be preceded by certain events, circumstances, or happenings in life, but the central aspect of the development of interest is studying the student's line of activity. Dewey, one of the earliest researchers of the interest concept, states (1913, p. 43):

> [g]enuine interest, in short, simply means that a person has identified himself with, or has found himself in, a certain *course of action*. Consequently he is identified with whatever objects and forms of skill are involved in the successful prosecution of that course. (emphasis added)

From this premise, the motivational variable of interest relates to this study in particular: the motivational variable of interest makes a distinction between shorter-term (situational) interest and longer-term (individual) interest (Renninger and Hidi, 2016). Further, the four-phase model describes interest as something that is developing over time. These distinctions make it meaningful to pose the question about the impact of student outreach, as the impact of outreach on a person can be characterized by their predisposition to reengage themselves with the content over and over again, during a period of time.

In addition to interest-based choices, other voices about conceptualizing students' career decision processes exist. Framing their study in expectancy–value theory (see Eccles, 2005; Wigfield and Eccles, 2000), Matusovich et al. (2010) proposed that attainment value (the consistency with personal identity or sense of self; see Eccles, 2005, p. 109) plays a prominent role in how the students' engineering-related values contribute to their choices to engage and persist in earning engineering degrees. Thus, choice to become an engineer depends on the types of value or personal importance that students assign to earning an engineering degree (Matusovich et al., 2010). The perceived importance of doing well on a task, and the consistency of engaging in the activity with self-concept, can be more important than the cost (the price of success) or utility (the perceived usefulness) when engaging in earning an engineering degree. This is different than the intrinsic interest point of view, suggesting that while students can have only little connection between engineering and student's sense of self, he or she still might persist in earning an engineering degree for other reasons including a high utility value. These reasons could include, for instance, pressure to earn a high salary or desire to help support one's parents (Matusovich et al., 2010, p. 299).

Next, I will concentrate on the different phases of interest of the four-phase model. The four phases of the interest development theory (Hidi and Renninger, 2006) are presented in Figure 1.

Situational Interest

Interest and its development start through situational phases (Hidi and Renninger, 2006; Krapp, 2002; Schiefele, 2009; Krapp and Prenzel, 2011; Hofer, 2010). This early phase (or phases) of the developing interest may arise in a short period of time but are vulnerable to interference. The first two phases, triggered and maintained situational interest, are psychological states that result from short-term changes in affective and cognitive processing associated with particular

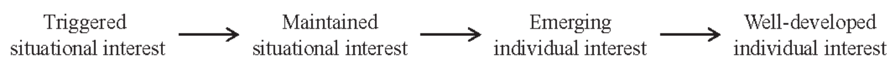

FIGURE 1 Four-Phase Model of Interest Development (adapted from Hidi and Renninger, 2006)

content (triggered) and involve focused—possibly repetitive—attention and persistence over time (maintained) (Hidi and Renninger, 2006; Renninger and Hidi, 2011, 2016). For instance, situational interest can be triggered by surprising information or in a learning environment including group work or computers. Then, as the learner finds tasks meaningful or becomes involved personally in the activity, his or her situational interest can be maintained.

Individual Interest

The latter two phases, emerging and well-developed individual interest, refer to psychological states as well as the beginning phases (emerging) or later phases (well-developed) of a relatively enduring predisposition to reengage with a particular class of content over time (Renninger and Hidi, 2016; Hidi and Renninger, 2006; Renninger and Su, 2012). Further, Hidi and Renninger (2006) suggests that positive feelings, stored knowledge, and stored value characterize emerging individual interest. During the individual phases of interest, a student begins to ask questions out of his or her own curiosity (Lipstein and Renninger, 2007), set challenges for himself or herself, and produce effort that feels effortless (Hidi and Renninger, 2006; Lipstein and Renninger, 2007; Renninger and Hidi, 2002). When moving to a stage of a well-developed individual interest, the learner can sustain long-term constructive and creative endeavors (Izard and Ackerman, 2000) and generate more types and deeper levels of strategies for work with tasks.

Well-developed individual interest activates students in creating links between practice and theory by themselves, which is an ability that helps students in building motivation in courses that are not in the area of their specific (individual) interest (Mikkonen et al., 2013). During his or her studies, a student may ask himself "why do I need this course," but recognizing the usefulness of new knowledge (theory) in relation to future goals (practice) keeps the student motivated even though particular content might not touch the areas of his or her individual interest (Mikkonen et al., 2013; Hidi and Renninger, 2006; Sansone et al., 2000).

2.2 Engagement

> An engaged student is a motivated student. (Norman and Spohrer, 1996, p. 26)

Student engagement in a classroom instruction setting has drawn much attention and has been studied widely in recent decades. From a teacher's perspective—I am one myself—we always like to see our students get engaged with the content they are working with so that the experience is pleasurable and memorable (O'Brien and Toms, 2008) rather than boring and something that students will, or even want to forget. Several studies have identified different manifestations of student engagement in schools, and examined the conditions that either promote or hinder student engagement (Finn, 1989; Finn and Voelkl, 1993; Maeroff, 1998). In earlier research, attention has been payed to, for instance, how the characteristics of teachers and teaching (Klem and Connell, 2004), school culture, and policies (Newmann et al., 1992) affect student engagement. In computing and engineering, the ability to engage in problem solving or designing artifacts, such as computer programs, has been seen as essential to future engineers (Daly et al., 2014; Prahalad and Ramaswamy, 2003), and much work has been put into enhancing student engagement in computing classrooms (Crouch et al., 2004; Rubio et al., 2015). In particular, the effects of computer games on student achievement and motivation have been investigated with increasing intensity in the last twenty years. In general, the results show that computer games can be utilized in formal learning environments to achieve better learning results (Tüzün et al., 2009; Adams, 1998; Virvou et al., 2005) and yield better motivated participants in the school environment (Tüzün et al., 2009).

One of the most important findings is that student engagement is linked to successful school completion. For instance, as a result of engaging, student participation with the schooling process fosters a sense of commitment and belongingness that contributes to school completion (Christenson et al., 2001). On the other hand, negative impact of nonparticipation on academic achievement has been found as well (Marks, 2000; Finn and Cox, 1992; Laffey, 1982; McKinney et al., 1975; Swift and Spivack, 1969). A variety of studies also provide evidence suggesting that engagement positively influences achievement. More specifically, a link between specific constructs incorporated into definitions of emotional engagement, such as interest, has been documented to have associations with achievement (Pintrich and De Groot, 1990; Schiefele et al., 1992); however, causal direction, such as whether interest causes achievement or vice versa, has not been completely shown (Fredricks et al., 2004, p. 71).

The conception of student engagement can be examined, for example, from the perspective of overall involvement with school (Finn and Voelkl, 1993), participation (Kuh et al., 2011), and motivation to learn (Shernoff and Hoogstra, 2001), as well as interest and emotional involvement with school (Steinberg et al., 1996). Further, as reviewed by Henrie et al. (2015), student engagement can also be defined as investment or commitment (Marks, 2000; Newmann et al., 1992; Tinto, 1975) or "effortful involvement in learning" (Astin, 1984; Pekrun and Linnenbrink-Garcia, 2012; Reschly and Christenson, 2012; Terenzini et al., 1982). Philosophical inquiries addressing ethical and political issues relating to student engagement have also emerged. McMahon and Portelli (2004, p. 70) put forward that engagement "is realized in the processes and relationships within which learning for democratic reconstruction transpires." Thus, there is variety in terminology and definitions, and each of these definitions has its own nuances, and reference to a particular definition or definitions is needed when inspecting the aspects of student engagement.

In their review, Fredricks et al. (2004) found that researchers describe three definitions (or conceptualizations) of engagement: behavioral, emotional, and cognitive engagement. Of these three definitions, behavioral engagement concerns behaviors and participation, such as "involvement in learning and academic tasks" (Fredricks et al., 2004, p. 62). This involvement implies a behavioral component and emphasizes the criticality what the individual does and how he or she behaves rather than what the individual thinks or feels (Astin, 1984, p. 519). Further, behavioral engagement includes behaviors such as effort, persistence, concentration, and attention. The activities for participation can be school activities that are academic and nonacademic. However, Finn (1989) makes a distinction between different levels of activities: those activities that require stronger student initiative, such as involvement in summer outreach events, are qualitatively different from the activities requiring less student initiative, such as involvement in classroom activities led by a teacher.

On the other hand, emotional engagement refers to "students' affective reactions, such as interest, happiness, boredom and anxiety" (Fredricks et al., 2004; Connell and Wellborn, 1991; Skinner and Belmont, 1993). Behavioral and emotional engagement in particular, along with cognitive engagement, have been linked to important educational outcomes, like student persistence in learning (Henrie et al., 2015; Kuh et al., 2008; Berger and Milem, 1999; Fredricks et al., 2004).

While multiple definitions for the term exist, in this work, when speaking about engagement, I mainly refer to behavioral engagement and emotional engagement. As the main focus of this thesis is investigating the student interest, (self-reported) activities, and orientation after attending outreach intervention, I have identified my research with behavioral and emotional engagement. In the articles included in this thesis, I address student effort, persistence, and contribution in class-related activities, which are components of behavioral engagement (Birch and Ladd, 1997; Finn et al., 1995; Skinner and Belmont, 1993). On the other hand, the development of student interest towards computer science, engineering, and science is discussed; thus I consider it important to make a distinction and to examine the students' affective reactions to the outreach in the sense of emotional engagement (Fredricks et al. 2004; also see Eccles 1983).

Computer science has been reported to be an engaging subject (Keller, 2010; Shernoff et al., 2003): In the K-12 level, CS as a school subject is found to engage students to the same degree as art studies (Shernoff et al., 2003). To further motivate students into studying CS and bringing CS into context, games have been used as an instructional component (Young et al., 2012; Annetta et al., 2009). Games have been used not only at the K-12 level but also at the university level to motivate learning contents (Lakanen and Lappalainen, 2014) and to decrease attrition among CS students. Finding areas of application where students have some familiarity but that still offer challenging and engaging examples can be tricky (Sanchez et al., 2007). Being "divorced" from the reality of the application can be unappealing for students regardless of age (Bayliss and Strout, 2006). As an area with demonstrable attraction for K-12 students, computer games seem to motivate students (Sweedyk et al., 2005; Wolz et al., 2006; Cliburn, 2006; Barnes et al., 2007, 2008) and increase their interest in selecting computing majors (Wallace et al., 2008; Rankin et al., 2008; Parberry et al., 2005; Wallace and Nierman, 2006). Outlining the game assignments with structure and including components from games that the students already know has been particularly fruitful (Cliburn and Miller, 2008).

Along with possessing an inherent appeal to students, games give teachers an entertaining way to introduce the otherwise technical practice of programming (Basawapatna et al., 2010; Squire, 2003; Sturtevant et al., 2008). Game development environments along with contextualized content often enable students to quickly create simple games. This fast "creation–feedback" loop can help students, as well as teachers, recognize computational thinking patterns during and after creating games (Repenning et al., 2000; Basawapatna et al., 2011), to some extent better than conventional programming (Sturtevant et al., 2008; Squire, 2003). Despite the presented benefits of using games, divergent opinions about their effectiveness as a part of programming courses have been voiced, especially when it comes to retention of females and other underrepresented groups who some argue are not as interested in games (Walker, 2003). One method of bringing down the obvious imbalance is introducing the game programming tasks along with storytelling components built into the curriculum (Howland and Good, 2015; Dann and Cooper, 2009; Kelleher and Pausch, 2005, 2007; Denner et al., 2012; Moskal et al., 2004).

2.3 Career Self-Efficacy and Flow

Career Self-Efficacy Theory

Betz and Hackett (2006) connect the choice of occupation to the development of interest in that person's beliefs of self, in particular perceptions of his or her own competence and the ability to succeed (e.g., in a career) greatly affect the choice of occupation. The research on career self-efficacy is based on the social cognitive career theory (SCCT) and the social cognitive view of self-efficacy (Bandura, 1986, 1993, 1997) as a dynamic (that is, not static nor passive) set of self-beliefs that interact with other people, behaviors, and contextual factors (Lent et al., 1994, p. 83). SCCT also includes a person's beliefs about probable response outcomes, called outcome expectations ("can I do this," and "if I do this, what will happen"), as well as goal setting, such as career plans, decisions, aspirations, and expressed choices (Lent et al., 1994, pp. 82–85). In this model, "interest is considered to be an outcome of cognitive evaluation" (Renninger and Hidi, 2016). The career self-efficacy theory enables very interesting vantage points when inspecting the computing and engineering education. One of the long-lasting issues in the technology, engineering, and computer science have been the underrepresentation of women pursuing these careers. The conclusions drawn within this branch of interest research suggest that if students do not think, or believe, they can pursue a career in technology and engineering (among mathematics and science), they will not have an interest in pursuing it (Lent et al., 2005). Similar observations have been made by Saarela and Kärkkäinen (2014). Though Lent et al. (2005, p. 90) conclude that their study does not fully explicate the gender imbalance in the technology field, it suggests that self-efficacy is a building block of interest, which in turn contributes to goals and choice of university major. Further, Lent et al. (1994) claim that students form a sense of their efficacy on particular tasks through repeated activity engagement, learning experiences, and feedback from important others, such as family members.

Flow

Csikszentmihalyi describes the concept of flow as "a state of deep absorption in an activity that is intrinsically enjoyable, as when artists or athletes are focused on their play or performance" (1991). The symbiotic relationship of a person's challenge and skills is highlighted; the experience of flow is believed to occur when one's skills are utilized with an optimal intensity to meet a given challenge. Flow theory has been found to be linked to classroom engagement in that challenge, skills needed to complete the activity, and relevance of instruction have been seen to be conditions of overall engagement (Shernoff et al., 2003). Further, in the context of computer games and the gaming community, flow theory is widely accepted for generating and studying engagement in games (Iqbal, 2012). In this regard, facilitating the emergence of flow in a learning setting can greatly help students to overcome difficulties but also enable students to spend more time on task, thus yielding better learning results.

3 THE STUDY

In this chapter I will shortly review some of the related work regarding outreach activities. After that, I describe the context of this particular study—that is, the game programming workshops and coding clubs—consisting of motives for conducting the outreach project and objectives and content of the workshops. In addition, I briefly cover the practical arrangements, such as programming tools, and demographic data about the students. Finally, I present the research questions and research approach.

3.1 Context of the study: game programming workshops and coding club

A variety of outreach strategies and activities have been conducted by colleges and universities, departments of education, among others, since the beginning of modern computing. One of the earliest reported outreach programs emerged in 1956 by Buchman when a course in computer programming and coding was being offered to a group of high school students. It was believed that not only the visit to an authentic environment, industrial establishments in this case, but also the hands-on experience in programming the machines "can do much to interest pupils in careers in the field of machine computing" (Buchman, 1956, p. 4).

In the more recent years, much effort has been put in acquainting young students with computing-related studies and careers (Egan and Lederman, 2011; Maxim and Elenbogen, 2009; Maxim et al., 2007; Lakanen et al., 2014). These events can be based, for example, on programming in general (Koorsse et al., 2015) or more specifically on game programming (as in this study) (Akcaoglu and Koehler, 2014; Howland and Good, 2015; Rodríguez Corral et al., 2014). Further, outreach topic often include electronics (Lau et al., 2009), robotics (Huggard and Goldrick, 2006; Doerschuk et al., 2011, 2007; Karp and Schneider, 2011), and contests involving a wide range of computing activities (Maxim and Elenbogen, 2009). Though some of these activities are "one-off" activities, many programs have been doing long-lasting work in encouraging students to pursue computing careers. In the United States, the National Science Foundation has had an important role in funding computer science outreach along with more general STEM (Science, Technology, Engineering and Mathematics) intervention programs; these programs are reviewed in Crutchfield et al. (2011).

In pursuing to increase interest in computing, often the motivation for conducting these activities is being emphasized by the weak status of CS in schools. One of the most important examples is England where the on-going change for the nationwide CS curriculum will give all students the possibility to learn CS core concepts through, for instance, programming (Brown et al., 2014, 2013). From this premise, similar attempts have been carried out in the United States. In a study by Guzdial et al. (2014), multi-faceted set of interventions included summer camps and after-school programs targeted to 4th–12th grade students as well as teachers. As a result of the multiple interventions, the study suggested that not only did participating in the outreach affect students' decision to choose to major CS (Harriger et al., 2012; McGill et al., 2015; Moskal et al., 2007), but also got more support from the policy stakeholders that will help to make CS to be available to more students, hopefully even nationwide (Guzdial et al., 2014).

The current research emerged during the student outreach project that was initiated in the summer of 2009, when a project group in my department started to run an outreach program for students 12 to 18 years of age. The outreach program first included week-long programming workshops during schools' summer holidays, between June and August. Later, a coding club activity was also included in the program to reach students during the school year. It has been claimed that students do not pursue education in computing fields because they do not have sufficient information about these fields (Carter, 2006). With this in mind, we targeted our activities for all students from the start, rather than focusing exclusively on students who were already interested in computer science or engineering careers. In this way, we wanted to answer the call to spread more information about what the study of computing involves and what sort of careers are available to computing professionals (Carter, 2006).

Besides the workforce argument, and other motives presented in Chapter 1, we must not forget the local and regional motive for conducting the outreach project described in this thesis. At the Department of Mathematical Information Technology, during the first decade of the 21st century, the decline in students majoring in computer science in the local area followed the global downward trend (Vegso, 2005; Frauenheim, 2004; Carter, 2006). The reported positive experiences from workshops arranged elsewhere, combined with the urge to bring more students into the field, encouraged us to develop the outreach program.

The objective of the summer workshops was to introduce middle and high school students to the discipline of computing and nurture creative computational thinking, as introduced in Chapter 1. To further motivate different aspects of computing and computational thinking, the course material and exercises dealt with computer games. The five-day workshop included training on problem solving and hands-on tutorials on programming computer games. Students formed teams (or worked alone) to design and develop their own game projects. Each student presented his or her project on the last day of the course. By doing so, they also competed for best project award. The games were made using an open source game programming library, Jypeli, developed in-house. Visual Studio was used as an integrated development environment. After the workshop, the students were given the necessary tools and materials to continue developing games on their own. Also, the students were introduced to the computer science studying opportunities in the University of Jyväskylä.

To summarize, the main objectives of the workshop were to

– Give middle and high school students an overview of programming with a real-world context (games);
– Motivate students to study more computer science, engineering, and mathematics;
– Give students relevant information about computer science on which they can base their choice between different alternatives for further studies and careers; and
– Let young students have fun with computing and give a positive experience of successfully making a working computer game.

The timetable of the workshop is presented in Figure 2. It consisted of lectures, tutorials and exercises, design and implementation of a game, and final showcase. Lectures or other teacher-led portions are indicated by dark areas in Figure 2, while the time spent in computer labs with problem-solving activities and programming assignments is indicated by white areas. The lectures were interactive, promoted active learning, and lasted 30–45 minutes each. The purpose of these sessions was to orient students to programming thinking and acquaint them with basic programming concepts and language syntax by showing illustrative examples. There was a maximum of two lectures per day, about 7 hours in total during the week.

During the first and second day of the course, all students made a classic *Pong* game by following a detailed tutorial consisting of seven phases, each addressing a particular programming concept (variables, procedures, handling keyboard input, etc.). There were also a number of exercises available for those who assimilated the content of the tutorial rapidly. All the tutorials were freely available on the workshop website, and students could use them as self-study material. While making these exercises, the students got used to the syntax of C# language and common programming structures, such as conditionals and loops. The code written in the Pong tutorial and the exercises could be utilized later on when students started writing the code for their own game.

Making their own games was naturally the most anticipated part of the course. Each student was guided to make a story or a plot (verbal design) and to draw a sketch (visual design) for the game. Students also designed visual elements for their game by drawing game characters and sprite graphics for the game elements. The stories and sketches were shared with other students in the

	Mon	Tue	Wed	Thu	Fri
9 am	Starting info	Functions	Loops, random numbers, gravity	Classes and methods of Jypeli library	How to continue at home
10 am	Get to know the tools	Carrying on with the Pong game	Designing and implementing own game	Implementing own games	Finalizing own game
11 am	Making the first game (Pong-tutorial)	Finalizing the Pong game	Implementing own game		
12 pm	What are algorithms	Handling collisions	How to make a level out of a tilemap (grid)		Showcase and best game voting
13 pm—15 pm	Carrying on with the Pong game	Designing own game	Implementing own game		

FIGURE 2 Timetable of the summer workshop

course wiki environment. The time reserved for students to create their own games was around 12 hours.

The workshop model underwent only small changes during the years. From the second year onward, one of the workshop weeks has been held off-campus, about 35 kilometers outside of the Jyväskylä. This particular week was marketed as a “programming camp” in an effort to attract students outside Jyväskylä region. While all the other workshops were free of charge for the students, the camps were subject to a fee that covered the accommodation and food, such as catering. All the other workshops were arranged within the university facilities. Further, changes to the workshop content have been very subtle, and, for example, the timetable has remained the same over the years. This enabled the survey data collected in the workshops to be considered cohesively and made it easier to analyze the gathered data. The teaching team has naturally experienced some changes. The author of this thesis was the corresponding teacher of the workshops until the summer of 2014. From the summer of 2015 onward, the lead of these workshops has been transferred to other staff of the department. However, all the activities described above have been supported with a teaching team with a mixture of technical knowledge (developers) and pedagogical expertise (qualified teachers).

Four to six instructors were available to the students in each course. The technical expertise of the teaching team guaranteed that students’ design ideas could be realized and new features could be added to the Jypeli library on the fly. From the pedagogical point of view, students were not only supported but given

TABLE 1 Participant statistics from summer workshops 2009–2015.

Year	Workshops	Participants	Boys	Girls
2009	2	45	38	7
2010	5	105	99	6
2011	4	83	74	9
2012	5	114	108	6
2013	5	115	112	3
2014	5	124	115	9
2015	5	116	110	6
Total	31	702	656	46

sufficient space to experiment with the exercises. For example, when they had produced some game content, they were immediately prompted to manipulate it (e.g., size) to discover the role of different structures in the code.

On the final day of the course, each attendee demonstrated the game to the rest of the class and lively discussions followed. Students voted for the best game, which was rewarded with a small prize. The number of summer workshop participants is presented in the Table 1.

The second context, presented in article PIII, was the technology and coding club, which was established as a continuation of the game programming summer workshops. In article PIII, the club activities during the academic year 2012–2013 were inspected. The club days were arranged on the weekends, once or twice a month, and a typical duration for the activity was 5–6 hours. The number of students participating each club day was around 25–30. Both outreach activities, the summer workshops as well as the coding clubs, have continued since writing these articles and are still active at the moment of writing this thesis.

3.2 Research questions

The main goal of this thesis is to provide a deeper understanding of the role of student outreach and its short-term and long-term impact on developing interest in computer science and engineering studies. In particular, I am focusing on the game programming outreach events held by the University of Jyväskylä, department of Mathematical Information Technology, during the years 2009–2015. In order to achieve this goal, it was important to answer the main research questions. The research questions are as follows.

1. Does participating in an outreach intervention impact the development of a student's interest in computer science and engineering studies? If it does, how?
2. Does participating in an outreach intervention result in a change in student's conception of computer science and engineering studies? If it does, how?

3.3 Methodological framework: mixed methods

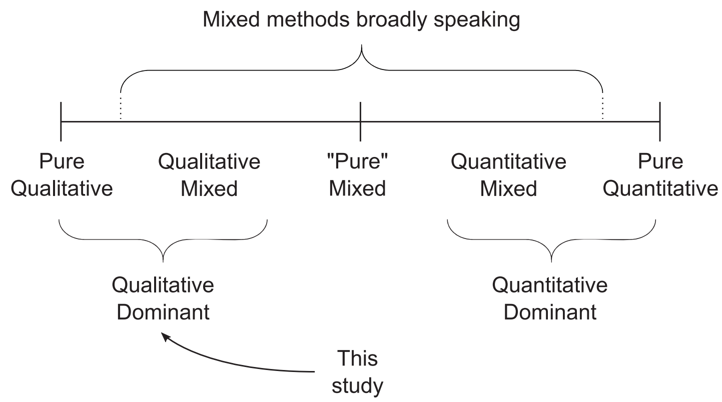

FIGURE 3 Mixed methods, and the current study, in relation to the qualitative-quantitative continuum (adapted from Johnson et al., 2007)

Mixed methods (MM) research has been defined as "a type of research design in which QUAL [qualitative] and QUAN [quantitative] approaches are used in types of questions, research methods, data collection and analysis procedures, and/or inferences" (Teddlie and Tashakkori 2003, p. 711; also see Greene and Graham, 1989; Johnson and Onwuegbuzie, 2004; Teddlie and Tashakkori, 2009; Venkatesh et al., 2013). MM is an expansive, creative form of research that suggests that researchers take "an eclectic approach to method selection and the thinking about and conduct of research" (Johnson and Onwuegbuzie, 2004, p. 17). In particular, MM has been advocated by social and behavioral scientists recent years starting from since the 1950s (Teddlie and Tashakkori, 2009, 2003). MM is also seen as a sampling strategy and a strategy to include multiple types of data, design, and analysis approaches within the study (Patton, 2002).

There is an on-going discussion about whether MM is actually anything new or is little more than a "fad" (Fetters, 2016). Further, it has been argued that research that combines qualitative and quantitative methods and data has been around for quite a long time in, for instance, natural sciences, physical sciences, geology, and social sciences, and just within the past 50 or 60 years researchers have begun to self-define the MM community and even positioned themselves in the center of this movement (Maxwell, 2016). However, many MM researchers make a clear distinction between the traditional quantitative and qualitative research traditions, and MM has in fact has been categorized as "the third methodological movement" in addition to quantitatively oriented scientists primarily working within the postpositivist or positivist paradigm and qualitatively oriented scientists primarily working within the constructivist paradigm (Teddlie and Tashakkori, 2009, p. 4).

On the other hand, the approach of mixing several research methods often flows from the pragmatic need to seek compatibility and integration of data acquired through qualitative methods with data acquired through quantitative methods (Patton, 2002, p. 556). This pragmatic need led to the utilization of multiple methods, both qualitative and quantitative, in the present study. One of the foci of this thesis is the long-term impact of the student outreach. As a traditional longitudinal study is a correlation research study that involves repeated observations of the same variables over long periods of time—often many decades—it would not be possible to conduct such a study in the time period given for this dissertation. Thus, another research approach had to be chosen and instead, in this thesis I will focus on understanding the impact of outreach in student's interest development. In order to shed light on this, multiple methods that were "more pragmatic" based on available resources (man-year, financial, time) were utilized.

Triangulation design is one of the four major mixed method designs (Creswell and Plano Clark, 2011), in which quantitative and qualitative data are collected and analyzed during the same phase (Plano Clark et al., 2008). After the analyses, the results are merged together into one interpretation (Plano Clark et al., 2008; Creswell and Plano Clark, 2011). The overall intent of conducting mixed methods research with a triangulation design is to develop a better understanding of a topic by obtaining two different but complementary types of data (Morse, 1991; Plano Clark et al., 2008). Denzin (1978) continues even further and differentiates this data triangulation (multiple data sources are included in the design) from methodological triangulation, where different methods of analysis are applied to the same data.

In the present study, the gathered quantitative and qualitative data can be seen as a one-phase design, as either one of the different methods was not required or needed in order to proceed with the other method. Thus, even though the different articles and gathered data were spread chronologically, from the research design perspective, the data from the different datasets were in one phase and can be used to form an overall interpretation. From this perspective, this study did not begin with a systematic plan of the whole research process, where each step of the data acquirement and analysis had been planned from a "pure" mixed method perspective (see Figure 3). The general triangulation design is illustrated in Figure 4. This study started by collection and analysis of questionnaire data that was acquired through a survey. Here, using quantitative methods and descriptive statistics, I wanted to gain an understanding of the student populations. However, after examining the data and after collecting more data from the subsequent outreach interventions, the need to strengthen the research approach by using several methods became evident. Applying methodological triangulation and data triangulation enables making comparisons and contrasts to be drawn, thereby synthesizing what is learned from each individual article.

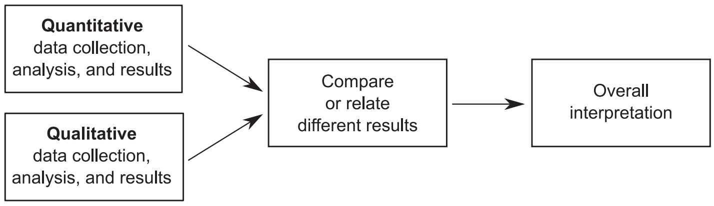

FIGURE 4 Triangulation design of mixed method research (adapted from Plano Clark et al., 2008)

Mixed methods were used in this thesis not just to add additional methods for the sake of "more" but to provide an approach to research design in which all the different methods inform one another (Hesse-Biber and Leavy, 2008, pp. 359–360). In particular, by gathering multiple types of data and using multiple analyses, it was possible to explain the results derived from analyzing only the qualitative data (Hesse-Biber and Leavy, 2008, pp. 366-371). Here, combining different strategies enabled me to compose an unrestrained and creative form of research (Johnson and Onwuegbuzie, 2004; Johnson and Turner, 2003) to (1) gain a better overall view of the students, (2) elucidate the divergent aspects of the phenomenon (Johnson and Turner, 2003, p. 299), and (3) gain a more in-depth view of students as individuals. Using this unrestrained form of research, I explored how the outreach, realized through two different activities (summer workshops, coding clubs), impacts students' interest from both short-term and long-term perspectives.

The emphasis in this study is primarily on qualitative research; this study is more focused on single events (more precisely, student outreach as a series of events) and understanding the phenomena rather than primarily on generalizations. I intend to demonstrate the intrinsic uniqueness of the students, discover phenomenon concerning the students, and generate ideas and theories rather than testing prior hypotheses.

Table 2 presents a summarized account of the articles included in this dissertation. The research methods used in the articles are described and discussed in the following sections.

TABLE 2 A summary of the foci, outreach contexts, participants, data, and analyses in the original articles. SW = Summer workshop, CC = Coding club.

Article	Focus	Context	*n*	Data acquired with	Analysis
PI	Interest in CS, short-term analysis of the workshop feedback	SW	150	Pre- and post-surveys	Descriptive stats, QUAL exploration, theoretical argumentation
PII	Engagement and (middle-term/long-term) reengagement with CS content	SW	58	Pre-, post-, and follow-up surveys	QUAN & QUAL analyses
PIII	Interest development (long-term) and predisposition to reengage with CS	CC	51	Survey	QUAL categorization
PIV	Differences in student populations, short-term interest development in CS	SW	462	Pre- and post-surveys	QUAN & QUAL analyses
PV	Student conceptions of programming	SW	541	Multiple surveys	Phenomenography
PVI	Long-term impact of the workshops on career choices	SW	20	Retrospective interviews, survey	QUAL categorization, theory-addressing, data-driven

3.4 Conventional content analysis

Qualitative content analysis was used in articles PI, PII, PIII, PIV, and PVI. In most of the original articles, data was gathered primarily through open-ended questions using a survey. Regarding the data that was acquired via interviews, questions were specific to the participant's comments rather than attempting to link the questions to a preexisting theory. Hsieh and Shannon (2005) call this approach *conventional content analysis*, where after the data gathering, the researcher approaches the data by capturing key concepts, thoughts, or ideas from the data. During the analysis process, the researcher labels the data with emergent coding that reflects the discovered concepts, thoughts, and ideas, forming categories that organize the codes into meaningful clusters (Hsieh and Shannon, 2005; Patton, 2002; Coffey and Atkinson, 1996). Then, relevant theories—such as, in this study, interest development and engagement—are addressed in the discussion section of the study, where the findings can be compared and contrasted with a particular theory (Hsieh and Shannon, 2005). The advantage of this conventional approach is that information from participants can be obtained without the imposition of any preconceived categories or theories, and it is up to the researcher to depict the theoretical perspectives that are relevant to the study (Hsieh and Shannon, 2005). Even though not all the data gathered in this study was open-ended, on many occasions the analysis of the numerical data was complemented with conventional content analysis of the open-ended data.

3.5 Phenomenography

In article PV, phenomenographic analysis was used. Phenomenography is a qualitative research approach that aims to investigate and describe the qualitatively different ways in which people experience or think about some phenomenon (Marton and Booth, 1997, p. 111). The result of the analysis is a set of *categories of description*, which form the so-called *outcome space* of the phenomenographic analysis (Marton and Booth, 1997, pp. 121–122). These categories intend to capture the different ways students express and perceive a particular phenomenon, such as programming. The aim of phenomenographic studies is often *not* to have a high generalizability (Marshall et al., 1999, p. 305), but rather to generate the set of conceptions within a particular context. Further, these conceptions and their characterizations may not be complete but can provide a premise for further discussion and analysis (Marshall et al., 1999, p. 305).

The relationship or structure between the categories can vary. First, the categories can have a hierarchical or inclusive relationship, that is, the categories can be put in an order that relates the richness, complexity or depth of the category to the phenomenon (Marton et al., 1993; Marton and Booth, 1997; Säljö, 1979). Thuné and Eckerdal (2009, p. 341) express the inclusive relationship model in that "[E]ach category presumes the understanding expressed in the preceding categories of description and is qualitatively different from these by including an additional feature [of a particular phenomenon]". However, even though the categories are often found to be hierarchically related (see, e.g., Thuné and Eckerdal, 2009; Eckerdal et al., 2005; Marshall et al., 1999), the categories might also be on the same qualitative level in the outcome space (Kalvaitis and Monhardt, 2011). That is, even though the categories describe the observed variation in understanding of a phenomenon, each category can be interpreted as its own phenomenon. Further, while the categories can be on the same qualitative level, they can extend a subcategory or include one within itself (Kalvaitis and Monhardt, 2011). This "mixed" model was present in article PV. While some of the categories included (or extended) one another, this was not the case for all the categories. I will discuss this further in Section 4.5, where I review article PV.

As phenomenography is a qualitative research approach, the data are often gathered in the form of interviews where expressing the understandings or experiences can be encouraged by the interviewer from different perspectives (Eckerdal, 2009, p. 29). However, recent research has began to include more versatile data and data processing techniques to be used within the phenomenographic tradition (Kalvaitis and Monhardt, 2011). For instance, a large quantity of respondents or a number of survey questions that deal with phenomenon from different perspectives can arouse data that is "rich" enough to be used as the basis for a phenomenographic study (Sharma et al., 2004). This question about the adequacy of the data concerns article PV, and is again discussed in more detail in Section 4.5.

4 OVERVIEW OF THE ORIGINAL ARTICLES

In this chapter, a short review of each paper included in this research is presented. The papers are presented in chronological order. In addition to the main results of each paper, I will present the aim of the study, the research objectives, and methods. After presenting each individual study, I will describe my contribution to each of these papers, as they all are co-authored by several authors.

4.1 Article 1: K-12 Game Programming Course Concept Using Textual Programming

Aim

The study in article PI introduced a programming tool, a library called *Jypeli*, to facilitate novice programming. Two game programming workshops were carried out utilizing the Jypeli library. The aim of the study was to explore some of the current visual and textual programming environments and evaluate the concept of a course that uses a textual programming environment. The evaluation was based on the student feedback and a literature rationale. Also, a description of the course concept along with teaching approach and pedagogical choices was highlighted to inform the reader about the context of the study. Finally, to investigate students' interest in computing and engineering careers, we asked students about their current motivation to pursue computer science careers, as well as their perceptions of the CS field.

Method

The data gathering was carried out in 2009–2010 and involved a total of 150 students, of whom 13 were female (9%) and 137 were male (91%). The data was collected through two questionnaires during summer outreach workshops. First, demographic (e.g., age, gender) and background data (e.g., earlier programming experience, frequency in playing computer games, interest in science studies) were acquired through a pre-questionnaire, which the students completed during the first day of each course, before any teaching.

In the second questionnaire, we asked students to provide their overall perceptions of the course, challenges, potential change in their conception of programming, and interest in further studying computing, engineering, or science. This second questionnaire was provided at the very end of the workshop, before the students left the workshop venue. We categorized students' answers to open-ended questions and calculated the frequencies of answers in each category.

Results and contribution to the whole

Interest in computing, engineering, and science careers was increased during the five-day workshop: Students who agreed in "I'm interested in applying for studying computing/science" increased from 37.9% (pre) to 43.6% (post). Further, the proportion of students who disagreed decreased from 27.9% to 17.9%, respectively.

The majority of the respondents (77.8%) had no or little earlier programming experience, and they did not have clear preconceptions about what to expect of programming. Through a qualitative analysis, we found that many students' conception of programming changed (49% agreed or fully agreed), and that their typical answers comprised ideas like "I thought it would be harder", and "I expected it to be more complicated." Further, the data indicates that the workshop changes students' possible negative "slant" towards programming to a positive attitude: 47 students filled in an open-ended question about how their conception of programming had changed during the course, and of these 47 students this change was observable in 23 cases. Only a third of the students answered this question, however; thus, the result has to be interpreted with some caution. Though learning a new language and writing faultless code were perceived to be laborious and unpleasant, students did find it a little less troublesome and more fun than they had expected. In this regard, our choice of textual programming environment was received well among students and was an accepted part of the learning experience. We used the term "textual programming" to make a distinction from visual programming environments, such as Alice, that are based on dragging and dropping elements to make programs.

In summary, the results, presented in more detail in article PI, indicate that the workshop arouses *maintained situational interest*. At this stage, the research data does not implicate *emerging individual interest*; investigating this was left for further research and is examined in later articles presented in this thesis.

Author's contribution

The first author of this study was the main author, and coauthored the paper. I designed the survey instrument in collaboration with the coauthors. I collected the survey data and transferred the handwritten data to digital form. I conducted the initial analysis of the data, and later iterations of the analysis were done in collaboration with the two other authors. I also acted as the leading teacher during the workshops. The reporting of the study was done in intensive collaboration with the other two authors; my biggest contribution was in Sections 3 ("Course Concept") and 4 ("Initial Evaluation").

4.2 Article 2. Life Two Years After a Game Programming Course: Longitudinal Viewpoints on K-12 Outreach

Aim

The purpose of article PII was to investigate the development of student interest in higher education computer science, engineering, and science studies. The focus of the paper was to inspect the programming-related activities of students after they take a course using a follow-up survey. Thus, the study was longitudinal in nature. We also investigated what factors, if any, in the students' background related to post-course programming.

Method

The data was acquired from 58 summer workshop attendees with three separate survey instruments:

– a survey made on the first day of each course (pre-survey)
– a survey made on the last day of each course (post-survey)
– a longitudinal follow-up survey made 1–2 years after the course, depending on when the student had participated in the course (follow-up survey)

The first two survey instruments were also utilized in article PI. Only minor corrections and additions were made to these instruments based on the feedback from article PI. The follow-up survey was sent to the participants via (traditional) mail, which the respondents also returned via mail. Some of the respondents were the same students who participated in the survey described in article PI. Post-course activities were described and categorized. Also, statistical tests were used to find statistically significant background factors.

Results and contribution to the whole

Most of the students (91.3%) that attended a game programming summer workshop continued programming or doing programming-related activities after the course. Further, their interest in science studies kept increasing, from 3.41 (post-survey, Likert scale 1–5) to 3.83 (follow-up). We observed some indicative trends in student backgrounds, notably pre-workshop programming experience, which had a Pearson correlation of .385 at a significance level of .01. This was an expected result; those who had earlier experience learned more programming in the workshop and kept on applying their skills in a self-directed manner. The more interesting result regarding this study was that 57% of the students who had no or little previous exposure to programming had continued programming 1–2 years after the course.

The results of this article suggest that it is probable that the students without previous programming experience (situational interest prior to the workshop) actually were continuously reengaged with the content after the workshop and were thus in a state of (emerging) individual interest during the follow-up survey. Concerning the students with prior experience with programming, however, it is uncertain whether their interest was in a situational or individual phase during the pre-survey. Thus, we were not able to interpret the development of their phase of interest, even though their self-reported interest in computer science and engineering studies did increase.

Author's contribution

I was the corresponding author and responsible for the overall writing process during the early phases of writing the manuscript. The two coauthors provided their expertise in reviewing the survey instrument, mapping the related literature, and reviewing and overall structuring of the paper, as well as contributing their observations on my initial analysis. The final paper was produced through several iterations of intensive discussions among all the authors.

4.3 Article 3: Understanding Differences Among Coding Club Students

Aim

The study described in article PIII was concerned with orientational and attitudinal aspects of interest in computer science studies and computing education, as well as the characteristic demographical and other aspects of student background (e.g., age, earlier computing experiences, preconceptions in programming) that could be used to divide the student cohort into descriptive categories. With this categorization we aimed to increase the knowledge about the development of student in towards computing, engineering, and science studies.

Method

The cohort under study consisted of 12–18-year-old students ($n = 51$) attending a voluntary, extracurricular coding club session that was arranged as a continuation of the summer workshops. Most of the attendees had previously participated in the summer workshops. Two datasets were used in this study. The first and primary dataset was the survey data from the first day of the coding club. The data were collected from fifty-one students. The questions concerned the contents of the coding club, prior programming experience, and post-workshop experimenting with programming and other computing topics. The primary dataset was supplemented with data from the summer workshops that took place before the coding club. The data was analyzed using qualitative analysis methods; Based on the survey data (open-ended and Likert scale questions), qualitatively different categories were recognized through conventional (data-driven) content analysis and pattern coding procedure (Miles and Huberman, 1984, pp. 67–69). Through an iterative process, the higher level categorical scheme was formed by identifying regularities in the lower level categories. Researcher triangulation was utilized to improve the transferability (Guba, 1981, p. 80) of the categorization.

Results and contribution to the whole

Through the qualitative analysis, we constructed four categories of description: *Professionalism*, *Experimenting*, *Lack of self-direction*, and *Inactivity*. The category into which each student fit was identified during the process; each student was placed in exactly one category. The smallest category consisted of seven students, while the biggest category consisted of 16 students.

1. *Professionalism* (9 students). These active club attendees possess clear plans for future career and express strong inclination toward STEM studies. They acquire knowledge about new techniques and concepts even outside of a formal classroom environment.
2. *Experimenting* (7 students). Students who are engaged in computing, engineering, and "tinkering." They independently experiment with programming due to the workshop / club learning experience. They also show strong interest in higher education and/or STEM subjects.
3. *Lack of self-direction* (16 students). The limited possibilities or the lack of self-directed experimenting prevents a deeper dive into computing activities. These students have minimal earlier programming experience and would benefit from external support or more formal instruction in a classroom setting.
4. *Inactivity* (12 students). Students who were "disengaged" and pose only little interest in aspiring to learn new concepts within programming or computing. Attending a summer course or coding club may be influenced strongly by a family member.

Within the Inactivity category, students were motivated to participate by personal relevance (games) or external factors (parents), and their situational interest has been triggered, but not maintained. Within the Lack of self-direction category, situational interest is held and sustained through personal involvement. The coding club, among other sources of external support, helps to maintain the situational interest. Individual interest does not emerge due to the lack of self-defined tasks and generation of curiosity questions. Within the Experimenting category, students begin to seek repeated re-engagement with CS topics and programming after the summer workshop. Individual interest has emerged and they are motivated to set challenges for themselves. The students in Professionalism category opt to pursue tasks themselves and clearly reflect well-developed individual interest. On the other hand, they had good prior knowledge of CS, and were inclined towards computer science and engineering studies before the workshop.

The results issues imply that it is important to provide the students with opportunities to engage with CS at regular intervals. Further, external support is beneficial for students who do not have a predisposition for self-directed, independent work with the content. We argue that regular exposure and proper support can contribute to students' interest development in CS and makes students more receptive to studying CS topics in later phases of their studies.

Author's contribution

This article was prepared in close collaboration with the coauthors. I was responsible for the early phases of the writing process. The survey instrument was designed in collaboration with the coauthors, who also provided their expertise in mapping the related literature, reviewing and overall structuring of the paper as well as contributing their observations about my initial analysis. I coded the data and made the initial categorization, which was then refined with the coauthors. Overall, the paper was produced through several iterations of intensive discussions among all the authors.

4.4 Article 4: Five Years of Game Programming Outreach: Understanding Student Differences

Aim

The study in article PIV focused on understanding the different populations among the summer workshop participants. After distinguishing the characteristics the emerged in the groups in the student cohort, we inspected the interrelation of these characteristics and attitudes as well as interest towards computing, engineering, and science studies.

Method

The research data for this study was acquired using two survey instruments, a pre-questionnaire and a post-questionnaire, each consisting of 27 quantitative and 11 open-ended questions. These were the same instruments used in the previous articles (PI; PII), with minor corrections and additions based on the feedback from the previous articles. Altogether, the answers of 462 students were included in the survey data. The same students also took part in the surveys that were made in articles PI, PII, and PIII. We presented descriptives and statistics of the events and performed a statistical cluster analysis based on pre- and post-survey data. The cluster analysis was complemented by a qualitative analysis.

Results and contribution to the whole

We found five groups (populations) with substantial differences: *Enthusiasts*, *Newbies*, *Uncertains*, *Experimenters*, and *Unsatisfieds*. In particular, the students who had the least programming background reported being the most impacted by the outreach and expressed the most significant increase in their interest. For the two big clusters, Uncertains and Unsatisfieds, the increase in interest was only small or non-existent. These results suggest that even though our workshop was an extracurricular activity with voluntary participation, not all of the students are orientated for future studies, ready to think about their educational choices or decide whether they would be interested in computer science as a career choice. This challenge, which shows up particularly in the Experimenters and Unsatisfieds groups, calls for greater engagement of students in our future courses and stronger efforts to arouse their interest towards computing, engineering, and science studies.

Author's contribution

I was the corresponding author of this paper and responsible for the overall writing process. I also collected most of the data and conducted the initial analysis. The two coauthors provided their expertise in mapping the related literature, reviewing and overall structuring of the paper as well as contributing their observations about my initial analysis. The paper was produced through several iterations of intensive discussions among all the authors.

4.5 Article 5: What Does It Take to Do Computer Programming? Surveying the K-12 Students' Conceptions

Aim

This phenomenographic study focused on summer workshop participants' conceptions of what it takes to do computer programming. The study resembles the research by Eckerdal et al. (2005), identifying and categorizing how students see the phenomenon of what it takes to do computer programming. Moreover, we inspected the relation between prior programming experience and students' views; that is, are any conceptions more typical to nonprogrammers than to those with some earlier exposure to computer science?

Method

The survey data originated from 541 students aged 11–17 years who attended the 24 summer workshops during the years 2010–2014. The data was subjected to phenomenographic analysis, which resulted in descriptions of the qualitatively different ways (categories of description) in which students experienced or thought about the phenomenon of programming. During the analysis process, each student's answer was marked with emergent codes that described and reflected the student perceptions about programming; there was no pre-set categorical scheme or theoretical framework. The analysis was iterative and incremental in nature, including constant interpretation and comparison as well as researcher triangulation.

While the data was gathered via surveys, which is untypical for a phenomenographic study, we considered the data to be adequate to be used in a phenomenographic analysis. I find at least two arguments that support this view. First, the perceptions were captured with three different questions, of which two were open-ended questions. Even though some students were brief with their answers, in general the composition of the answers to three questions gave quite a descriptive and illustrative view of the perception of the individual student. Second, the number of respondents was large, which—through multiple reads and re-reads of the data—helped in being confident on the final categorization.

Results and contribution to the whole

After interpreting the students' conceptions and the underlying focus of the responses, we discovered five major, qualitatively different themes. In summary, students find that programming takes, or "is about":

1. *Syntax and language features*. Programming is a routine-like mechanical activity of writing program code. (Theme A)
2. *Nature of programming work generally*. A programmer has to remember a lot of things, but also constantly learns new things. (Theme B)
3. *Computational thinking and problem solving*. Programmers need to abstract and reason. On the other hand, imagination and creativity helps in finding different ways to solve problems. (Theme C)
4. *Prerequisites*. Programming is perceived as utilizing computers fluently, and understanding the "notion of the machine." (Theme D)
5. *Auxiliary skills*. Skills such as language, visual, or graphic skills are activities that contribute to software construction as a whole. (Theme E)

The analysis revealed that student conceptions about what it takes to do programming were manifold. The most often occurring conceptions were about the nature of programmer's work generally (Theme B). The single most often occurring category was that programming is about memorizing things and that it takes a lot of perseverance to develop programs. On the other hand, while doing so, the programmer constantly learns new things.

The conceptions of programming as problem solving or developing logical reasoning (Theme C) seem to increase due to programming experience. However, even novices see programming as an activity that requires imagination.

These conceptions not only inform the design of outreach programs but also speak for the use of "beginner environments," as the non-programmers tend to emphasize mechanical work and memorization while doing programming. Further, we argue that individual interest can be better triggered when the components of problem solving, creativity, and computational thinking can be brought into students' consideration in novice classrooms, as the conception of mechanicality and memorization seem to decline in the presence of these components. Further, Theme E relates to the aspect of design skills (game design, visual design, and other creative aspects) that can be engaging and important to some students to increase their feel of ownership of the end result. When teaching programming concepts through games and game programming, some design skills can naturally be applied in, for instance, level and character design (Repenning et al., 2000; Basawapatna et al., 2011; Sturtevant et al., 2008).

While the categories did not form a strict hierarchy, some categories can be argued to be inclusive or complementary. In particular, the category B3 Constant learning can be seen to presume B2 Perseverance, which in turn includes B1 Memorization. Further, to understand D2 Notion of the computer, requires a fluent use of a computer (category D1) at least to some degree. Thus, within a particular theme some categories can be seen to be subcategories of some other category. However, the themes are more general and in the same qualitative level in the outcome space. Even though these themes are many times related in practice (e.g., to be able to do problem solving with programming—Theme C—one needs to know at least some syntax and language features—Theme A), we concluded that the themes did not form a strict hierarchy.

Author's contribution

The research was designed in co-operation with the coauthor. I was responsible for the overall writing process, data gathering, and conducting the initial analysis. The coauthor provided his expertise in methodological questions, reviewing and overall structuring of the paper as well as providing his observations based on my initial analysis.

4.6 Article 6: Identifying Pathways to Computer Science: Long-Term Impact of a Short-Term Game Programming Outreach Intervention

Aim

The article PVI investigated the long-term impact of summer outreach workshops. The aim was to evaluate the impact of the outreach on student attitudes and interest in computing, as well as ability to perform better in computing activities. The impact was investigated by constructing pathways to describe and characterize phases that lead to students' educational choices. The findings are compared and contrasted to the four-phase model of interest development (Hidi and Renninger, 2006).

Method

All students who participated in the game programming workshops from 2009 to 2011 were contacted. Of those contacted students, we asked those aged 18 years or more, and thus had completed (or were just about to complete) their upper secondary education, to be interviewed. Most importantly, these interviewed students had submitted their applications for further education. A total of 20 students were interviewed. The semi-structured retrospective interviews lasted from 20 minutes to 90 minutes. The data was then transcribed, coded, and analyzed for emergent themes.

Results and contribution to the whole

The results of this study support the claim that attending a game programming summer workshop does have a long-term impact on student's interest in computer science. The qualitative analysis resulted in the following categories that describe the different pathways:

1. *Confirms CS as a probable career option.* The workshop acted as a window to the computer science field, boosting their willingness to choose CS as their major. While the students already possessed an emerging individual interest, it was evolved into well-developed individual interest after the workshop.
2. *Sees CS as a career option that he/she would not have considered before.* These students did not plan to major in CS, but after participating in the outreach, they decided to choose CS, or at least considered it seriously. Initially, the students had (individual) interest in computer games, but only situational interest in a CS career. However, their interest turned into emerging individual interest, which "ignited" their thoughts on majoring in CS.
3. *Will not major in CS, but interest in university studies is developed.* These students were situationally interested in programming but eventually followed

their original career aspirations for university studies and did not consider CS career-wise. However, their image of CS was changed, and further, their interest towards academic studies was reinforced.

4. *Workshop confirms that CS is not an interesting career option*. These students felt that the workshop confirmed that they would not consider a career in computer science. Rather, some negative feelings about the topic emerged that hindered the students' valuation of computer programming and computing careers.

The impact of the outreach extends to decision-making processes taking place in important phases of life. The impact works in both ways, meaning that after participating in an event, students found it easier to express their level of interest in CS, regardless of whether the change in interest was positive or negative. However, the summer workshop impacts not only interest development in computer science and engineering studies but also interest in studies in higher education in general.

Author's contribution

I was the corresponding author and responsible for the overall writing process during the early phases of writing the manuscript. The coauthor provided his expertise in interpreting the results, writing the discussion section, mapping the related literature, reviewing and overall structuring of the paper as well as contributing his observations about my initial analysis.

5 DISCUSSION OF THE RESULTS

The overall aim of this thesis was to provide a deeper understanding of the role of student outreach and its short-term and long-term impact in developing interest in computer science and engineering studies. This aim was approached from two different outreach contexts in the original articles: game programming summer workshops and an extracurricular coding club.

My main research questions were (1) does participating in game programming outreach have impact on student interest in computer science and engineering studies, and (2) does such outreach change student's conception of computer science and engineering studies? As the two questions appeared to be closely related—even intertwined—I will consider these together in the following.

Figure 5 shows how the individual articles have spread out chronologically (X-axis) and length of perspective of each article (Y-axis).

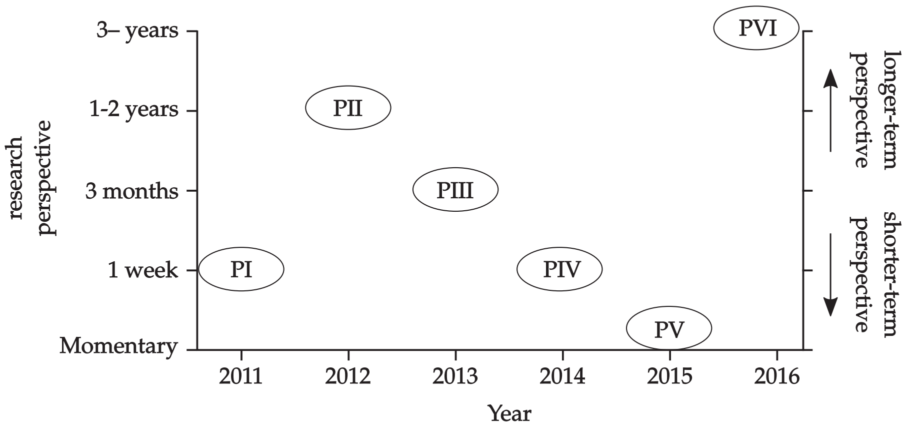

FIGURE 5 Research time span. The higher the article name is on the Y-axis, the more long-term perspective it adds to the present thesis. The articles lower on the axis add shorter-term perspective, for instance, about student conceptions

5.1 Impact on student interest and role of the outreach

Student interest was investigated in articles PI, PII, PIII, PIV, and PVI. In these articles, interest was studied from either a short-term or long-term perspective. In articles PIII and PVI, the four-phase model of interest development was used explicitly to project the results towards the particular theory. The articles PI, PII, PIV, and PV also strongly consider interest, but without contrasting the results to a particular theory. The impact from a short-term perspective is discussed first, followed by a discussion of the impact from a long-term perspective.

Short-term impact

First of all, the majority of the respondents (77.8%, PI) had no or little earlier programming experience, and they did not have clear preconceptions about what to expect of programming. Thus, for the majority, but not all, this was the first experience with programming. The main motivation for participation varied: many students reported that they were intrinsically motivated, "wishing to learn to program," and only a few students reported that they were pressured externally by, for instance, a family member. In this regard, the students were at least on the first "step" of the four-phase scale of interest development, except perhaps for those who did not want to participate in the first place. During the workshop, the participants were strongly supported by the environment (tasks, learning material, peer participants, teachers) to find a basis for connecting with the content. Even though in articles PI and PIV the results were not explicitly interpreted through the four-phase model, the positive results in students' willingness to apply for CS studies support the assumption that the workshop helped the students to sustain their interest and begin to develop value for content, which resulted in maintained situational interest.

In articles PI and PIV, interest was examined from a short-term perspective, where interest in computer science and engineering studies was evaluated both on the first day of the workshop and immediately after the fifth and final workshop day. The students who were initially not interested in studying computer science expressed the most significant increase in their interest (PI). Further, the students with the least programming experience ("Newbies", PIV) were impacted the most. It seems fair to make the assumption that the students who entered the workshop were initially at least *situationally interested* (Hidi and Renninger, 2006) in game programming, which inspired them to attend the workshop.

There may be several explanations for this increase in interest. First, the increased interest could be explained by the change in students' conception of programming over the course of the workshop. While some of the students found programming harder than anticipated, 41% of the students (PIV) agreed on the question "My conception of programming changed during this course." In particular, students who had no earlier programming knowledge tended to think programming was difficult. However, they were willing to reconsider their skeptical perception and change their view about programming being particularly hard. In article PV, which focused on student conceptions about programming, we found that 37% of the non-programmers (students with little or no earlier programming experience) saw programming as memorizing, and 23% saw it as mostly consisting of mechanical tasks. However, this view of mechanicality or memorizing decreased after they gained personal experience with programming. These experiences originated from voluntary courses from school, self-directed experiments, or other extracurricular workshops.[1] A second explanation for the positive short-term impact is that these students had good self-regulating skills, and with that they found it natural to persist and focus on content that involves attention. The “Newbies” category (PIV) is a good example of this phenomenon. These students were among the youngest of the cohort (14.1 years) had the least programming experience, and reported the highest scores to the question “the assignments were hard.” However, these students were among the most satisfied of the cohort, and also presented the highest scores in the question about recommending the workshop to peer students.

Long-term impact

I now turn to the long-term perspective of the impact, which was considered in articles PII, PIII, and PVI. Positive impacts were highlighted first in article PII, where as much as 91.3% of the students had been personally involved in programming-related activities. In that article, programming-related activities were defined broadly and included, for example, modifying program source code (their own or someone else’s), reading the course learning material, or interacting with social websites related to programming. This can be interpreted as held and sustained interest through personal involvement (Harackiewicz et al., 2000; Hidi and Renninger, 2006). Whether the interest of these students was in a situational phase or in an individual phase remains unsettled. However, 38% of students (PII, “None” and “Little” categories combined) reported they had no earlier programming experience and had actually made or edited games or programs after the workshop. Thus, these students were willing to explore programming-related content and set themselves challenges or take subsequent steps in processing work with programming (Renninger and Hidi, 2002). As it takes some effort to install the integrated development environment, copy the source code from the university website, and begin developing the code in the development environment, it is probable that these students persevered through some challenge to meet the goal (Renninger and Hidi, 2016, p. 13) and achieved in continuing to work with the code content. This valuation of the opportunity to reengage with programming can be interpreted as a state of emerging individual interest. Further positive long-term impacts were found in article PIII, in which a group of students with a good amount of CS experience and high level of career self-efficacy

[1] As some students participated multiple times in the workshops, it is possible that some students’ earlier experiences originated in those.

(Betz and Hackett, 2006) were encouraged to seek repeated reengagement with programming, and inclination towards CS was recognized.

The most visible positive long-term impact on student interest emerged in article PVI, in which two of the four distinct pathways, comprising 11 of the 20 interviewees, reported a notable development in their interest due to the workshop. Of these eleven students, six said that the summer workshop was an occasion with an important, "confirming" meaning during their career aspirations—these six students ended up majoring in computer science or game design in a university. Further, of the eleven students, five stated that without taking the course the students would have gone on to study some other subject; three of these five students chose CS as their university major. This shows the high relevance of the workshop, as these students would not have been aware of the possibility of studying CS and thus would have chosen differently if they had not participated in the outreach event. My interpretation is that all these students ended up in a phase of well-developed individual interest in a career in CS, and there is a high possibility that they would be in a different phase if they had not attended the workshop.

Again, I present my conclusion about the reasons for the well-developed individual interest. The students reported that the workshop resulted in a "feeling" that they are creating something new when they write a computer game from scratch. Succeeding in creating a working computer games was important, as it was a concrete example of what one can do with programming. As they engaged with the content (games, creation, building up "new things"), they became confident working with the content and were motivated to anticipate the next steps in processing work with content. Though there were variations in the ways the students worked with the content (self-directed, not self-directed, voluntary, obligatory), becoming more and more interested in the academic possibilities due to the engagement in the creative aspects of computer science seemed to be a common pattern.

However, not all students found that the workshop had a "positive" impact on them in terms of interest development. In articles PIII and PII, there were a number students who were situationally interested in CS, but eventually (timescale varied from three months to two years after the workshop) showed little or no effort in trying "something new" in programming. Thus, it seems that the workshop did not increase their interest in computer science and engineering studies. Students who had no previous background in programming seemed to take this position more often than those who had done programming prior to the outreach workshop. The need of these students possessing a "not-positive" impact for external support was clearly visible as they were unable to work in a self-directed manner. One student (article PIII) posed a question: "To learn new programming tricks without instruction? How on earth could that be possible?" I find this sentence very intriguing. On one hand, it is an illustrative representation of the conception about programming being solely memorizing (article PV). Further, it speaks to the conception of programming being a compilation of tricks that cannot be *learned*, but are transcendental in the sense that they can only be transferred from one person to another. This phenomenon became most strikingly evident in PVI, where for a group of the interviewees, regardless of their career aspirations, the summer workshop confirmed that they would not go on to study computer science or engineering. Even though these students found working with computer games interesting, they were disengaged (Shernoff et al., 2003). I find this outcome of diminishing interest or disengagement worthy of further discussion. Silvia (2008), who approaches interest from an emotional perspective, describes interest as occurring in people who are "dealing with" or trying to understand an unexpected and complex event. Silvia (2005, p. 58) continues on to state that if people perceive an event as new and as comprehensible, then they will find it interesting, but if the content strikes them as new *but* meaningless and incomprehensible, they do not find it interesting. People may experience something as meaningless if they feel that they lack "coping-potential," that is, skills, knowledge, and resources to deal with the content (Silvia, 2005; Lazarus, 1991). My interpretation is that if students do know absolutely nothing about programming, they may find it so overwhelmingly confusing that they choose to turn away and "not look back."

5.2 Implications for educational practice

The results of the original articles offer insight for curriculum development and for educators and scholars aiming to develop student interest. I will base these implications on the results from the original articles, and at the same time, provide my personal interpretation of the results in light of educational practice.

While focusing on student conceptions, the results point out that students with no earlier knowledge of CS tend to emphasize memorizing and mechanical tasks of programming. However, this view decreased after they had a personal experience with programming.[2] Computing concepts and content related to programming knowledge can remain largely unfamiliar until a concrete hands-on experience is practiced, even if a person is situationally interested in the topic. Unfortunately, students often opt out of computing majors due to a lack of prior experience in computing and a lack of knowledge of field-based job opportunities (Munson et al., 2011; Dabbagh and Menascé, 2006; Tangney et al., 2010). From this premise, I suggest that to be able to affect their attitudes, beliefs, and knowledge regarding computer science or information technology, students need to be exposed to computer science concepts in a hands-on manner. This can impact their interest with respect to computer science and engineering and their desire to pursue degrees in this area. Establishing computer science as its own school subject, whether obligatory or elective, with a consisten national curriculum, would give students the best opportunity to engage with CS content and figure out whether

[2] These personal experiences originated from voluntary courses in school, self-directed experiments, or other extracurricular workshops, and possibly from the workshops presented in this work.

they find the subject interesting career-wise. This development has been seen in some European countries, in particular, the United Kingdom (Barendsen et al., 2015). Computational thinking, among programming skills, has now been included in Finland's core curriculum of compulsory education. As it is built into the curriculum of mathematics (and other subjects), it, unfortunately, does not have same position as other subjects that have their names explicitly listed in the core curriculum. Regarding mathematics, it has been claimed that math does not provide the sort of open-ended problem solving that computing does (Brown et al., 2014). Naturally, bringing computer science to all students does not come without challenges. The biggest challenge in developing a national curriculum is that it requires training a sufficient number of teachers with proper subject knowledge to deliver the content to students (Sentance and Csizmadia, 2016). In England, there is a national network of teaching schools taking a leading responsibility for initial teacher education in their areas (Brown et al., 2014). In Finland, the distinguished network of teacher training schools could be reinforced with a joint network of universities, universities of applied sciences, and, in the starting phases, selected private companies. Other challenges, such as differentiation, lack of time, and approaches to teaching, are discussed in detail in Sentance and Csizmadia (2016).

Engaging students with the content is important. The ability to engage in a creative process to solve problems or design artifacts, for instance, computer programs, is seen as essential to engineering (Daly et al., 2014). Daly et al. (2014, p. 437) argued that aspects of creative skill development are often missing from engineering courses and suggested that to provide a more complete learning experience to students, instructors could incorporate teaching about originality, openness to explore ideas, and reflection. Learning programming by creating computer games can be seen as learning CS through developing creative skills. In the workshops described in this thesis, much emphasis was placed on students' personal ideas and visions. For instance, students made drafts (drawings using pen and paper) of their game ideas to present their design. Students were encouraged to be creative and include as much storytelling as possible in these drafts. With this, we wanted to enhance the students' ownership of their work. At the same time, it is also important not to compromise the learning objectives—the computing concepts. Even though creativity was not explicitly measured, the results of this study suggest that a creative atmosphere is useful in this setting and gives students an engaging learning experience.

Even though there may be some growing public attraction in learning to program and learning to solve problems with computing, the number of women involved in computing activities remains low. This was also the case in our study; we have not been able to "close" the gender gap with our approach to programming using computer games as the motivator. I believe that this is an issue that all outreach organizers should take into account. I mentioned some methods for bringing down the gender imbalance at the end of Section 2.2, and some proposals for including more female participants have indeed been made, with promising results (Rubio et al., 2015; Howland and Good, 2015; Denner et al., 2012; Dann and Cooper, 2009). Based on the findings from this work, it seems important to acknowledge that, first, female students *are* enthusiastic about games and find value in games (PVI) even though they might report spending less time playing games than male students (PIV). Second, both games and programming are less familiar to female students than to male students (PIV; PVI). If the challenge is too high for non-programmers, the students might find the content incomprehensible, and feel that their skills are insufficient, which significantly hinders the learning experience and prevents their situational interest from developing into individual interest. This supports the idea of "threshold concepts," or concepcts that can be very troublesome even though students put a lot of effort in them (Boustedt et al., 2007). In the worst case, if these concepts appear too troublesome for the students, they can alienate students from making progress in learning computer science concepts. To keep students' interest in programming over time, novel experiments should be more rewarding in the sense that they remain understandable as the complexity increases.

5.3 Trustworthiness of the research

In order to do high-quality mixed methods research, the researcher must consider the relevant characteristics of quantitative and qualitative research (Johnson and Onwuegbuzie, 2004). This leads to a question of the validity of a mixed methods study. While the concepts of validity and reliability are commonly used in quantitative research to evaluate the trustworthiness and generalizability of a study, other concepts have additionally been suggested for evaluating the quality of qualitative research (Johnson and Onwuegbuzie, 2004; Golafshani, 2003). Next, I will discuss the trustworthiness of this research in the light of the criteria presented by Lincoln and Guba (1985), along with their analogous concepts from the quantitative tradition (Teddlie and Tashakkori, 2009, p. 296). The criteria consists of (i) credibility (internal validity), (ii) transferability (external validity), (iii) dependability (reliability), and (iv) confirmability (objectivity). I will also discuss the actions that have been undertaken to ensure that this research meets the criteria for trustworthiness. The framework used to consider these actions and relate them to the criteria is based on Teddlie and Tashakkori (2009).

Credibility refers to the confidence in the "truth" of the findings (Lincoln and Guba, 1985; Teddlie and Tashakkori, 2009). In the quantitative tradition, the analogous term is *internal validity* (Teddlie and Tashakkori, 2009, p. 297). When considering the credibility of this study, it is important to ask whether this study examined the phenomena that it was supposed to examine, that is, "how the outreach activity impacts students." To evaluate and enhance credibility, the following matters were taken into account. First, the outreach events were described in detail both in the included articles and in this summary. Further, these descriptions were thoroughly checked by the coauthors to ensure their accuracy. Second, in order to ensure that all the data accurately reflected the same phenomena, modifications to the outreach activities (contents, surroundings, personnel) were kept to a bare minimum. Third, we used multiple methods and occasions to acquire and analyze the data. For instance, when the students filled in the surveys (PI, PII, PIII, PIV, PV), a minimal amount of prior information—such as examples of program code, teacher's opinions or views of programming, and so on—was given to them to ensure that their conceptions or interests were affected as little as possible by the environment or the general mood of the activities. On the other hand, student background and demographics were utilized during the retrospective interviews (PVI). In the analysis phase, quantitative and qualitative methods were used to gain a holistic picture of the impact phenomenon in general. Fourth, the results were considered from both short-term and long-term perspectives, and this perspective was extended to both the data inquiry and analysis methods. Finally, our interpretation of the previously mentioned phenomena was supported by the results described in PV, in which students' conceptions about programming were investigated.

Transferability concerns the extent to which the findings of one study can be applied to other situations (Lincoln and Guba, 1985; Teddlie and Tashakkori, 2009; Merriam, 1998). In the quantitative tradition, the analogous term is *external validity* (Teddlie and Tashakkori, 2009, p. 297). Making broad generalizations from this study in the quantitative sense would have required a large sample population and a randomized controlled trial. This was, of course, not the case. Rather, it can be argued that the studied K-12 students were a "special" group that voluntarily participated in the outreach events, thus showing that they possessed at least a slight interest in our outreach activities, and therefore, interest in game programming and computer science. Further, this study is dependent on many variables, such as students' age and gender, workshop agenda, and also local and national environment and surroundings. By this I mean that variables specific to Finnish culture or geography, for instance, could also have influenced students' decision to participate in the outreach.

The main target of this research project was to understand the phenomena holistically from the perspective of the national surroundings rather than to focus on a high degree of universal generalizability. However, to enhance transferability of our inferences from a specific context to other contexts, the following steps were taken. First, thick description was used in this study; thick description involves providing detailed descriptions of the context and other aspects of the research (Lincoln and Guba, 1985). Providing sufficient detail about the context of the fieldwork helps other researchers to make comparisons with the contexts in which they are working (Shenton, 2004). In this study, thick descriptions of the research setting and factors that could possibly influence the research were provided. These included, for example, the fieldwork of the researchers and the phases of the analyses. Further, detailed descriptions of the workshop content, teaching personnel, activity venues, and so on, were included. Second, we acquired detailed student demographics with the rigorous pre-survey administered to students (PI, PII, PIV, PV), which were also shared in the results of the individual articles. Thus, even though the intention of this thesis was not to generate broad generalizations, the findings of this study may provide a baseline understanding of the outreach impact phenomenon. Particularly, this study's findings on the patterns related to interest development—using the theoretical framework of interest development—can be important tools for researchers investigating student interest. Thus, subsequent research in this area can be compared to this work as well as extending this work with different environments and contexts.

Dependability (Lincoln and Guba, 1985) can be seen as analogous to *reliability* in the quantitative tradition (Teddlie and Tashakkori, 2009, p. 297). In the quantitative tradition, the term refers to techniques that strive to show that the research procedure, if repeated in the same context, with the same methods and participants, would yield similar results (Guba and Lincoln, 1994). Articles PII, PIII, PV, and PVI were fully or partially based on qualitative, conventional content analysis. In a conventional content analysis, the categories are derived from data during data analysis (Hsieh and Shannon, 2005). Regarding the dependability (reliability) of the research, it is important to develop a good coding scheme that is systematic, logical and scientific (Folger et al., 1984; Hsieh and Shannon, 2005). To achieve this, in each of the articles where we carried out a conventional content analysis, interpretations of the categories were developed through intensive discussions among all the coauthors. Likewise, the research process was thoroughly explicated in PI and PIV, which included quantitative approaches. Qualitative analyses were often times iterated with all the authors together in the same physical space, and disagreements about the categorizations were resolved consensually. Further, on many occasions, coauthors shared their preliminary analysis by turns and continued to work with the data and the preliminary analysis from where the other author had left off. Finally, agreement on the final version of the categorization was reached. Such in-depth coverage of the research design and its implementation can be seen as a method that increases the dependability of the results of qualitative research (Strauss and Corbin, 1990).

Confirmability refers to "the objectivity in science with the use of instruments that are not dependent on human skill and perception" (Shenton, 2004). In the quantitative tradition, the analogous term is *objectivity*. To ensure confirmability, multiple methods and triangulation (Denzin, 1978) were used, including questionnaires with multiple scales (nominal, ordinal, open-ended) and interviews. However, as these instruments were designed by the researchers, the intrusion of the researcher's biases cannot be totally avoided (Patton, 2002). It is, however, important to admit these researcher predispositions (Miles and Huberman, 1984). These underpinnings have been included in the research reports, and researcher biases have been acknowledged.

5.4 Methodological reflections

Evaluating the impact appeared to be challenging. In this thesis, four-phased model of interest development was chosen as the main theoretical framework;

thus, impact was inspected through a change in student interest in the scale of the four-phase model by Hidi and Renninger (2006). As acknowledged by Renninger and Hidi (2011, p. 170), there are no precise methods that can distinguish among the four phases of interest, even though the different indicators of interest, such as behavioral (e.g., frequency of engagement) in addition to direct indicators (e.g., answers to questions) have been suggested to provide reliable information about the phase of interest (Renninger and Hidi, 2016).

Second, it is difficult, if not impossible to express *precisely* how much of the impact can be attributed to the outreach or workshops. Would the students have experimented with programming even if they had not participated in our outreach events? There is always room for speculation in this matter, and these questions cannot be fully addressed with the research methods utilized in this thesis. This became evident, for instance, in the case of article PII. From the survey data collected in that particular study, we were unable to reveal the details of different reasons that could have contributed to the students' development of interest. This challenge is also recognized by Renninger and Hidi, who state that when measuring interest that develops, "[d]espite the frequency of their use, surveys have potential complications when they are the only source of data employed" (2016, p. 62). One of the question raised by the use surveys in this study was that how respondents interpret the questions on surveys. In article PVI this problem using sole surveys was tackled with utilizing more qualitative approach with retrospective interviews.

5.5 Conclusions and future work

The present work investigated the impact of computer science outreach interventions. The outreach comprised game programming workshops and coding club activities which were studied through several individual studies. The participants were mainly 12- to 18-year-old students from compulsory education and upper secondary education, for whom the outreach was an extracurricular event.

The long-term impact of the outreach appears to be two-fold. On one hand, there are clear indications that the outreach indeed has a positive impact on students' interest in computer science and engineering studies. This positive impact was either "confirmatory" (confirms earlier career aspirations) or "emergent" (individual interest emerges due to participation). This is naturally a desired result from the organizer's perspective and the perspective of CS advocates. From the organizational point of view, I found evidence that the outreach increases students' awareness of CS studies, and, in particular, increases awareness of and interest in the course organizer's department. Based on the analysis made in article PVI (Category I), there are students who would probably have gone to some other place to study computer science if they had not participated in the outreach. From this perspective, conducting outreach not only the students, as it can make the decision between different studying options significantly easier, but also the organization.

On the other hand, we found that there are many students whose plans are not affected by the outreach. Moreover, some students the workshop confirmed that CS is not their field at all, diminishing their (situational) interest in a CS career. This can also be seen as a positive result, as many students make uninformed choices when choosing to major in CS or engineering and later leave or change their major (Seymour and Hewitt, 1997). If the outreach contributes to students' career aspirations, it contributes to the person's career self-efficacy, i.e., the perception of his or her own competence or ability to succeed (Betz and Hackett, 2006; Festinger, 1962).

This research project emerged from the local desire to recruit more students to study CS. There are a multitude of things that impact the number of students majoring in a particular subject. These "external forces" include public opinion, media, politics, advertising, role models, friends, family, and so on. As an example, while Finnish media have the tendency to eagerly proclaim the labor reductions and lay-offs regarding CS and the information and communication technology (ICT) fields, academia could help by communicating the successful employment of graduates, providing positive signals about the status and the prospects of the field. However, these are factors that we generally cannot control from inside the university. It is my strong belief, which I base on the results of this thesis, that regardless of the fluctuating cycles in student intake—resulting from the aforementioned circumstances—it is worth doing student outreach.

There are a number of interesting future directions that can extend the research started in this thesis. Clearly, there is still a need for further research in the area of long-term impact of student outreach. A good first question would be how many of the workshop participants actually major in CS, and can we observe, for instance, increased intake from the local area. Being able to show some numerical data about student intake would be beneficial with regard to future research. One of the directions would be to conduct further follow-up with the students who participated in the workshop and who we know are majoring in CS based on previous studies. Does their interest develop into even more well-developed individual interest? Do they persist in the CS field? Are they more efficient in terms of study time or some other numerical indicator? Does the phase of interest in the four-phase scale come into the picture in some way? A second important topic for further study is how to maintain the student interest triggered in outreach programs such as those in this study. Providing sources for external support could help students maintain their situational interest. Third, this study highlights the need for diverse research methods. While this thesis primarily used qualitative methods, a more rigorous mixed method research design would enhance the reliability of the results. For instance, a research design combining quantitative methods (such as activity tracking or online surveys) and qualitative methods (such as interviews or observations) would contribute to investigating the gradual development of student interest. Fourth, future studies could also include additional theoretical aspects, such as motivation theory. In this thesis, I have mostly stressed the concept of interest along with other theoretical aspects, but as recognized by the authors of the four-phase model (Hidi and Renninger, 2006), motivation and interest are deeply intertwined.

YHTEENVETO (FINNISH SUMMARY)

Useat maat ovat viime vuosina alkaneet sisällyttää tietotekniikkaa (engl. *computer science*) ja laskennallista ajattelua (engl. *computational thinking*) koulujen kansallisiin opetussuunnitelmiin. Viimeaikaisten tutkimusten valossa tietotekniikan keskeisten käsitteiden oppiminen on tärkeää, sillä tietoteknisen osaamisen varmistaminen on varsin keskeistä tulevaisuuden digitaloudessa. Toisaalta tietotekniikan on nähty olevan hyödyllistä kaikille oppilaille, sillä se kehittää ongelmanratkaisutaitoja ja päättelykykyä. Näistä hyödyistä huolimatta tietotekniikan yliopisto-opiskelijoiden määrä laski tuntuvasti 2000-luvun alussa, minkä seurauksena monet korkeakoulut aloittivat rekrytointikampanjoita uusien opiskelijoiden tavoittamiseksi tietotekniikan alalle.

Tämä väitöstyö sai alkunsa tästä tarpeesta vastata tietotekniikan opiskelijoiden määrän laskuun, joka globaalina ilmiönä kosketti myös Jyväskylän yliopistoa ja tietotekniikan laitosta. Väitöstyön keskiössä ovat ohjelmointiaiheiset koululaisten kesäkurssi- ja kerhotoiminnat. Työssä tutkitaan, miten osallistuminen näihin tilaisuuksiin vaikuttaa oppilaiden kiinnostuksen kehittymiseen tietotekniikan opintoja kohtaan. Vaikuttavuutta ja kiinnostuksen kehittymistä analysoidaan niin lyhyellä (heti kurssin jälkeen) kuin pitkällä aikajänteellä (kolme kuukautta – viisi vuotta kurssin jälkeen). Varsinkin pitkän aikavälin vaikuttavuutta on aikaisemmin tutkittu vähän. Väitöskirja sisältää viisi julkaistua artikkelia sekä yhden käsikirjoituksen, jotka käsittelevät tutkimuskysymystä hyödyntäen monimenetelmäistä tutkimuskehystä (engl. *mixed methods*). Selkeä pääpaino on kuitenkin laadullisissa tutkimusmenetelmissä.

Tulosten perusteella kurssien ja kerhojen vaikuttavuus näyttää olevan kaksitahoinen. Ensinnäkin kurssien rooli pitkän aikavälin näkökulmasta voidaan nähdä joko oppilaan yksilöllistä polkua vahvistavana tekijänä (kurssi vahvistaa oppilaan jo olemassa olevan opiskelu- ja urasuunnitelmia) tai herättävänä tekijänä (henkilökohtainen kiinnostus herää osallistumisen seurauksena). Toisaalta tutkimuksessa havaittiin, että joidenkin oppilaiden kohdalla kurssitoiminnalla ei ollut merkittävää vaikutusta oppilaiden suunnitelmiin, ja muutamilla kiinnostus tietotekniikan opintoja kohtaan jopa väheni. Jälkimmäistä havaintoa voidaan toisaalta pitää myös positiivisena sikäli, että tietotekniikan sisältöjen parempi ymmärtäminen parantaa oppilaiden mahdollisuuksia tehdä tietoisia valintoja jatko-opintojen suhteen.

Tutkimus antaa viitteitä siihen, että käytännöllinen ja oma-aloitteinen työskentely ohjelmoinnin ja tietotekniikan tärkeiden sisältökäsitteiden parissa auttaa kiinnostuksen kehittymisessä. Harjoitusten ja tehtävien suunnittelussa on hyvä ottaa huomioon oppilaiden mielenkiinnon ja toisaalta ymmärrettävyyden ylläpitäminen.

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ORIGINAL PAPERS

PI

K-12 GAME PROGRAMMING COURSE CONCEPT USING TEXTUAL PROGRAMMING

by

Ville Isomöttönen, Antti-Jussi Lakanen, Vesa Lappalainen 2011

In SIGCSE '11: Proceedings of the 42nd ACM Technical Symposium on Computer Science Education

PII

LIFE TWO YEARS AFTER A GAME PROGRAMMING COURSE: LONGITUDINAL VIEWPOINTS ON K-12 OUTREACH

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