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# Learning theories in pedagogical agent research: A two-phased systematic review

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**Abstract:** The use of technology in education has advanced significantly over the past 25 years, including pedagogical agents. Pedagogical agents are on-screen characters designed to facilitate learning. However, it is recognized that research of learning theories in the context of pedagogical agents is still inadequate and rarely discussed. The main aim of this study was to gain an understanding of the state of current research on learning theories with pedagogical agents and to identify and synthesize the utilization and trends. Another aim was to identify the types and technologies of pedagogical agents in recent research.

The study was carried out as a two-phase systematic review, using four databases: Scopus, ScienceDirect, Taylor & Francis, and ERIC. The first phase, an umbrella review of previous reviews and meta-analyses from 2013-2023, included a total of eight studies presenting 17 different learning theories or related principles and hypotheses. The second phase, the systematic literature review of recent empirical studies from 2021-2023, identified a total of nine studies, presenting nine different learning theories or related principles and hypotheses. All included studies incorporated the educational context and the use of technology in relation to pedagogical agents and the implementation of one or more learning theories. The systematic approach was carried out using Fink's seven-step model and the PRISMA guidelines for documentation.

The learning theories found were analyzed using the framework of Illeris' three dimensions of learning: content (cognitive perspective), interaction (social perspective), and incentive (emotional perspective). All three dimensions were present in the study's results. Often the learning theory combined two or all the dimensions. The Cognitive load theory and the Cognitive theory of multimedia learning were identified as central pillars within pedagogical agent research, giving rise to numerous smaller theories, hypotheses, and principles. The utilization of learning theories in the studies varied and the results of the support found were often mixed. The identification of types and technologies of pedagogical agents in the studies revealed that they were predominantly utilized as character agents, lacking chatbots or software components. The embodiment of the agents varied, with some being more human-like than others. Although some agents were able to prompt and provide feedback based on user input, interactions were predefined and lacked generative artificial intelligence (AI) such as the use of large language models. Recommendations for future research to address the gaps identified in this systematic review are discussed. Learning theories and related research should be considered in the design and use of pedagogical agents.

**Keywords:** pedagogical agent, learning theory, systematic literature review, umbrella review

**Suomenkielinen tiivistelmä:** Koulutusteknologian hyödyntäminen opetuksessa ja oppimisessa on kehittynyt merkittävästi viimeisen 25 vuoden aikana. Tämä koskettaa myös pedagogisten agenttien hyödyntämistä. Pedagogiset agentit ovat ruudulla esiintyviä hahmoja, jotka on suunniteltu tukemaan oppimista. Tähänastinen tutkimus pedagogisista agenteista on osoittanut, että oppimisen teorioiden käyttö ja hyödyntäminen on ollut vähäistä. Tämän tutkimuksen päätavoitteena oli selvittää pedagogisten agenttien ja oppimisen teorioiden yhdistävän tutkimuksen nykytila sekä tunnistaa ja koostaa olemassa olevasta tutkimuksesta havainnot ja suuntaukset. Toinen tavoite oli tunnistaa millaisia pedagogisia agentteja sekä niissä hyödynnettäviä teknologioita esiintyy viimeisimmissä tutkimuksissa.

Tutkimus toteutettiin kaksivaiheisena systemaattisena kirjallisuuskatsauksena. Aineiston haku toteutettiin neljään tietokantaan: Scopus, ScienceDirect, Taylor & Francis ja ERIC. Tutkimuksen ensimmäinen vaihe oli sateenvarjotutkimus, jossa toteutettiin kattava

tiedonhaku aiempiin kirjallisuuskatsauksiin sekä meta-analyyseihin vuosilta 2013-2023. Sateenvarjotutkimukseen valikoitui kahdeksan tutkimusta, joissa esiteltiin 17 erilaista oppimisen teoriaa tai oppimisen teoriaan liittyvää osaa ja hypoteesia. Tutkimuksen toinen vaihe oli systemaattinen kirjallisuuskatsaus viimeaikaisiin empiirisiin tutkimuksiin vuosilta 2021-2023. Toiseen vaiheeseen valikoitui yhteensä yhdeksän tutkimusta, joissa esiteltiin yhdeksän erilaista oppimisen teoriaa tai oppimisen teoriaan liittyvää osaa ja hypoteesia. Kaikki mukaan valikoituneet tutkimukset olivat tehty koulutuskontekstissa, sisälsivät pedagogisten agenttien eli koulutusteknologian sekä yhden tai useamman oppimisen teorian tutkimusta. Systemaattisessa tutkimusmenetelmän toteuttamisessa hyödynnettiin Finkin seitsemän portaista mallia sekä PRISMA-ohjeistusta.

Löydetyt oppimisen teoriat analysoitiin hyödyntäen Illeriksen kolmea oppimisen ulottuvuutta. Ulottuvuudet ovat sisältö (kognitiivinen näkökulma), vuorovaikutus (sosiaalinen näkökulma) sekä kannustin (emotionaalinen näkökulma). Kaikki kolme ulottuvuutta olivat edustettuina tutkimuksen tuloksissa. Usein oppimisen teoria yhdisti useamman kuin yhden ulottuvuuden. Kognitiivisen kuormituksen teoria sekä kognitiivinen teoria multimediaoppimisesta tunnistettiin pedagogisen agenttitutkimuksen keskeisiksi oppimisen teorioiksi, sillä niiden pohjalta oli rakennettu lukuisia pienempiä oppimisen teorioita, hypoteeseja sekä oppimisen periaatteita. Kirjallisuuskatsaukseen valikoituneissa tutkimuksissa tapa, miten oppimisen teorioita hyödynnettiin vaihteli, ja oppimisen teorioiden tutkitut tulokset olivat usein ristiriitaisia. Pedagogisia agentteja analysoitaessa havaittiin, että tutkimukseen mukaan tulleet pedagogiset agentit esiintyivät vain hahmoina, eikä yhtään chatbottia tai ohjelmiston osana esiintyvää agenttia ilmennyt. Agentit esiintyivät erilaisina hahmoina, joista toiset olivat ihmismäisempiä kuin toiset. Osa agenteista pystyi antamaan käyttäjälle kehoituksia ja palautetta käyttäjän toimintaan perustuen, mutta kaikki toiminnot olivat ennalta määriteltyjä. Tutkimuksessa mukana olleet pedagogiset agentit eivät hyödyntäneet generatiivista tekoälyä, kuten laajoja kielimalleja. Tutkimuksessa löydettiin hyödynnettäviä käytänteitä sekä esitetään jatkotutkimuksen aiheita. Pedagogisten agenttien suunnittelussa, hyödyntämisessä ja tutkimuksessa suositetaan käytettävän oppimisen teorioita.

**Avainsanat:** pedagoginen agentti, oppimisen teoria, systemaattinen kirjallisuuskatsaus, sateenvarjokatsaus

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# 1 Introduction

According to Siegle et al. (2023), the use of technology in education has advanced significantly over the past 25 years. This is also valid for pedagogical agents, which are on-screen characters designed to facilitate learning. Learning theories play a central role in the design of technology-enhanced learning environments and are necessary for good pedagogical design (Hammad et al., 2020). Siegle et al. (2023) identify a literature gap of questions who, when, and where regarding the use of pedagogical agents in learning, which can be approached from the perspective of learning theories. Prior research indicates a deficiency in the utilization of learning theories and theoretical frameworks within the current state of pedagogical agent research, particularly in examining agents and their effects on learning (Dolata et al., 2023; Zhang et al., 2023). The existing literature also highlights that studies often come from either pedagogical or computer science domains, rarely integrating both (Dolata et al., 2023; Siegle et al., 2023).

The aim of this study is to find out how learning theories have been utilized in the research of pedagogical agents and to identify what types and technologies of pedagogical agents have been applied in the systematically searched and selected studies. The main purpose is to create an understanding of the state of recent research on pedagogical agents with learning theories and, to discover implications and literature gaps that need further investigation. Clearly, recent technological improvements such as generative AI and large language models increase interest in especially pedagogical conversational agents (Sikström et al., 2022).

The study is conducted as a two-phased systematic review. The first phase, umbrella review, is focused on how learning theories are utilized in the previous systematic reviews and meta-analyses on pedagogical agents (years 2013-2023). The second phase, systematic literature review, is focused on learning theories in pedagogical agent research, as well as the types and technologies of pedagogical agents in the latest primary empirical studies (years 2021-2023). The learning theories will be analyzed using the framework of Illeris' (2008, 2018) three dimensions: content (cognitive perspective), interaction (social perspective), and incentive (emotional perspective). Interest is in the pedagogical agents' types and technologies, and aspects of appearance, interaction capabilities, and technology of pedagogical

agents are identified where available. The study is conducted in English following the main language in existing research literature on pedagogical agents.

This study is structured into six chapters. In Chapter 2, the theoretical background and framework are introduced and the key terms, learning theory and pedagogogical agent, are discussed. In Chapter 3, the process of defining the chosen research questions is illustrated. The chapter also contains the discussion of chosen research methods and their validity, as well as the implementation of these methods. In Chapter 4, the research strategy and review process of the umbrella review are presented. The findings of the umbrella review are also included in the chapter. In Chapter 5, the research strategy and review process of the systematic literature review are presented. The findings of the review are also included in the chapter. Finally, Chapter 6 is a discussion of the study's findings and concludes the study. The validity of the research, limitations, and contributions to theory, practice, and further research are presented. Throughout the study, AI tools (ChatGPT, DeepL) have been used to enhance the quality of the grammar.

# 2 Theoretical background

The theoretical background of this study consists of an introduction to the pedagogical agents and learning theories. Both terms are quite versatile, and they will be presented from the perspective of this review. It is vital to understand the complexity of both pedagogical agents and learning theories, as each review and article that resulted from the search queries in this study have a unique view on these subjects. Moreover, the study aims to combine these differing perspectives and form a consensus, that can help answer the research questions. In order to do so, a solid basis for defining both topics is needed and presented in this chapter. A theoretical framework that is connected to learning theories and used for the analysis of results will also be introduced.

## 2.1 Learning theory

Learning theories can be seen as sets of perspectives emphasizing different aspects of learning, and these aspects represent different types of pedagogy (Beetham & Sharpe, 2019). Until the 1950s, learning theories were developed through four separate approaches: German Gestalt psychology, American behaviorism, Russian cultural-historical theory, and Piaget's constructivism, and throughout the years, theorists have attempted to develop more coherent learning theories (Illeris, 2018). Defining the term learning theory has been challenging, and researchers in the education field do not fully agree on what is considered a learning theory (Hammad et al., 2020; Illeris, 2018; Khalil et al., 2023; Mayes, 2019; D. Schunk, 2012).

Since theories and interpretations of learning vary in perspective, content, and epistemological foundations, Illeris (2008) has depicted the primary aspects of understanding a learning theory (see Figure 1). This framework presents the components of learning and their interconnectedness. According to Illeris (2008), learning is rooted in biological, psychological, and social conditions. All learning comprehends the integration of an external interaction process between the learner and their environment (social, cultural, and material), and an internal psychological process of amplification and acquisition. Different applications of how the learning theory is attached to the structure, such as a policy of learning or chosen pedagogy, are also involved.

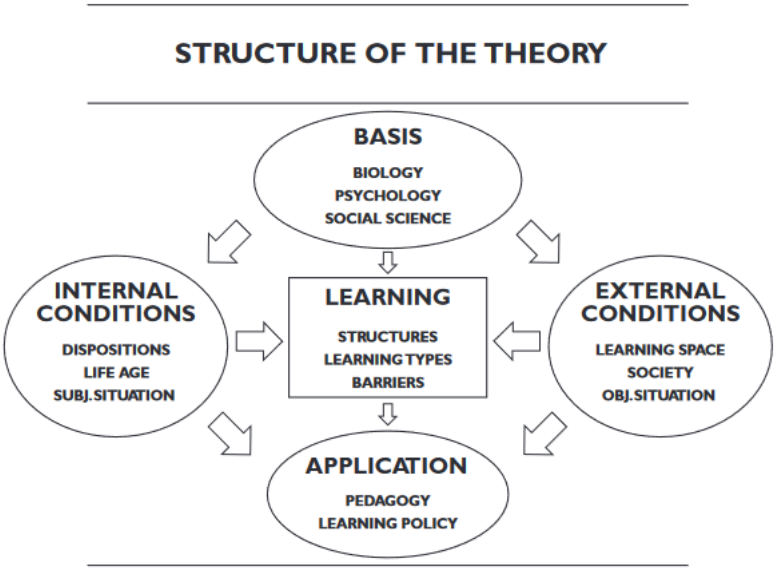



Figure 1 The main areas of the understanding of learning (Illeris, 2008)

The technology implicated in learning theories has different perspectives as well. Bower (2019) presents that there has been a wide variety of theoretical views to audit the use of technology in education, such as Social-cognitive theory, Activity theory, and multimodal and multimedia learning. Many of these focus on limited aspects, such as cognitive or affective impacts, or are adapted from other areas of research. Bower (2019) urges to widen the perspective and theoretical framework from technology-enhanced learning to holistic theorization of technology-mediated learning. Mayes (2019) adduces that the landscape of learning theory and pedagogical design has been notably extended and a new understanding of implicit learning is emerging. Cognitive theory research has expanded in cognitive development and neuroscience, with neural networks connecting to associative models and the participative web attaching to situated learning approaches (Mayes, 2019).

To conclude, it was acknowledged that qualifying and specifying a learning theory is not straightforward. In this study, the term *learning theory* covers theories of learning, newer approaches, parts of theories and frameworks such as defined principles of theories, and different hypotheses that are implicated in learning. For the categorization and presentation of these findings, a framework of Illeris' three dimensions, content, incentive, and interaction, is used as it roofs and effectively considers the versatile aspects and use of learning

theories. Illeris (2018) himself also uses the model of three dimensions to categorize and analyze learning theories, and many times identifies multiple dimensions within one theory.

The aforementioned model of the three dimensions of learning and competence development by Illeris (2008) is presented in Figure 2. Illeris (2008) presents that a necessary condition for learning is that two basic processes, the external interaction process and the internal psychological process, are integrated. The internal process includes the psychological acquisition process which consists of two functions, the function of managing the learning content and the incentive function. The incentive function controls and contributes mental energy to the process. The interaction process is always involved and usually integrated in both content and incentive functions. (Illeris, 2008, 2018.) This forms the triangulation of the three dimensions.

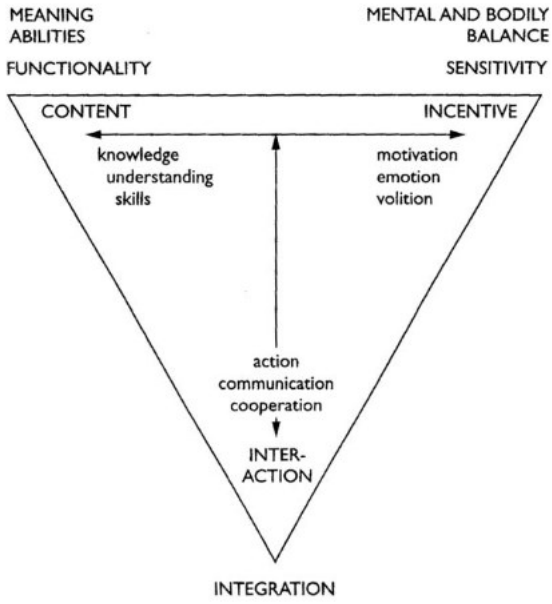



Figure 2 The three dimensions of learning and competence development (Illeris, 2008, 2018)

In this study, the framework of Illeris' three dimensions is adapted and presented in three perspectives: cognitive, social, and emotional. Illeris (2008, 2018) presents that the content dimension is about what is learned. It can be many different things such as meaning, strategies, and opinions, but is often mentioned to be skills and knowledge. The learner develops functionality and constructs meaning and ability which are cognitive. This provides the

cognitive perspective. Illeris (2008, 2018) introduces the interaction dimension to be social, as it contributes impulses to conduct learning. Interaction can have multiple levels as it can happen in integration, situations, society, the environment, or other conditions. Interaction can be communication, action, cooperation, or other ways of influence. This provides the social perspective. Also, Illeris (2008, 2018) introduces the incentive dimension to be mainly emotional**,** as it relates to directing and providing mental energy for the learning process. It includes interest, motivation, and engagement. The incentive function is to develop a personal sensitivity and secure the mental balance of the learner. This provides the emotional perspective. The framework of Illeris' three dimensions including content (cognitive perspective), interaction (social perspective), and incentive (emotional perspective) is utilized in the categorization of learning theories.

## 2.2 Pedagogical agents

Pedagogical agents are typically on-screen characters designed to facilitate learning (Siegle et al., 2023). Pedagogical agents are also directable and can enable students to find new ways to learn, reflect, and reason (Okita & Clarke, 2021). According to Siegle et al. (2023), the beginning of pedagogical agents and related research dates to the early 1990s. During this time, three interconnected agent properties – activities, visuals, and vocalizations – were identified as the central elements of pedagogical agent research. Agents can have characteristics from motivational, pedagogical, and/or conversational types, and it is common that the agents are multifaceted and embody features from more than one type. The main feature of pedagogical agents that sets them apart from purely motivational or conversational agents is the design for learning facilitation. The types of agents and their main qualities are presented in Figure 3.

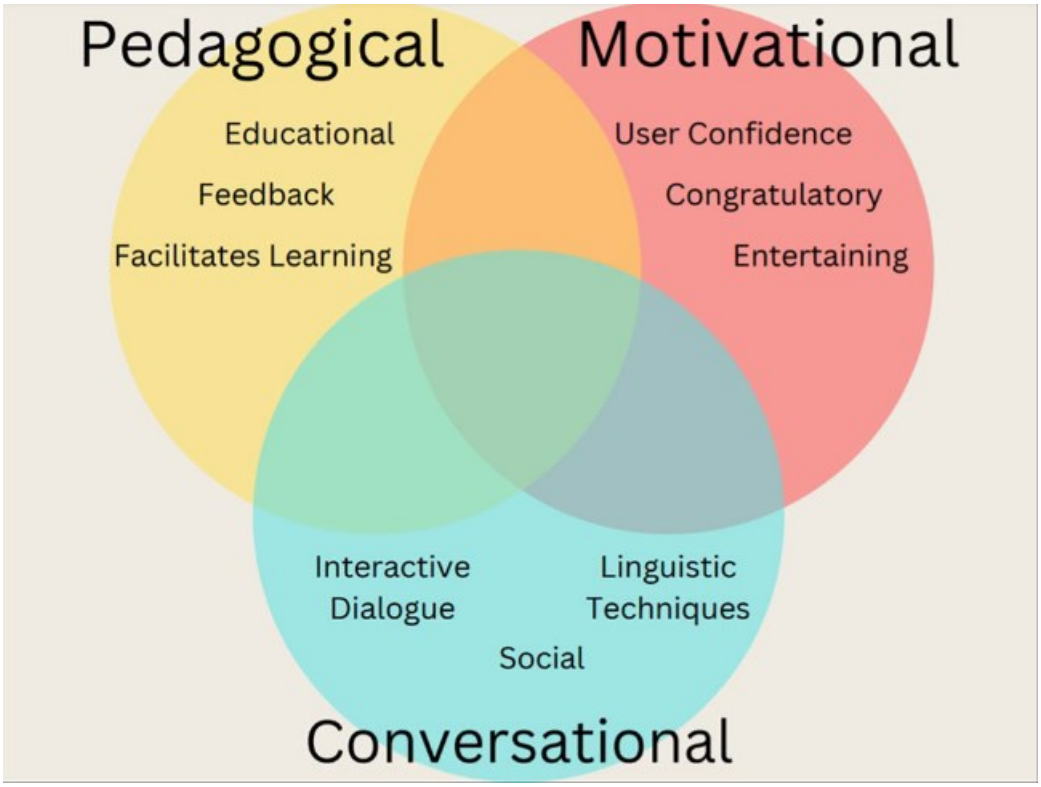



Figure 3 Types of agents (Siegle et al., 2023)

According to Dai et al. (2022), the role and purpose of pedagogical agents vary, as some are only used to deliver materials and instructions to the learner whereas others have a more motivating and coaching function. The main elements – interface, appearance, and underlying technology – also differ among agents. Agents can be either scripted or adaptive, and they can be in the form of e.g. 2D cartoon-like talking heads, or human-like and embodied 3D agents with gestures and expressions. Agents can also be in the form of functionalities in software that are not visible to the user on screen, which affects the way that the user encounters the agent and the way it is utilized in terms of user interface.

Some agents are purposely cartoon-like and do not aim to look human-like, whereas others have human-like features and, for example, use gestures mimicking human actions. The purpose of the agent in the learning situation determines its necessary features, level of human-likeness, and interactivity. Examples of agents with varying forms of embodiment can be seen in Figure 4. In order to provide a more personal and useful dialogue to the user, large

language models such as GPT-3 technology can be utilized when designing agents (Demetriadis & Dimitriadis, 2023).

Figure 4 Examples of pedagogical agents (Dever et al., 2023; Bian & Zhou, 2022; A. P. Lawson et al., 2021; Beege & Schneider, 2023; Li et al., 2022)

There are multiple physical types of pedagogical agents with varying underlying technologies. Examples of pedagogical agent types are chatbots and character agents. A chatbot can be in the role of a peer agent, motivational agent, teaching agent, or teachable agent (Kuhail et al., 2023). Chatbots can also consist of either rule-based technology, meaning that they are basing their communication on predefined rules, or generative technology, meaning that they use machine learning and generative AI to adapt to user inputs (Adamopoulou & Moussiades, 2020). Character agents, occasionally referred to as avatars, represent the embodied, usually more human-like type of pedagogical agent, with varying degrees of gestures, expressions, and personality.

Intelligent Tutoring Systems (ITS) are technological environments in which pedagogical agents are utilized. Agents' role in an ITS is to facilitate self-regulated learning by providing interaction between the user and the system, scaffolding, as well as giving individualized directions and feedback based on learner inputs (Dever et al., 2023). An example of an ITS is MetaTutor, which is a hypermedia-based multi-agent ITS with embedded pedagogical agents designed to facilitate self-regulated learning (Azevedo et al., 2022). MetaTutor's user interface is shown in Figure 5, with number 7 in the upper corner demonstrating the positioning of the pedagogical agent, which in this case is a talking head.

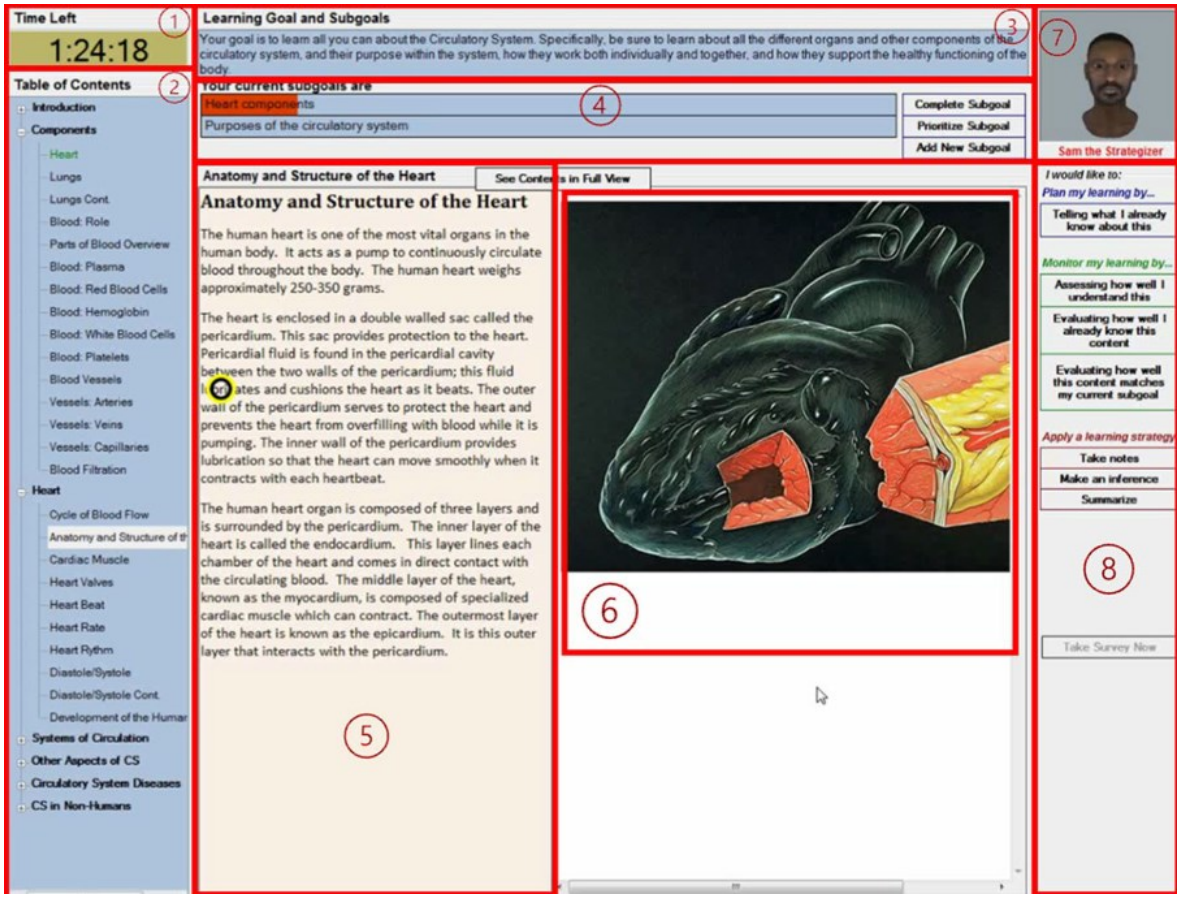



Figure 5 MetaTutor's user interface (Dever et al., 2023)

Siegle et al. (2023) identify a literature gap of questions who, when, and where regarding the use of pedagogical agents in learning, which can be approached from the perspective of learning theories. *Who* refers to the question of who benefits from the use of agents, *when* to the timing of agent utilization in a learning context, and *where* to the question of where agents are most effective. This literature gap has seen little progress, as the possibilities for pedagogical agent utilization are very versatile in terms of environments and learners. According to Siegle et al. (2023), this results from the diversity of learner types and agent implementation restrictions in learning contexts. Drawing on this literature gap, the unification of learning theories and pedagogical agents in research is justified and therefore a pivotal element of this study.

# 3 The study

This study is conducted as a two-phased systematic literature review guided by research questions designed specifically for each phase. Firstly, this chapter introduces the defined research questions of the study. Then, the applied systematic research methods, namely umbrella and systematic literature review, are posed. This is followed by an introduction of three guidelines used throughout the study: Fink's seven-step model for research strategy, the PRISMA 2020 protocol for documentation, and the JBI Critical Appraisal Checklist for quality assessment. Finally, the implementation of the used method is illustrated.

## 3.1 Research questions

The aim of the study is to find out how learning theories have been utilized in the research of pedagogical agents and to identify what types and technologies of pedagogical agents have been applied in the found studies. The study is conducted in two phases. The first phase is focused on how learning theories are utilized in previous systematic reviews and meta-analyses on pedagogical agents (years 2013-2023). The purpose is to systematically review pedagogical agent research and gather the found learning theories. The found learning theories will be investigated further, focusing on how they were used and how they appear in the pedagogical agent context. The learning theories will be categorized using the framework of Illeris' three dimensions, based on the use and characteristics of the learning theories. The target is to synthesize and conclude the utilization and trends of learning theories in pedagogical agent research and form the base for the second phase. The research question for the first phase is:

1. What learning theories are present in systematic literature reviews of pedagogical agents and how have these theories been utilized?

The second phase is focused on learning theories in pedagogical agent research, as well as the types and technologies of pedagogical agents in the latest primary, empirical studies (years 2021-2023). The purpose is to systematically review pedagogical agent research and gather the found learning theories as well as the types and technologies of pedagogical

agents. The found learning theories will be identified, reflected against the findings of the first phase, and categorized using the framework of Illeris' three dimensions. In the second phase, the interest is also on the pedagogical agents and recognizing the types and technologies applied. The aspects of appearance, interaction capabilities, and technology of pedagogical agents will be identified where available. The target of the second phase is to synthesize the utilized learning theories and features of pedagogical agents and to offer the information to conclude the whole study. The second phase's research questions are:

2. What learning theories are present in recent empirical studies of pedagogical agents and how have these theories been utilized?
    a. What are the types of pedagogical agents found in these empirical studies?
    b. What technologies are applied in the pedagogical agent context in these empirical studies?

The main purpose of the study is to create an understanding of the state of recent research on pedagogical agents with learning theories, and discover implications and literature gaps that need further investigation.

## 3.2 Systematic literature review method

The nature of the systematic literature review is rigorous and meticulous, and articles resulting from the review process go through intense screening (Salminen, 2011). The systematic literature review method was chosen for this research, as it provides a possibility to gather the existing knowledge on a certain topic and identify trends, literature gaps, and the scope of past research. It has been recognized that there is some, but not much prior research on learning theories in the pedagogical agent research context, and this study aimed to gather existing knowledge together and propose practical and theoretical contributions. This is in line with the general aim of systematic literature reviews, which is to map out existing knowledge and conversation on a topic, while highlighting any scientifically important or interesting outcomes and studies (Salminen, 2011).

Systematic literature reviews aim to combine large amounts of information. This should be done by either aiming to create an exhaustive review from prior research or, if it is not

possible to gather all existing information, create a selective but impartial review (Vilkka, 2023). The systematic nature of the research requires thorough documentation, which makes it easier to evaluate the credibility and transparency of the study and reduces the risk of inconsistencies.

Fink (2019) presents the division of the systematic literature review process into seven steps. The selection of research questions to guide the review is the first step. Selecting the appropriate databases for search comes second. After this it is required to choose suitable search terms and phrases that are coherent with the research questions. Fourthly, the practical inclusion and exclusion screening criteria such as language and publication dates of the articles are applied. Next, to ensure the quality of the included articles, the methodological screening criteria are set. The sixth step is to test the planned process, conduct the review, and abstract the data from articles. The last step is synthesizing the results. The Fink model was applied in both phases of this study.

To summarize the main elements of a systematic literature review, they combine large amounts of information by creating an exhaustive/selective and impartial review from prior research on a certain subject. Systematic literature reviews are conducted using precise, commonly agreed upon, and transparent methods with rigorous documentation. (Vilkka, 2023.) Moreover, umbrella reviews can be summarized as systematic reviews of previous systematic reviews by integrating, comparing, and analyzing information from prior research. Umbrella reviews give an overall view of the information gathered on a certain subject and can be used for concluding large amounts of evidence. (Choi & Kang, 2022.)

For comprehensive execution of the literature review, it is important to use applicable tools and guidelines for reporting. According to Booth et al. (2016), reference management tools such as Excel are essential in helping the review process as it is necessary to precisely know which studies have been included and excluded and at what stage (title, abstract, full text). For structured and complete reporting of systematic reviews, it is recommended to adopt the PRISMA statement or another equivalent guideline, as was done in this study.

The PRISMA (*Preferred Reporting Items for Systematic Reviews and Meta-Analyses*) statement (Page et al., 2021) is a guideline for reporting systematic reviews and is designed to

help transparently report the reason for the review, what was done by the authors, and what was found. The PRISMA 2020 statement is an updated version and replaces the previous version that was published in 2009.

The PRISMA 2020 guideline includes checklists for abstracts and items as well as flow diagrams that are tools to clarify and express the search, exclusion/inclusion, and review processes. Page et al. (2021) describe the terminology used in PRISMA 2020 as follows. The record is the title or abstract of a report that is indexed in a database. The report, such as a journal article, is a document that supplies information about the study that was researched. The study is an investigation, such as a review or empirical study, that might include multiple reports.

## 3.3 Validity of the research method

The Finnish Code of Conduct for Research Integrity (TENK, 2023) guides the basic principles and good research practices that follow the European Code of Conduct for Research Integrity. The basic principles are reliability, honesty, respect, and accountability. The good research practices are destined to be followed by individual researchers, but also by the leadership and personnel of organizations. Important researchers' responsibilities include designing, executing, and documenting their research in an accurate way, following the open science principles when possible.

In the systematic literature review, it is important to be disciplined to provide reliability, validity, and generalization. Vilkka (2023) explains that together these provide a formula of accuracy and transparency of a research method. Transparency refers to the specific information about all the steps of the systematic approach so it can be repeated. Transparency includes the visibility of data acquiring, inclusion, and exclusion criteria. One challenge of the systematic literature review method is the extent of the literature, which can affect the quality of the research if available resources cannot meet the needs of the research question and literature. The use of multiple researchers can improve the quality of the research. (Vilkka, 2023.)

Another point that Vilkka (2023) poses is that criticality in a literature review is the continuing reflection of chosen decisions and acts. Everything must be explained and consistent. Critical reflection is related to the purpose of the study or research questions. Assessing the quality of the literature review includes the quality of the chosen studies and the quality of the literature review. According to Booth et al. (2016), the assessment of the chosen studies varies in different types of reviews. Invariably, the assessment process must be systematic and visible. Researchers need to define the criteria of assessment based on what will be relevant for the review. Moreover, the focus of the assessment is on how the study is conducted and whether it answers the set research questions and the aim of the review. Assessment is carried out together with the steps of selection. The subject, used data, how data was collected, results, and conclusion of the study need to be recognized. Vilkka (2023) also points out that when assessing the quality of studies, validity, reliability, and applicability need to be considered.

For systematic review assessment, JBI Critical Appraisal Checklist for Systematic Reviews and Research Synthesis (Figure 6) can be conducted from applicable parts (Vilkka, 2023). The checklist for assessment is suitable for both umbrella and systematic literature review methods (Aromataris et al., 2024), therefore it was used together with other guidelines to ensure the quality of both phases of this study.

| | | Yes | No | Unclear | Not applicable |
|---|---|---|---|---|---|
| 1. | Is the review question clearly and explicitly stated? | ☐ | ☐ | ☐ | ☐ |
| 2. | Were the inclusion criteria appropriate for the review question? | ☐ | ☐ | ☐ | ☐ |
| 3. | Was the search strategy appropriate? | ☐ | ☐ | ☐ | ☐ |
| 4. | Were the sources and resources used to search for studies adequate? | ☐ | ☐ | ☐ | ☐ |
| 5. | Were the criteria for appraising studies appropriate? | ☐ | ☐ | ☐ | ☐ |
| 6. | Was critical appraisal conducted by two or more reviewers independently? | ☐ | ☐ | ☐ | ☐ |
| 7. | Were there methods to minimize errors in data extraction? | ☐ | ☐ | ☐ | ☐ |
| 8. | Were the methods used to combine studies appropriate? | ☐ | ☐ | ☐ | ☐ |
| 9. | Was the likelihood of publication bias assessed? | ☐ | ☐ | ☐ | ☐ |
| 10. | Were recommendations for policy and/or practice supported by the reported data? | ☐ | ☐ | ☐ | ☐ |
| 11. | Were the specific directives for new research appropriate? | ☐ | ☐ | ☐ | ☐ |

Figure 6 Checklist for quality assessment of reviews (Aromataris et al., 2024)

The assessment of quality is carried out through the whole review process, using steps of the Fink model (Vilkka, 2023). After the systematic approach, the assessment of valid studies and data, and the initial synthesis of results, it is important to analyze the results and determine what is missing. A high quality literature review identifies the limitations of the evidence and recognizes the likelihood of bias. (Booth et al., 2016.)

Booth et al. (2016) state that the systematic method helps to reduce selection bias in the review, as it allows the exclusion of non-relevant studies and ensures that the relevant studies are included. The problem of selection bias is missing data in the studies. The results of the review should be based on all relevant studies, meaning that a clear understanding of relevance is essential. Publication bias is also related to missing studies and can refer to the study's language, location, and database. (Booth et al., 2016.) In addition, Vilkka (2023) presents that publication bias also considers the possible bias in what kind of studies and

results are conducted and published on the topic of the review. An example of publication bias is that statistically significant results are more likely to be published than non-statistically significant results.

## 3.4 Implementation of the research method

This study is implemented as a two-phased systematic review. The first phase is an umbrella review of prior reviews and meta-analyses. The second phase is the systematic literature review of empirical studies. The research strategies for both phases were carried out using the seven-step Fink model. The steps are chronological, but the progression has been adjusted where actions on steps have needed to be fixed, for example, the need for more specific exclusion criteria has arisen in testing. The first five steps were largely identical or defined in the overview of the study, such as defining the research questions and deciding which databases to use. However, the sixth step, testing the process and gathering information, had its phase-related specificities, as did the seventh synthesis step. Research strategies and the use of the Fink model are introduced in the research strategies of both phases.

Throughout the systematic process, comprehensive documentation is required as it supplements the quality and transparency of the study. In addition, seamless documentation enables the possibility of replicating the study. For the reporting of the reviews, the PRISMA 2020 checklists for abstracts and report items were used where applicable, as well as the flow diagrams. For data and reference management and documentation, Excel spreadsheet editor and Zotero reference management software were used.

Zotero was primarily used to store sources and manage bibliographic data. Once articles were screened at the abstract level and qualified for full-text reading, they were downloaded into Zotero as PDF files. The Zotero plug-in for Word was used to manage references and create bibliographies. Some databases were not compatible with Zotero, so Excel was used to manage sources while screening. Most importantly, Excel was used as a research data management tool for mapping the information, such as taking notes, creating lists and summaries of articles/reviews, and creating charts based on statistics from the results.

Throughout the study, the JBI quality assessment checklist guided the review process. To minimize errors, researcher triangulation was used. The inclusion/exclusion process was conducted so that any unclear or ambiguous articles were decided on together. Moreover, both researchers familiarized themselves with all included studies, in order to minimize errors due to misunderstanding or bias. The quality assessment was recapitulated in the discussion.

# 4 Umbrella review

The first phase of the study, conducted as an umbrella review, is presented in this chapter. Firstly, the research strategy used in this umbrella review is introduced, including the search process and inclusion and exclusion requirements of the results. Secondly, the findings of the umbrella review are presented. The identified learning theories are introduced and categorized based on Illeris' framework, introduced in Chapter 2. Finally, a summary of the findings and analyses will be presented, followed by a transition to the second phase of the study.

## 4.1 Research strategy

Fink's (2019) seven-step model for conducting systematic literature reviews was implemented in this umbrella review. The first step, defining the research questions that guide the review, has been carried out in Chapter 3. The process continued by defining the chosen databases, search terms, and screening criteria as well as conducting the review, abstracting the data, and synthesizing the results, based on the seven steps of Fink's model. Special emphasis was put on the sixth step related to testing the planned process, conducting the review and abstracting the data, as part of the researchers' learning process.

The umbrella review was conducted using a query string containing terms from four requirements presented in Table 1, which are the educational purpose, technology, learning theory, and type of result (systematic literature review). These criteria were chosen to ensure that the results were situated in an educational context, with a focus on pedagogical agents as a used technology and learning theories as an investigational perspective. As this phase was an umbrella review, results needed to be reviews or meta-analyses, which contributed to the fourth requirement of the query string. Search criteria was a time span of 2013-2023, reviews had to be in English and peer-reviewed, there was full-text availability, and the designated terms were found in either the title, keywords or abstract. However, all criteria were not supported by filters or search options in each database, so manual selection of results and database-specific adjustments were done.

Table 1 Requirements for the query string

| Requirement | Used term in query | |
|---|---|---|
| Educational purpose | “pedagogical” | AND |
| Technology | “agent*” / “agent” OR “agents” | AND |
| Learning theory | “theor*” / “theory” OR “theories” OR “theoretical” | AND |
| Type of result | “review” OR “meta-analy*” / “review” OR “meta-analysis” | |

Fink’s sixth step of the systematic literature review model requires testing of the planned process. The final query string was formulated based on the requirements in Table 1, however, multiple tests with varying search terms were conducted before committing to the final string. The evolution of the query string for each database is documented in Appendix A. For example, queries were tested with both “conversational” and “pedagogical” agents as well as “learning” and “educational” theories. From the technology perspective, the terms “chatbot”, “ITS”, “artefact”, and “AI” were informally tested to view the accuracy of records. The final terms were chosen based on how well they could provide results matching the defined research questions. As the only technological term in the final string was “agent”, it was acknowledged that the technological requirements for the pedagogical agent were low.

The query was conducted in four databases: Scopus, ScienceDirect, ERIC, and Taylor & Francis. The results of these queries are documented in Table 2. The search was done in a similar way in Scopus and ScienceDirect, however ScienceDirect did not support wildcards in queries and therefore alternative options for terms were added into the string, as presented in Table 1. Neither ERIC nor Taylor & Francis had the capability to conduct simultaneous

searches across multiple fields (abstract, title, keywords), and they were not compatible with Zotero. The number of records from all databases was 49.

Table 2 Number of results per database

| Database | Result |
|---|---|
| Scopus (27.1.2024) | 40 |
| ScienceDirect (27.1.2024) | 8 |
| Taylor & Francis (13.2.2024) | 1 |
| ERIC (13.2.2024) | 0 |

After running the queries, the process continued with transferring all results to Zotero and/or Excel depending on the technical abilities of the database, afterwhich the duplicates were checked and excluded. One record was recognized as a book and was excluded. After this elimination, there were 43 records for further screening.

Abstracts of the remaining articles were read and the ones not relevant were excluded based on the following requirements:

- **Role of the agent**: Results were excluded if the term "agent" was not used in the right role. "Agent" was used in the wrong context, if it referred to a learner, teacher, or movement. Many times it was used in the context of "an agent of change".
- **Type of study**: Results were excluded if they were an empirical study or in other ways did not meet the criteria of a published systematic review.
- **Context of the study**: Results were excluded if the context was not educational and instead was, for example, healthcare or business related.
- **Full text availability**: Results were excluded if they were not available in full text.
- **Length**: Results were excluded if they were not at least five pages long.
- **Language**: Results were excluded if they were not in English.

The 11 reports that were assessed for eligibility were downloaded to Zotero. From these 11 results, final studies for the review met the following requirements:

- **Context**: Results were included if the context of the study was educational or learning related and not, for example, psychological.
- **Role of learning theories**: Results were included if the learning theories were utilized in the study and not only mentioned.

This process resulted in eight studies that were included in the review. The search process and results during each elimination round are shown in the Figure 7. The origin of the used flow diagram is from the PRISMA website (*PRISMA*, n.d.). The figure is adapted using the PRISMA 2020 statement (Page et al., 2021).

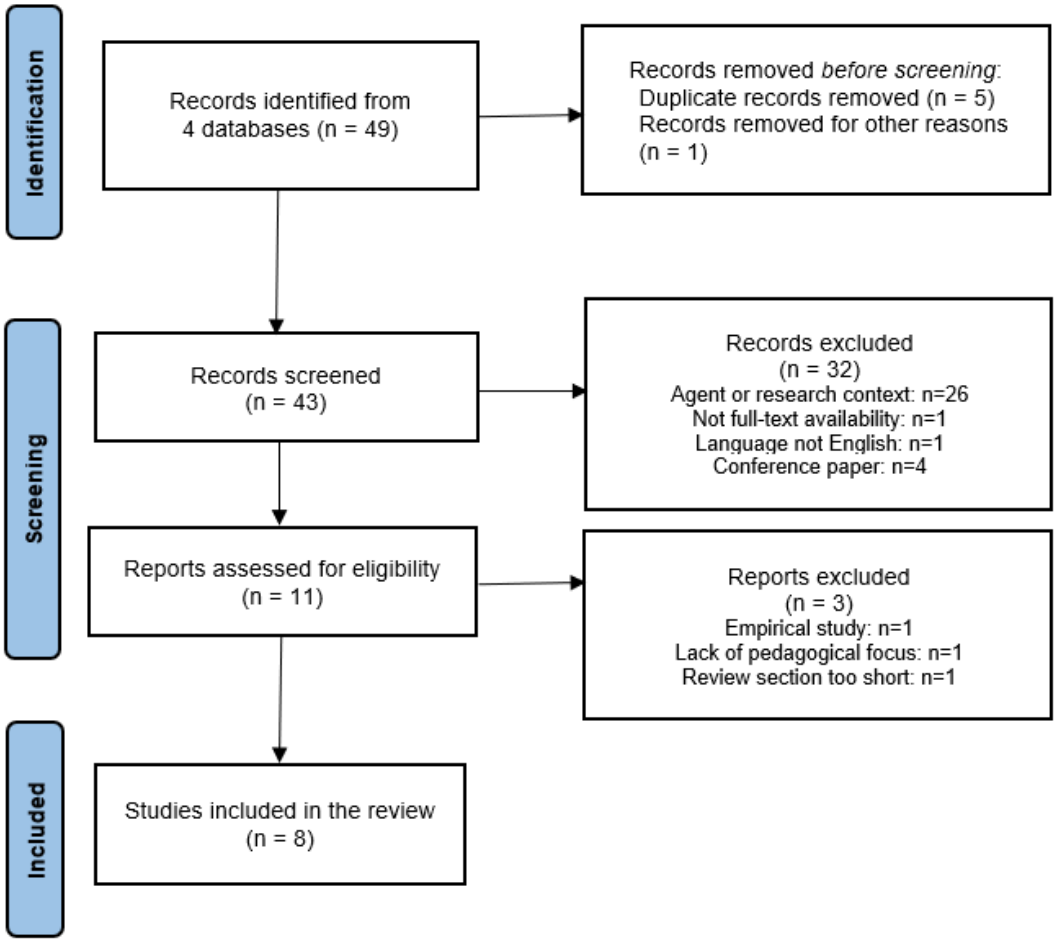



Figure 7 PRISMA 2020 flow diagram of the first phase of the systematic literature review

Once the included studies were chosen, the data extraction phase of the umbrella review was conducted. This phase is in line with the sixth step of Fink's (2019) systematic literature review model. Articles were systematically scanned multiple times in order to gather all necessary elements, which were the identification and implementation of learning theories and related results. Excel was used to compile information from the articles by gathering article-specific information on what learning theories were identified and how they were utilized. Findings related to the support of each learning theory were also documented. In addition, any trends that rose from the reviews were highlighted, deepening the understanding of the field of research. The compiled information was then synthesized and analyzed

according to the seventh step of Fink's (2019) model and based on Illeris' model of three learning dimensions, introduced in Chapter 2. The seventh step, findings, is presented in the next section.

## 4.2 Findings

The umbrella review was intended to provide knowledge on learning theories in past reviews of pedagogical agent research and to gain an understanding of what and how learning theories were utilized in these past reviews. The aim of this umbrella review was to answer the following research question: *What learning theories are present in systematic literature reviews of pedagogical agents and how have these theories been utilized?*

Finally, after the systematic evaluation process, eight studies were included in the review and analyzed extensively. It was acknowledged, and a reason to execute this study, that the research in learning theories in the context of pedagogical agents is still insufficient and rarely discussed (Dolata et al., 2023; Zhang et al., 2023). While gathering the information from found reviews, the ways that learning theories were discussed varied. Some used findings from empirical studies to insert into suitable theories offering theoretical context and reference for future research, some used a theoretical framework based on one or more theories to examine empirical studies, and some connected empirical research findings to predictions of different learning theories. Also, naturally, the time span of the empirical studies discussed in each review differs. Time span was collected to detect the age of empirical studies as theories and technology evolve and that is expected to impact the research. This is documented in Table 3, along with a brief description of the review's topic.

Table 3 Included reviews

| **Review** | **Theories** | **Years of empirical studies** | **What was studied** |
|---|---|---|---|
| Castro-Alonso et al., 2021 | Cognitive load theory, Cognitive theory of multimedia learning, Social agency theory | 2012-2019 | Effectiveness of multimedia pedagogical agents through |

| | | | |
|---|---|---|---|
| | | | predictions of learning theories |
| Dolata et al., 2023 | Activity theory | 1973-2020 | How characteristics of activity with features of agents and learners influence learning outcomes |
| Noetel et al., 2022 | Cognitive load theory, Cognitive theory of multimedia learning | 1989-2021 | Testing the effects of multimedia design on learning or cognitive load |
| Schroeder et al., 2013 | Cognitive load theory, Social agency theory, Split attention principle | 1998-2010 | Effect of using pedagogical agents on learning |
| Sikström et al., 2022 | Cognitive load theory, Collaborative learning, Self-regulated learning theory, Social agency theory | 2010-2020 | How pedagogical agents communicate with students |
| Wang et al., 2023 | Cognitive affective theory of learning with media, Emotional contagion theory, Emotional response theory, Interference theory, Social agency theory, Social presence theory | 2007-2022 | Effects of affective pedagogical agents in multimedia learning environments |
| Yang & Kyun, 2022 | Activity theory | 1/2007-2/2021 | Current research trends of AI-supported language learning |
| Zhang et al., 2023 | Cognitive theory of multimedia learning, Collaborative learning, Constructivism, Flow theory, Motivation theories, Output hypotheses, Self-regulated learning theory, Situated/contextualized learning theories | 2000-8/2022 | Pedagogical and implementational aspects of chatbot-assisted learning |

From eight past reviews on pedagogical agent research, 17 theories shown in Table 3 were identified. Some reviews only focused on one theory, e.g. Dolata et al. (2023), whereas others more briefly implemented multiple theories into their review, e.g. Zhang et al. (2023).

For analysis and syntethization, the theories were categorized using Illeris' framework (2008, 2018) that presents three dimensions of learning: content, interaction, and incentive. Illeris (2008, 2018) introduces that many theories focus on only some of the dimensions, for example, experiential learning concentrates on the content dimension and the Activity theory focuses on interaction and content, but not incentive dimensions. In the categorization of findings, the theories were set to the category based on the emphasis on dimension found in the study. The emphasis is presented with the theory. It is noticed and made visible that theories may have characteristics of multiple dimensions.

The three dimensions were applied and presented followingly:

1. Content – cognitive perspective
2. Interaction – social perspective
3. Incentive – emotional perspective

Some of the found theories were explored in detail and in multiple reviews, whereas some were more briefly discussed and only implemented in one review. For example, Emotional response theory and Interference theory were both discussed in only one review, whereas Cognitive load theory, for example, was introduced in multiple reviews. This does not necessarily mean that all theories that were discussed in only one review were insignificant, but instead demonstrates the wide variety of theories found in this umbrella review. However, theories that were included in multiple reviews, such as Social agency theory and Cognitive load theory, can be seen as notable and central theories regarding pedagogical agent research, resulting in a high number of occurrences. The occurrence of the theories is presented in Figure 8, afterwhich the theories and related findings will be introduced. Each theory is briefly introduced in a general manner, followed by reviews' findings related to the certain theory.

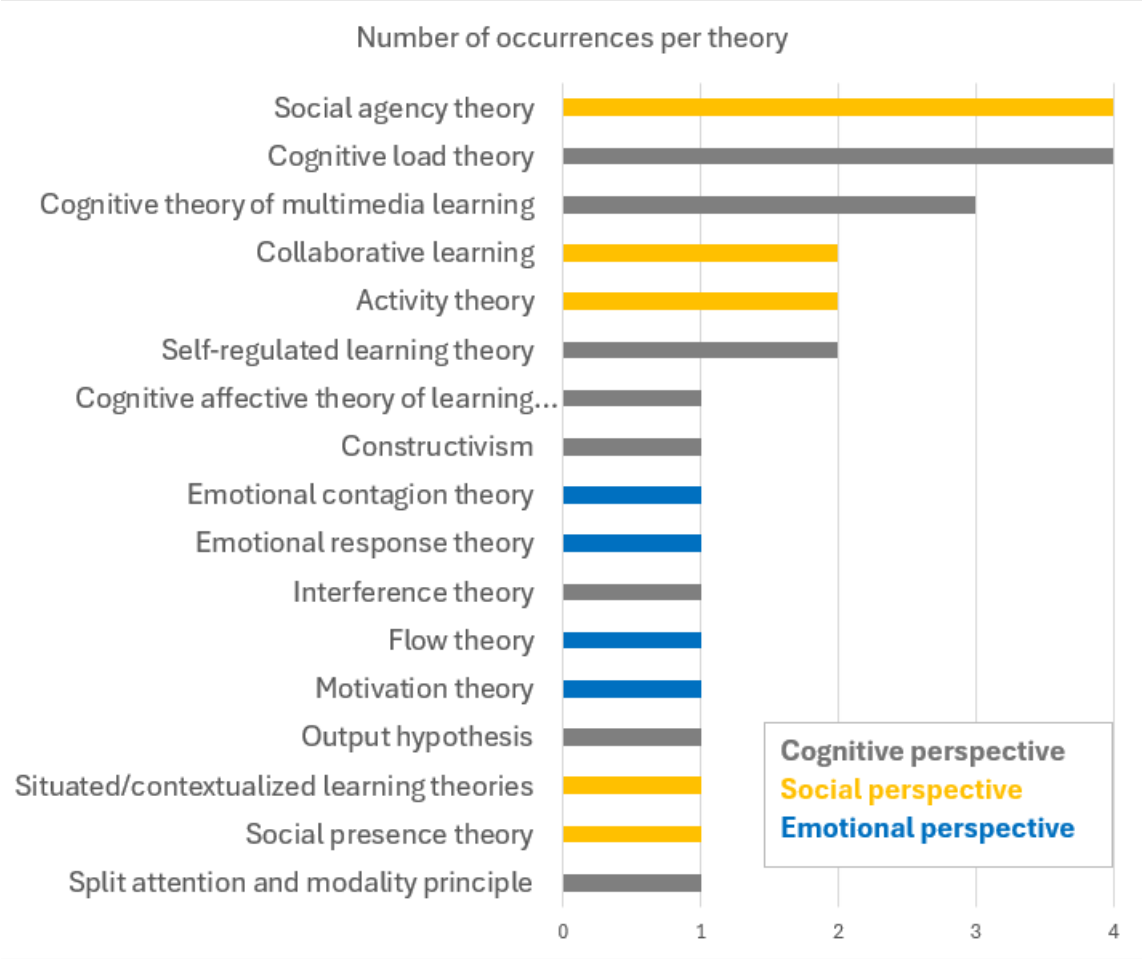



Figure 8 Number of occurrences per theory in the first phase

### 4.2.1 Content – Cognitive perspective

The content dimension is about what is learned. This provides a cognitive perspective as it can be many different things such as meaning, strategies, and opinions, but is often mentioned to be skills and knowledge. The learner develops functionality and constructs meaning and ability. (Illeris, 2008, 2018.) The theories introduced in this section emphasized the cognitive perspective.

**Cognitive load theory**

According to the Cognitive load theory proposed by John Sweller (2011), knowledge is divided into biological primary and secondary knowledge. Primary skills are learning to speak and listen, whereas secondary knowledge is subject to instruction and requires large storage

when dealt with. Evans et al. (2024) propose that secondary knowledge is constructed as a result of interactions and is processed in the working memory and connected to information in the long-term memory. This process can cause issues in educational settings depending on how new information is passed on to students and how the limited working memory is utilized, which is vital for long-term memory encoding. Furthermore, Sweller et al. (2019) introduce another perspective on cognitive load which divides it into three types – intrinsic, extraneous, and germane – as presented in Figure 9. These categories emphasize information complexity, how the information is presented and processed, as well as the role of working memory.

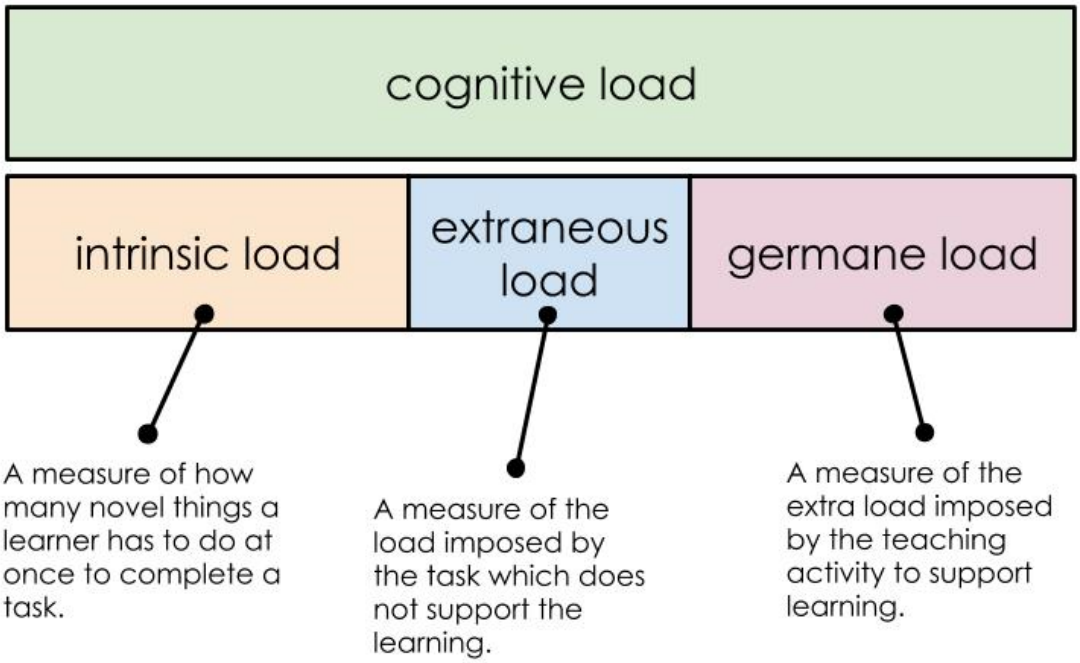



Figure 9 Three types of cognitive load (BenRogers, 2018)

Based on the findings from four reviews discussing the Cognitive load theory, the appearance, gestures, voice, and expressions of pedagogical agents are crucial regarding the inflicted cognitive load. Results by Castro-Alonso (2021) stated that a more cartoon-like 2D agent was seen as a better option compared to a highly visual 3D-agent, which results from the redundancy effect of the Cognitive load theory. The redundancy effect emphasizes a need for avoiding nonessential visual information in learning material, and is seen as a vital

part of the Cognitive load theory analysis. An abundance of information can overload the working memory and therefore can interfere with learning. As concluded by Castro-Alonso et al. (2021), this effect extends to the agent's overuse of gestures, eye gaze, and facial expressions.

The role of extraneous cognitive load was highlighted in the results of Noetel et al. (2022) and it was stated that a key goal of implementing the Cognitive load theory is to reduce extraneous cognitive load, which is linked to the assessment that 3D agents are more cognitively distracting compared to 2D agents. Agent's appearance was further discussed from the perspective of extraneous cognitive load by Schroeder et al. (2013), introducing the Cognitive load theory prediction that extraneous cognitive load can be potentially caused by the agent's appearance, voice, gestures, and movements and can delay or harm learning. It was discovered that tests with animated pedagogical agents resulted in a higher effect in cognitive load than tests with static agents. Also, it was discovered that animated agents may lack the ability to direct the learner's attention to relevant information, but they were rated more human-like and engaging. Schroeder et al. (2013) concluded that the use of features and other animations can lead to an increase in extraneous cognitive load; however, increasing familiarity and keeping features consistent can potentially decrease cognitive load over time. Drawing on Schroeder et al.'s (2013) findings, pedagogical agents can potentially facilitate learning, despite them causing extraneous cognitive load or distraction in the learner.

From a more conversational and interactive perspective, Sikström et al. (2022) found that an increase in mental effort and students' interest was visible, when agents had a more conversational approach to giving instructions. Moreover, loss-framed messages were seen to have a more increasing effect in germane load than gain-framed messages. Also, regarding the interaction of agents, an abundance of non-task comments was seen as hindering in regard to learning and the perception of agent-learner interaction. The role of signaling was a somewhat central element in Noetel et al.'s (2022) results, showing that agent effects on learning were stronger when agents showed meaningful signaling, i.e. gesturing to what is important, as well as learners preferring signaling agents over those that did not. A proposed conclusion regarding signaling was that pedagogical agents tend to not reduce cognitive load but increase learning in moderation, perhaps since they provide signaling.

Coping mechanisms for cognitive load were also discussed in the study by Noetel et al. (2022). Dealing with intrinsic cognitive load was presented to be helped by using segmenting, simpler language, and self-paced multimedia rather than system-based multimedia, where self-paced enables the use of personal cognitive load coping strategies. The importance of offering learners different intrinsic cognitive load coping mechanisms to increase learning was also emphasized.

**Cognitive theory of multimedia learning**

Mayer (2024) describes that the Cognitive theory of multimedia learning is connected to the field of educational psychology and shaped by prior theories, including the Cognitive load theory. The present state of the Cognitive theory of multimedia learning is that it describes, evidence-based, how people learn from instructional multimedia messages. Multimedia learning material is to advance learners' skills or knowledge. The format of the multimedia material can be words such as spoken and printed text, or graphics such as video, photos, and immersive virtual technology. Presentation can be in books, on screen, or in virtual reality. The implications as design principles, for effective multimedia message, are inflicted in the theory.

Mayer (2024) presents that there are three guiding assumptions in the Cognitive theory of multimedia learning based on cognitive science. As visualized in Figure 10, the dual-channel assumption is that there are interacting but separate channels to process auditory/verbal and visual/pictorial information for humans. According to Mayer (2024), the assumption of limited capacity is that in each channel, the number of separate pieces of information that humans can process at the same time is limited. The active processing assumption is that meaningful learning results for learners when there is a need for cognitive processing, like relevant past knowledge is activated from long-term memory.

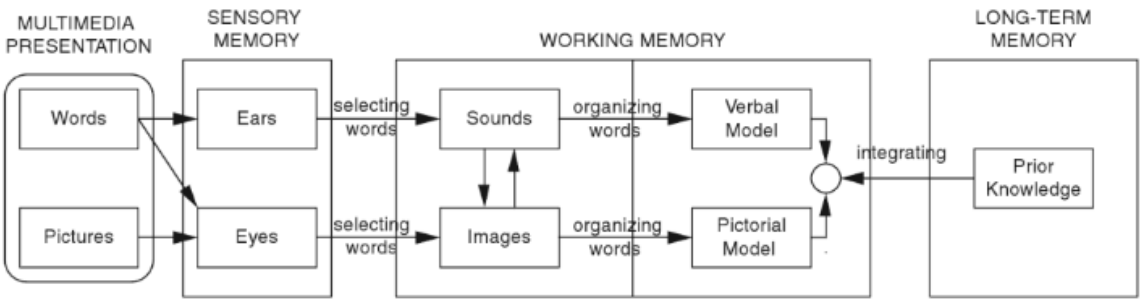



Figure 10 Cognitive Load of Multimedia Learning (Mayer, 2014, p. 52)

The Cognitive theory of multimedia learning was presented in three articles of the umbrella review. Castro-Alonso et al. (2021) and Noetel et al. (2022) introduced the results in close link to the Cognitive load theory. Unnecessary information can overload the capacity of the working memory and overload of dual-channel, visual and auditory, processing should be avoided as it might disturb learning (Castro-Alonso et al., 2021; Noetel et al., 2022).

However, pedagogical agents were found to be beneficial for learning (Castro-Alonso et al., 2021; Zhang et al., 2023). Zhang et al. (2023) introduced how chatbots could contribute to learning by offering versatile types of multimedia-enhanced learning materials, like picture handbooks, instructional videos, or reading materials depending on learners' needs and proficiency. Multimedia, like entertaining elements, were investigated as if they increase learners' enjoyment of chatbots and lead to more effective learning. Chatbots activating multiple channels in learners' cognitive systems with multimedia elements will lead to high efficiency in learning when facilitating learners' comprehension of the content. However, to achieve these positive effects on learning, it is essential to prevent dual-channel process overload.

**Split attention and modality principles of multimedia learning**

Split attention and modality principles of multimedia learning are instructional implications to designing multimedia materials (Ayers & Sweller, 2014, pp. 206; Low & Sweller, 2014, pp. 227). The split-attention principle states that, in multimedia learning, to require the learner to split attention between multiple sources of information should be avoided. Reducing extraneous cognitive load, caused by mentally integrating multiple sources, releases resources for learning. (Ayers & Sweller, 2014, pp. 106.) The modality principle also refers to

the Cognitive load theory and derives from the split-attention effect. The modality principle illustrates that the humans' working memory is limited in capacity, although, essential for learning. The modality principle proposes that in well-defined conditions to effectively expand working memory, some information should be presented in visual mode and others in auditory mode. (Low & Sweller, 2014, pp. 227, 241–242.)

Schroeder et al. (2013) pointed out that some studies had suggested that pedagogical agents' presence on screen should not split learners' attention between two or more information sources, supporting the split-attention principle. Schroeder et al. (2013) did not find support for the split-attention principle's predictions and agents on screen did not disturb the learning. The discussion provided an explanation that multimedia, the pedagogical agents, might not require cognitive resources as much after being processed the first time, which is also in line with the predictions of the Cognitive load theory.

Schroeder et al. (2013) presented that the modality principle was well supported in previous studies involving pedagogical agents providing dual-channel, visual and aural, information. Unlike the previous studies, Schroeder et al. (2013) did not find support for this claim and modality principle. Results showed a better impact in learning when agents communicated through text rather than through narration.

**Cognitive affective theory of learning with media (CATLM)**

According to Moreno and Mayer (2007), CATLM focuses on mechanisms for meaningful learning when a learner is directly interacting with the instructional system within a multimodal environment. CATLM widens the idea of the Cognitive theory of multimedia learning to cover media such as agent-based learning environments and virtual reality. Media in this case can be either visual or auditory. The model of CATLM is visualized in Figure 11.

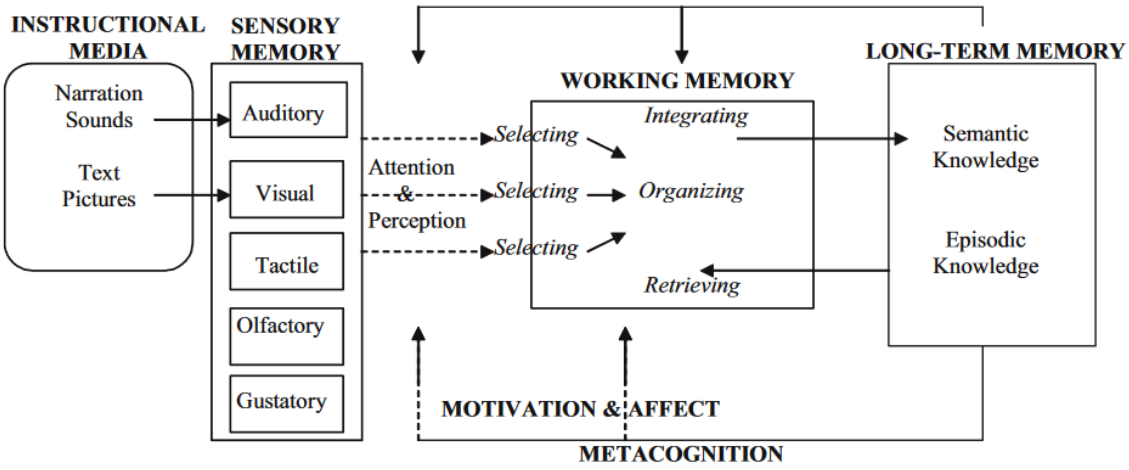



Figure 11 The CATLM model (Moreno & Mayer, 2007)

CATLM was explored by Wang et al. (2023), and from the viewpoint of if activation of affective-motivational states would impact learning. Earlier studies proposed that cognitive engagement in learning is impacted increasingly or decreasingly by the activation of affective-motivational states. Instructors showing positive emotions was seen to promote cognitive processing. Affective pedagogical agents' emotions were recognized by learners, which led to reflecting positive emotional tones. It was concluded that CATLM was supported because learners' intrinsic motivation was improved, positive emotions provoked, and learning was promoted when affective pedagogical agents were compounded to multimedia teaching.

### Constructivism

Constructivism is a notable learning theory with origins from Vygotsky and Piaget, among others (Al-Sakkaf et al., 2019). According to Dennick (2016), new and existing knowledge are seen as intertwined, with new knowledge being interpreted by existing knowledge and then joined together. This relates to the constructivist view, where knowledge is meant to be built on top of existing knowledge. One's social and physical interaction with the environment is the basis for knowledge construction, and education should go beyond repetition and other basic learning and teaching tactics, and instead focus on interactions and profoundness in learning situations (Bremgartner et al., 2015). Constructivism can be seen from a cognitive and social perspective (Al-Sakkaf et al., 2019), and this section will focus on the cognitive aspect due to the nature of found results.

Zhang et al.'s (2023) review results demonstrated how chatbot-assisted learning and it's connection to learner authenticity could result in meaningful learning situations facilitating one's contextualized internalization of current learning topics and targets. This view was strongly connected to the Constructivist theory, which highlights the role of purpose and profoundness of learning situations. According to traditional Constructivist views (Piaget, 1973), by using prior knowledge and understanding the context and environment, learners can construct new knowledge. The Constructivist framework was associated with the observations outlined by Zhang et al. (2023), indicating that chatbots play a role in establishing the learning environments essential for constructing new knowledge. Chatbots were found to be beneficial in making learning scenarios vibrant and significant, thereby aiding in the understanding and retention of key knowledge.

**Self-regulated learning theory**

According to Zimmerman (2002), self-regulation is seen as a process in which learners create academic skills from one's own abilities. Self-regulation refers to the proactivity of learners and their desire to learn for themselves. Self-regulated learning requires learners to understand their own strengths and set their own goals and strategies. This is seen as an important element regarding life-long learning and learner motivation, but requires learners to continuously be aware and practice self-reflection. The focus of self-regulated learning should be on activating, altering, and sustaining certain methods of learning in both social and independent learning situations.

Zimmerman (2002) divides the self-regulatory process into three cyclical phases, which are the forethought phase, performance phase, and self-reflection phase, as presented in Figure 12. The forethought phase consists of task analysis and self-motivation, performance phase of self-control and self-observation, and the self-reflection phase of self-judgement and self-reaction.

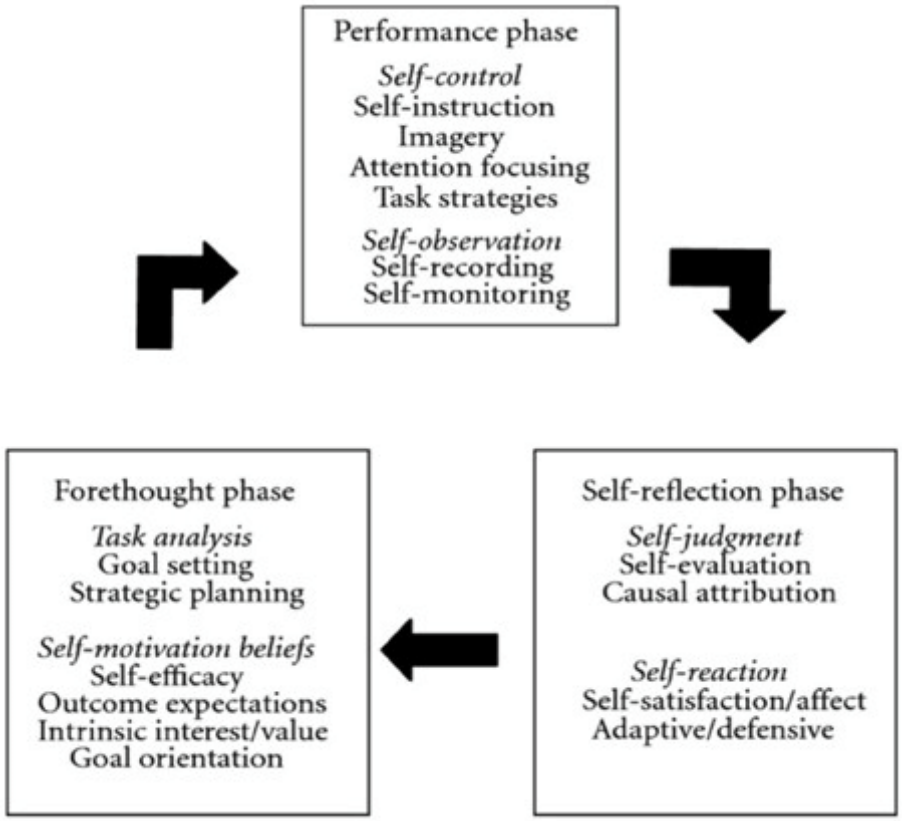



Figure 12 Cyclical model of the self-regulatory learning process (Zimmerman, 2002)

Based on the results of Zhang et al. (2023), chatbot-assisted learning can be very self-regulated resulting from the personalization of tasks and the facilitation of positive engagement in a learning context, which can potentially lead to an increase in positive emotions and learning efficiency. This is in line with self-regulated learning principles, which emphasize the importance of learner's control on the content and style of learning, and the resulting active engagement on high learning efficiency. Sikström et al. (2022) found through previous studies that agents' metacognitive support was seen to improve self-regulated learning. Effects of agent scaffolding, motivation, metacognition, and self-efficacy were all said to be better understood when utilizing self-regulated learning.

Self-regulated learning in the context of cognitive load has not been explored in many articles, and it was proposed that this should be a focus point in future research. Nevertheless, it was concluded by Zhang et al. (2023) that self-regulated learning can, to some extent, be

seen as a solution to the heavy cognitive load that burdens chatbot-assisted learning and its usefulness, but the need for further research was strongly emphasized.

**Interference theory**

Regarding the Interference theory, Wang et al. (2023) introduced concerns found from research which had discovered affective pedagogical agents to be a distraction to learning. The Interference theory suggests that any additional distraction, such as material that is not essential for intended learning, reduces effective working-memory capacity (Moreno et al., 2001), which is also in line with the predictions of the Cognitive load theory. Based on the Interference theory, Wang et al. (2023) anticipated that affective pedagogical agents offer information that is irrelevant to learning. This may cause negative effects in learning and distract students from the main information. However, Wang et al.'s (2023) results did not find support for the Interference theory.

**Output hypothesis**

The Output hypothesis proposes that language production, both verbal and written, plays a key role in the process of second language learning under specific circumstances. (Swain, 2005). Swain (2005) also introduces the three functions of output in second language learning to activate the cognitive process, which are triggering, hypothesis-testing, and reflecting. The results found by Zhang et al. (2023) regarding the Output hypothesis were positive, as there were findings implicating that students have a strong willingness to produce output in the human-chatbot interaction. When students had unlimited attempts and get immediate feedback, it was discovered that they had enjoyable, stress-free, and supporting feelings. These findings were in line with Swain's Output hypothesis. Zhang et al. (2023) suggest that the Output hypothesis is supportive in learning.

### 4.2.2 Interaction – Social perspective

The interaction dimension is social, as it contributes impulses to conduct learning. Interaction can have multiple levels as it can happen in integration, situations, society, the environment, or other conditions. Interaction can be communication, action, cooperation, or other

ways of influence. (Illeris, 2008, 2018.) The following theories emphasize the social perspective in the findings.

**Collaborative learning**

Collaborative learning is defined by Barkley and Cross (2014) as an umbrella term for interactive group work which has three key elements. The first element is intentional design, which means that there must be purposeful, structured learning tasks that activate group work and learning together. The second element, co-laboring, indicates that all group members must actively work together and engage in the learning. Meaningful learning is the third element, and it stands for intended and curriculum based instructional goals. Social constructivism is the background in collaborative learning as both predicate that knowledge is constructed socially among the group.

Stahl and Hakkarainen (2021) introduce Computer-supported collaborative learning (CSCL) as a theory and research based vision of what the development of computational support and new means of conceptualizing knowledge could lead collaborative learning to be like. Stahl and Hakkarainen (2021) present that technology can be a part of the collaboration as one participant, whereas Barkley and Cross (2014) see technology as an educational tool to create collaboration. Sikström et al. (2022) introduced the CSCL findings from prior studies. CSCL was found to have a significantly positive influence on students' motivation, awareness, and group process such as cohesion and atmosphere, via pedagogical agents' metacognitive support.

From a more communicational point of view, Sikström et al. (2022) presented that pedagogical agents' interventions in discussions positively influenced learning outcomes and students' performance in pairs. It was found that communication with pedagogical agents improved learners' attitudes regarding collaborative online learning, but did not increase self-regulation skills. Sikström et al. (2022) also discussed that communication with pedagogical agents scaffolds collaborative learning and improves learning in many ways. Examples are increasing group and personal performance, attitudes towards collaborative learning, and awareness in tasks and groups. In their review, it was discovered that there can be multiple positive impacts in learning collaboratively, supported with pedagogical agents. A

recommendation for the future was to use pedagogical agents in a more central role to foster pair and group communication and collaboration.

Zhang et al. (2023) discovered that chatbot-assisted learning is beneficial in the context of collaborative learning theories. Detected activities to support peer collaboration and communications by pedagogical agents were similar to Sikström et al.'s (2022) findings. Zhang et al. (2023) found pedagogical agents' support for collaborative learning beneficial in collaborative product design, scaffold collaborative writing, role-playing activities, and engagement in collaboration.

**Social agency theory**

According to the Social agency theory as presented by Jackson and Williams (2021), the use of visual and verbal cues with a human-like voice can make a human-computer interaction (HCI) situation feel as if the learner is taking part in a human-to-human conversation. Learners are encouraged to consider HCI situations with multimedia elements as social ones, with similar characteristics as situations between humans. Social agency is seen to have a positive effect in facilitating learning, and this is done through both cooperative and non-cooperative social behaviors. Generally, through the lens of the Social agency theory, it is thought that the relationship between human and computer is inherently social. However, as research and technology evolve, there are different views regarding the role and characteristics of a "social agent" in the HCI context.

Social and emotional cues were seen as pivotal elements of pedagogical agent design and research, from the perspective of social agency (Castro-Alonso et al., 2021; Wang et al., 2023). Castro-Alonso et al. (2021) stated that instructors with human social cues are seen as more beneficial and effective for learning than instructors that show fewer or no signals, resulting in the conclusion that multimedia pedagogical agents using nonverbal social cues would be more beneficial for learning compared to an instructor lacking signals. It was also stated by Wang et al. (2023), that social cues of agents can lead to a higher eagerness in learning, highlighting that multiple emotional cues by agents can result in learners' deeper processing when trying to understand the agent. According to prior research introduced by Wang et al. (2023), this is true, as agents showing more than single emotional cues had a

positive effect on learning performance and processing when compared to those affective agents showing only single cues. From the emotional point of view and contrary to the Social agency theory principles, results by Wang et al. (2023) showed how affective agents were better at triggering positive emotions in learners compared to human efforts. This was somewhat explained by the nonsystematic use of voice and images, as well as emotions resulting from these in prior research.

Gestures and other physical actions were discussed in multiple reviews connected to the Social agency theory. Castro-Alonso et al. (2021) predicted that agents using gestures, eye gaze, and expressions would trigger larger effects than those agents with little to no social signals. However, Schroeder et al. (2013) expressed their concern for stereotypes regarding agent appearance that rose in past research and proposed further research on agents appearing generally dislikeable. They also stated a need for further investigation of the degree and intent of agent animation, especially analyzing the relationship between the degree of animation and learning effects. Castro-Alonso et al. (2021) identified that eye gaze has a positive effect on learning, and that the benefits of gesturing can be a result of their signaling role. Also, Schroeder et al. (2013) presented that agents may benefit from using gestures as the theory relies on the creation of social interaction, and that gestures can make the agent seem more human-like to the learner, which can enhance the understanding of conveyed information.

From the communication perspective, prior studies show how an agent's conversational style to giving instructions can positively affect learning, motivation, and cognitive load, as opposed to formative instructions (Sikström et al., 2022). Moreover, results by Sikström et al. (2022) show that elaborate feedback as opposed to simple feedback can also have a positive effect on learning. The voice principle of Social agency theory predicts that an agent's human voice is more beneficial for learning compared to a synthesized machine voice in the context of narrations (Castro-Alonso et al., 2021). However, a different view was posed by Castro-Alonso et al. (2021) stating that recent studies and meta-analyses have shown no difference in effectiveness of human and machine narrations of agents. This statement contradicts the seminal study and supporting evidence of the voice principle, although the lack

in difference can somewhat be explained by the increased quality of machine narration (Castro-Alonso et al., 2021).

**Activity theory**

Engeström (2016) introduces the Activity theory to be commonly used in educational investigations. The triangular model of an activity system, presented in Figure 13, enables visibility of the context, meaning the systemic formation between components and identified relations. As educational processes are becoming more distend in networks and are being distributed, the unit of analysis is extending from a single activity system to incorporate multiple interconnected activities. McAvinia (2016) summarizes that the Activity theory pursues to illustrate the relationship among different constituents and conditions for intentional activities. The theory suggests that activities are done for a set purpose, happening under particular conditions, have a scheme, and are mediated by certain instruments, artefacts, or tools. The base of the Activity theory is that activities are conscious and defined by intention. Activities are not permanent as they change in relation to surroundings.

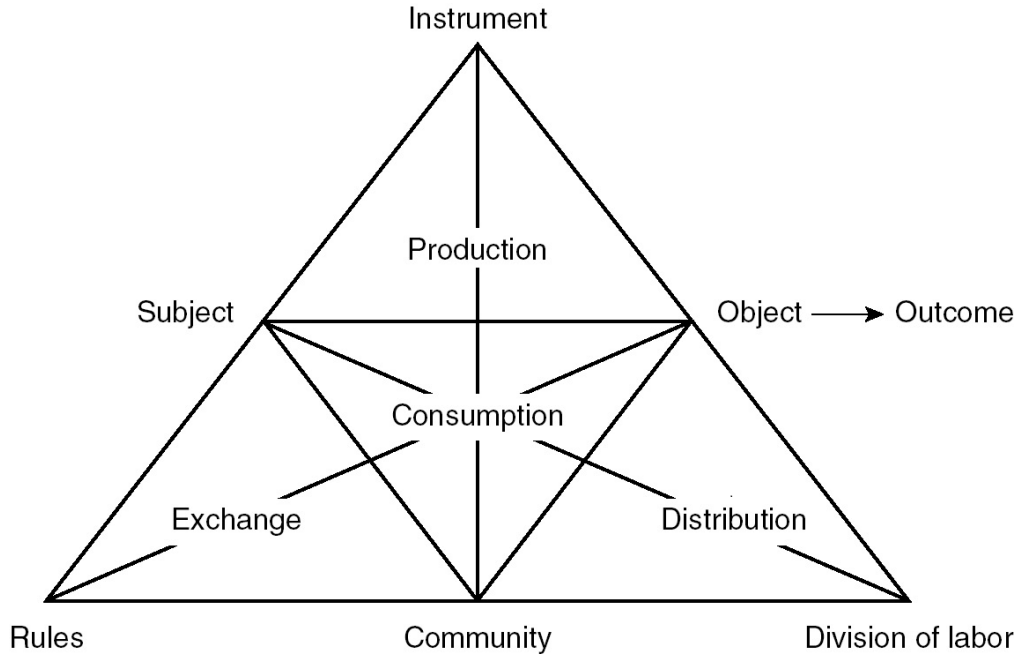



Figure 13 Activity Theory (Engeström, 2014)

Activity theory was investigated in two reviews. Yang and Kyun (2022) reviewed research trends regarding artificial intelligence in language learning using an Activity theory

perspective. The article used the seven constituents of the Activity theory and pedagogical agents were discussed in four of them: tools, object, outcomes, and division of labor. Tools present the instrument constituent. The other three constituents observed were subject, community, and rules.

The second review by Dolata et al. (2023) was an analysis about learning with digital agents based on the Activity theory. The aim was to evaluate effects in learning outcomes influenced by different characteristics of the activity, such as pedagogical agents and learners. The six constituents of the Activity theory were used, with outcomes and object joined as one. The Pedagogical Agent Model (LPAM) was introduced and varied from two activity perspectives, LPAM Learner's Activity System (LPAM-LAS) and LPAM Pedagogical Agent's Activity System (LPAM-PAAS). The difference in framework models is the perspective (learner or pedagogical agent), and this rules how the constituents are determined.

Yang and Kyun (2022) discovered that there were multiple tools to support language learning: AI robots such as chatbots, intelligent or humanoid robots, AI agents such as pedagogical or conversational agents, intelligent tutorial systems, and AI-supported voice-based smartphone apps. In general, the outcome results were positive, but some studies also found that all the pedagogical assisted systems could not improve learning. From the division of labor point of view, it was noticed that developers, researchers, and teachers were the participants directing the learning system, instructions, development of pedagogical agents, and design of learning content, while learners had a comparatively passive role.

Yang and Kyun (2022) recommend the two pedagogical implications. Firstly, a mixed module of formal teacher instruction and AI-supported language learning should be integrated in pedagogical design. Secondly, the collaboration between learners in language learning should be AI-supported, as research showed that learners prefer working with their peers in this context.

Dolata et al. (2023) discovered in their results that combining results from different studies and providing conclusive LPAM-based analysis of impact on learning outcomes is not applicable. The ways that learning outcomes were measured varied significantly in different studies. The influence in learning outcomes appeared positive, negative, mixed, and neutral

in the studies. It is suggested that a prompt and initiative pedagogical agent might motivate learners and impact the learning outcome positively. Also, highly adaptive pedagogical agents supporting learners to reach better desired outcomes was suggested, but not yet confirmed.

**Social presence theory**

Cui et al. (2013) presents the Social presence theory to be commonly attached to the context of mediated communication. Social presence is described as a momentarily continuous awareness of the presence and sense of another intellectual entity in psychological, emotional, and intentional states (Biocca & Harms, 2002). According to Cui et al. (2013), the definition of social presence is not constant as it can be seen as a complicated social and psychological construct. In online learning, instructional design and studies about social presence have developed. For social presence, the quality of media and users' perceptions of them are both implied.

From the found reviews, Wang et al. (2023) introduced the Social presence theory. According to the theory**,** learners' experience of the learning process is influenced by understanding the existence of a teacher in virtual learning environments. The Social presence theory predicts that learners' motivation and performance levels can increase if real-time feedback and communication is offered, based on the cognitive and emotional states of learners. The review takes into consideration the role of agent appearance, type, and movement. Body movement was found to be an enhancer of motivation and transfer performance. This finding supports Social presence theory predictions, as the theory states that body movement of agents provides human-like elements and increases the feeling of a social environment in learners. However, Wang et al. (2023) also present contradicting results saying that affective pedagogical agents' movement did not affect positive emotions or retention performance.

**Situated/contextualized learning theory**

The Situated/contextualized learning theory was introduced by Zhang et al. (2023) and conveyed the results of how chatbots could make learning environments similar to real-life situations. Reflecting on the Situated learning theory view of Brown et al. (1989) that those learning environments that are connected to the target knowledge often help in integrating

and retrieving knowledge to/from one's memory, Zhang et al. (2023) propose that chatbots can be used to create learning environments that are positive and resemble real-life situations, with these situations connecting to the content knowledge.

### 4.2.3 Incentive – Emotional perspective

The incentive dimension is mainly emotional**,** as it relates to directing and providing mental energy for the learning process. It includes interest, motivation, and engagement. The incentive function is to develop a personal sensitivity and secure the mental balance of the learner. (Illeris, 2008, 2018.) Followingly introduced theories emphasized the emotional perspective.

**Motivation theories**

As introduced by Urhahne and Wijnia (2023), motivation is a widely studied psychological construct in the context of education, and theories of motivation are used to describe and predict learning behaviors. Multiple different learning related theories deal with motivation, for example, Expectancy-value theory, Social cognitive theory, Self-determination theory, Interest theory, Achievement goal theory, and Attribution theory. The basic motivational model presented in Figure 14 serves as a basis for different motivation theories.

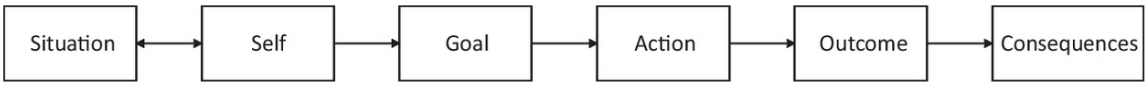



Figure 14 Basic motivational model (Urhahne & Wijnia, 2023)

Results from the review by Zhang et al. (2023) agree with Motivation theory predictions, as chatbot-assisted learning could increase learner motivation through supportiveness, enjoyment, security and freshness. This is because, according to Motivation theories, increase in learner motivation can often lead to an increase in learning outcomes. According to Zhang et al. (2023), the fact that many students had no prior experience with chatbot-assisted learning contributed to feelings of curiosity, which had an increasing effect on learner motivation due to chatbot unfamiliarity.

### Flow theory

As presented by Miller and Maderfeld (2021), the Flow theory proposes that the ideal level of learning can be encountered when learners work on tasks that have a skill-challenge balance, together with the individual's interest, strong concentration, and control. The skill-challenge balance is a dynamic state where the learner's skills are not overrated or underrated to the given task. The theory was developed by Csikszentmihalyi (Beard, 2015).

Zhang et al. (2023) introduced results that chatbots may help learners to reach the flow state which fosters high efficiency in learning and positive affective states. Rich human-computer interaction and high autonomy were found as factors enabling learners to reach the flow state. Flow was defined as the experience of deep engagement in activities and high levels of concentration and excitement. Analyzing and supporting chatbot-assisted learning may benefit from the use of the Flow theory.

### Emotional contagion theory

According to Mottet and Beebe (2000) and the Emotional contagion theory, a person will mimic the expressions, movements, and gestures of others automatically, resulting in similar emotional influence. Emotional contagion is seen to have an effect on shaping social interactions in the classroom, and can influence any conversation or subjective emotional experience.

The findings by Wang et al. (2023) support Emotional contagion theory predictions of the affective-motivational processing and learning performance, stating that these are strongly affected by affective agents. The theory is also supported by findings regarding learners' positive emotions, which are evoked by affective agents. These findings are also consistent with past research and go on to involve the enhancement of learning outcomes, performance, and intrinsic motivation as a result of affective agents portraying positive emotional states.

### Emotional response theory

Horan et al. (2012) describe the Emotional response theory to consist of three elements, which are instructor behavior, student emotional responses, and student approach-avoidance behaviors. The emotional responses that a student has to instructor communication have a

pivotal role in shaping the relationship between student behavior and instructor messaging. Resulting from instructor communication, the theory states that the student will emotionally react in one of three ways. Options are to experience emotions based on how one feels (e.g. comfortable/uncomfortable), how mobilized one feels (e.g. excited/calm), or by how powerful one feels (e.g. decisive/indecisive).

According to the Emotional response theory and introduced by Wang et al. (2023), instructors' communications can be an influencing factor in the behavior of learners, as both nonverbal and verbal communication can affect learners' emotions. These verbal and nonverbal cues could support the intrinsic motivation and emotional response of learners, and the results of the review showed that affective pedagogical agents did have positive effects on emotions, motivation, and learning outcomes.

### 4.2.4 Summary

The aim of this umbrella review was to answer the following research question: *What learning theories are present in systematic literature reviews of pedagogical agents and how have these theories been utilized?* The umbrella review provided an overview of learning theories represented in the eight reviews and meta-analyses. A total of 17 different learning theories, related principles, and hypotheses were discovered.

The research question was answered based on the synthetization of the chosen reviews, with the support of theoretical background information from relevant research. The utilized learning theories were identified and introduced. Moreover, the theories' perspectives on pedagogical agent implementation were analyzed to the extent that they were found in the reviews, some more in-depth than others.

The learning theories were categorized based on the framework of Illeris' three dimensions: content (cognitive perspective), interaction (social perspective), and incentive (emotional perspective. Illeris' framework was chosen as it roofs and effectively considers the versatile aspects and use of learning theories. The results of the first phase represented all three dimensions of learning, with the cognitive perspective being the most common. It is noteworthy, that of the eight learning theories from the cognitive perspective, only two,

Constructivism and Output hypothesis, were not investigated in relation to the Cognitive load theory. This reveals that the Cognitive load theory is considerably used in pedagogical agent research.

It was also noted that some learning theories had characteristics of multiple dimensions. An example of this is Constructivism, which has elements of both cognitive and social perspectives and was categorized under the cognitive perspective due to the nature of Zhang et al.'s (2023) results and their focus on the individual's knowledge construction. On the other hand, theories under the emotional perspective represented the social perspective as well, as the learner's emotions in an educational setting are affected by the social interaction with the agent. An example of this is the Emotional response theory, which focuses on the emotional responses that a student has to instructor communication. The representation of multiple learning dimensions was anticipated when starting the categorization process, as Illeris (2018) identified the social perspective as a vital part of both cognitive and emotional perspectives and highlighted the multidimensional nature of learning theories.

The found learning theories are summarized in Table 4 by categorizing them based on how they were supported by the reviews' findings. The majority of learning theories were found to be supported and review results were in line with theory predictions. However, Modality principle, Split-attention principle, and Interference theory were not supported by review results and Activity theory, Cognitive load theory, Social presence theory, and Social agency theory had mixed results with some supporting elements. Theories were found to be supported if their predictions and expectations were in line with the reviews' results. Mixed results stemmed from partial alignment of predictions and results. This was due to the lack of prior research needed for proving all learning theory related hypotheses, or to the differing results from studies related to the same theory.

Table 4 Support for identified learning theories in the first phase

| Support/no support/mixed results | Theories |
|---|---|
| Support | CATLM, Cognitive theory of multimedia learning, Constructivism, Collaborative learning, Emotional contagion theory, Emotional response theory, Flow theory, Motivation theories, Output hypothesis, Self-regulated learning |
| No support | Interference theory, Modality principle, Split attention principle |
| Mixed results | Activity theory, Cognitive load theory, Social agency theory, Social presence theory |

It must be acknowledged that the analyses of this umbrella review are based on results of prior systematic reviews, meaning that they have already been synthesized once. These results compile large amounts of information together and are, therefore, not as profound; instead they provide an overlook of the theoretical context in pedagogical agent research. Also, it should be noted that some of the well-known theories, such as Constructivism, did not appear broadly in our results. This does not downplay the importance of these theories but instead demonstrates the variety and depth of different theories represented in found reviews. On the other hand, the Social agency theory and the Cognitive load theory were both found in four of the eight reviews, resulting in a 50% occurrence rate. Moreover, the Cognitive theory of multimedia learning was found in three reviews, also resulting in a high percentage.

The second phase of this study will be based on the overview provided in the first phase. In the second phase, the aim is to collect information from empirical studies of pedagogical agent research. It will be important to focus on the theories that have been discovered in the first phase as well as on any new theories that might arise. As the reviews in the first phase are compiling studies of prior research, the articles in the second phase are anticipated to deepen the understanding of learning theories. Unlike in the first phase, the second phase will not be limited to learning theories, as there will be a systematic review of types of pedagogical agents and used technologies. The aim is to combine the theories from two phases

and merge the technological aspect to the theoretical aspect. In the second phase, only recent studies will be included, as the timeframe is restricted to the years 2021-2023. It is expected that by solely utilizing recent studies, an understanding of the current theoretical orientations will be attained. Given the novelty of the articles included in the second phase, there is also interest in exploring potential connections related to technological advancements.

# 5 Systematic literature review

The second phase of the study conducted as a systematic literature review is presented in this chapter. Firstly, the research strategy used in this review is introduced, including the search process and inclusion and exclusion requirements of the results. Secondly, the findings of the review are presented. The identified learning theories are introduced and categorized based on Illeris' framework, introduced in Chapter 2. Furthermore, the identified types and technologies of agents are presented. Finally, a summary of the findings and analyses is included.

## 5.1 Research strategy

As in the first phase, Fink's (2019) seven-step model for conducting systematic literature reviews was implemented in this review. The first step, defining the research questions that guide the review, has been carried out in Chapter 3. The next steps related to defining the chosen databases and search terms were not necessary to be conducted again, since the same databases and terms were used as in the first phase, excluding the requirement for systematic reviews in the query string. Determining the screening criteria, conducting the review, abstracting the data, and synthesizing the results were performed specifically for the second phase, aligning with Fink's model.

The systematic review was accomplished using a query string containing terms from three requirements: educational purpose, technology, and learning theory (Table 5). These requirements were chosen for the same reasons as in the first phase, which were to ensure that the results were situated in an educational context, with a focus on pedagogical agents as a used technology and learning theories as an investigational perspective. The second phase did not have a requirement for the type of study within the query string, unlike in the first phase. However, the type of study was restricted in criteria and had to be an empirical study. The time span of articles was 2013-2023, which was later narrowed to 2021-2023 in order to attain the most recent and current views on pedagogical agent research. Other search criteria were the same as in the first phase, meaning that the articles had to be in English and peer-reviewed, there was full-text availability, and the designated terms were found in either the

title, keywords or abstract. The query strings for each database are documented in Appendix B.

Table 5 Requirements for the query string

| **Requirement** | **Used term in query** | |
|---|---|---|
| Educational purpose | “pedagogical” | AND |
| Technology | “agent*” / “agent” OR “agents” | AND |
| Learning theory | “theor*” / “theory” OR “theories” OR “theoretical” | |

Fink’s (2019) sixth step of the systematic literature review model requires testing of the planned process. The final terms of the query string were chosen as part of the first phase, based on how well they could provide results matching the defined research questions. The amount of search process testing was minimal in the second phase, as all crucial decisions were made in the first phase and limitations of each database were already acknowledged.

The queries were conducted in the same databases as in the first phase (Scopus, ScienceDirect, Taylor & Francis, ERIC). The number of results from each database are presented in Table 6. The total number of records from all databases was 340.

Table 6 Number of results per database

| Database | Result |
|---|---|
| Scopus (27.1.2024) | 240 |
| ScienceDirect (27.1.2024) | 46 |
| Taylor & Francis (20.2.2024) | 36 |
| ERIC (20.2.2024) | 18 |

After the queries were conducted, the process continued by transferring all results to Zotero and/or Excel depending on the technical abilities of the database. Duplicates were checked and excluded. After this elimination, there were 277 records for further screening.

Abstracts of the remaining articles were screened and those not relevant were excluded based on similar requirements as in the first phase. The most common reason for exclusion was the wrong context of using an agent as well as the lack of educational or learning aspects within the study.

- **Role of the agent**: Results were excluded if the term "agent" was not used in the right role. "Agent" was used in the wrong context, if it referred to a learner, teacher, or movement. Many times it was used in the context of "an agent of change".
- **Type of study**: Results were excluded if they were not an empirical study.
- **Context of the study**: Results were excluded if the context was not educational and instead was, for example, healthcare or business related.
- **Full text availability**: Results were excluded if they were not available in full text.
- **Language**: Results were excluded if they were not in English.

In the screening step, the criterion of the time span of reports was narrowed to 2021-2023 to provide a more current picture of the research. This led to the exclusion of 32 records.

After the screening, 23 reports were included in the eligibility assessment and full-text reading. Articles were included as final studies for the review if they met the following criteria:

- **Learning theory**: Included studies had to utilize learning theories in their research, not only mention them.
- **Pedagogical agents**: Included studies needed to have pedagogical agents as a vital part of the empirical study and considered as a pedagogical technology. However, the pedagogical agent was not allowed to be the subject of the study, for example, where students are observed building pedagogical agents.

After full-text reading and eligibility assessment, nine studies were included in the review. The steps and numbers of exclusions and inclusions are reported in the PRISMA flow chart, presented in Figure 15.

It was searched if the included studies have appeared in the reviews of the first phase. The result was that three of the final included studies were utilized in the reviews of the umbrella review. However, these three articles were also included in this review as the perspective of research differs from the reviews in the first phase, and, therefore, including these articles can add additional value.

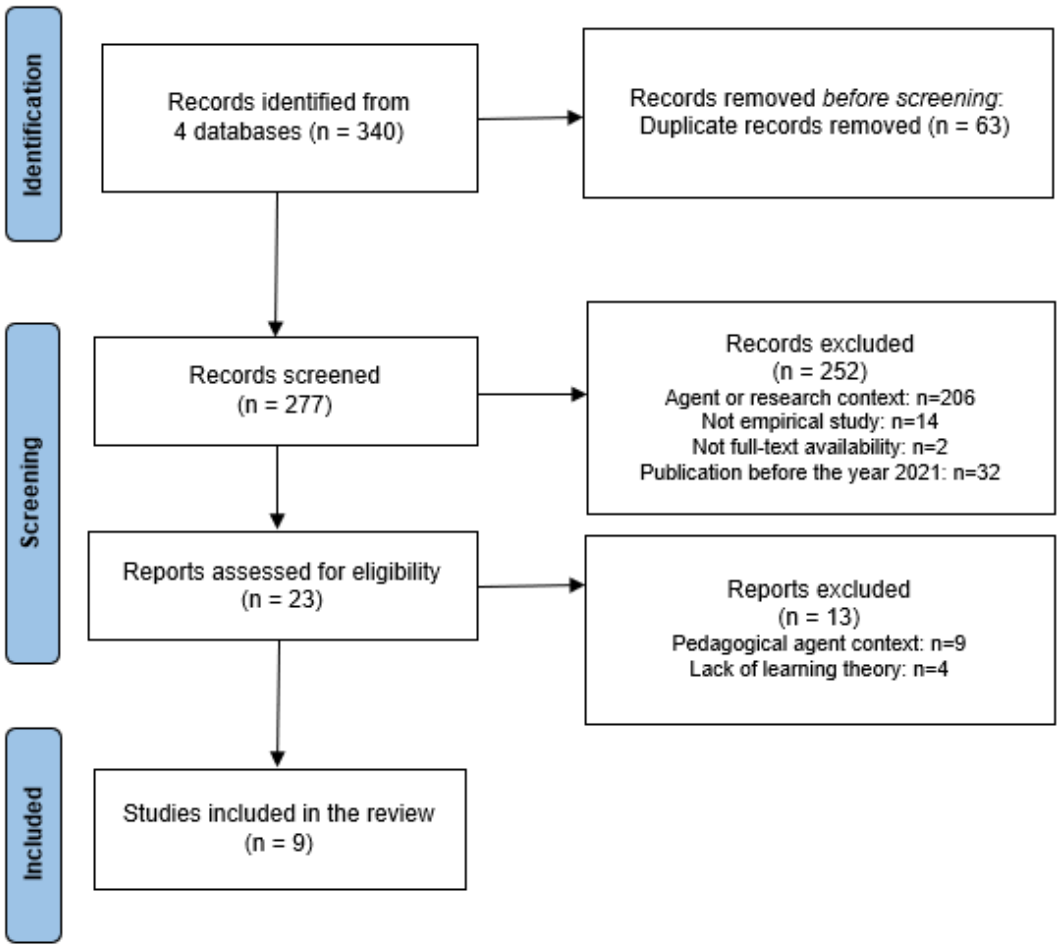



Figure 15 PRISMA 2020 flow diagram of the second phase of the sys-temat-ic literature review

Once the included studies were chosen, the data extraction phase of the systematic literature review was conducted. This phase is in line with the sixth step of Fink's (2019) systematic literature review model. Articles were systematically scanned multiple times in order to compile all necessary elements. Excel was used to assemble information from the articles by gathering article-specific information on what learning theories were identified and how they were utilized. In addition, the types, technologies, and interaction capabilities of agents were documented. The compiled information was then synthesized and analyzed according to the seventh step of Fink's (2019) model and based on Illeris' model of three learning dimensions, introduced in Chapter 2.

## 5.2 Findings

The systematic literature review was intended to provide knowledge on learning theories in recent pedagogical agent studies and to gain an understanding of how learning theories were utilized in these past studies. The gathered information is used to answer the following research question: *What learning theories are present in recent empirical studies of pedagogical agents and how have these theories been utilized?* In addition, the purpose was to identify the types and technologies of pedagogical agents in recent research in order to answer the following research questions: *What are the types of pedagogical agents found in these empirical studies?* and *What technologies are applied in the pedagogical agent context in these empirical studies?*

The topics and used research methods of the studies included in the second phase are presented in Table 7. The three articles that were included in the reviews in the first phase are marked with an asterix. Each article in Table 7 is given a key, by which they will be referenced to in upcoming tables. The research methods of each study are introduced, as they provide an overview of how pedagogical agents have been studied.

Table 7 Introduction of articles from the second phase

| Article | What was studied | Method |
|---|---|---|
| Beege & Schneider, 2023 (Key = A1) | Emotional design of pedagogical agents: the influence of enthusiasm and model-observer | Educational videos and questionnaires<br><br>n = 129 |
| Bian & Zhou, 2022 (A2) | Motivation effect of animated pedagogical agent's personality and feedback strategy types on learning in virtual training environment | Study 1: use of a virtual learning studio, learning outcomes recorded as videos, questionnaire, Study 2: Baseline measurement, learning through a sample program, experimental physical activity, questionnaire<br><br>n = 81 total from 2 studies |

| | | |
|---|---|---|
| Dever et al., 2023 (A3) | A complex systems approach to analyzing pedagogical agents' scaffolding of self-regulated learning within an intelligent tutoring system | Questionnaire, pretest, learning session, posttest<br><br>n = 117 |
| Huang et al., 2022 (A4) | Test similarity-attraction theory in terms of children's selection of pedagogical agent's design and whether math self-efficacy and math anxiety affect student choice of pedagogical agent | Survey<br><br>n = 287 |
| *Jeon, 2022 (A5) | Usage patterns on a self-directed interactive app, how the app supports students' basic psychological needs in EFL learning | Survey, introduction session to app, learning analytics from app, interview (for 20 chosen students)<br><br>n = 179 |
| Lawson et al., 2021 (A6) | Do learners recognize and relate to the emotions displayed by virtual instructors | Prequestionnaire, video lessons, posttest, postquestionnaire<br><br>n = 119 |
| Li et al., 2022 (A7) | The influence of animated pedagogical agents on learning outcomes and brain activity during learning | Video lesson, measurement of brain's cortical activity<br><br>n = 40 |
| *Schneider et al., 2022 (A8) | The impact of video lecturers' nonverbal communication on learning – An experiment on gestures and facial expressions of pedagogical agents | Questionnaire, educational videos in learning environment, 2 tests<br><br>n = 163 |
| *Wang et al., 2022 (A9) | Benefits of affective pedagogical agents in multimedia instruction | Pretest, learning materials, posttest, questionnaire<br><br>n = 279 total from 3 studies |

As seen in Table 7, the main research methods in the articles of the second phase are questionnaires and tests. A common research method consists of prior knowledge testing, educational videos with agents, and knowledge transfer and retention tests. However, other

methods such as gathering learning analytics and measuring brain activity have also been used. The included studies were conducted in Asia, North-America, and Europe, with Li et al.'s study (2022) being a collaboration between Asia and North-America. The geographical information was gathered to demonstrate the scope of the included studies and to identify any regions with notable emphasis. The studies were conducted on different aged students, with Huang et al. (2023) conducting the same study on two different age groups (middle school and college). The length of the studies varied ranging from a one-time experiment to a study lasting 8 weeks in total. Examples of study topics were physical exercise, language learning, science, and mathematics.

### 5.2.1 Identified learning theories and dimensions

The following section aims to answer the following research question: *What learning theories are present in recent empirical studies of pedagogical agents and how have these theories been utilized?* Learning theories were implemented in varying ways among the included studies. They were used to set the basis for research as a framework as well as to determine hypotheses. Theories were also used to analyze the studies' results related to pedagogical agents, as the results were reflected on the theoretical predictions.

Five of the found theories from the second phase were also found in the first phase, marked with an asterix in Figure 16. These theories are Cognitive load theory, Self-regulated learning theory, Social agency theory, Cognitive affective theory of learning with media (CATLM), and Emotional response theory. As was done in the first phase, the learning theories analyzed in the second phase, seen in Figure 16, were categorized using Illeris' (2008, 2018) framework presenting the three dimensions of learning: content (cognitive perspective), interaction (social perspective), and incentive (emotional perspective). In the analysis of findings, the theories were set to the category based on the emphasis on dimension found in the study. The emphasis is presented with the theory. Similarly to the first phase, it is noticed and made visible that theories may have characteristics of multiple dimensions.

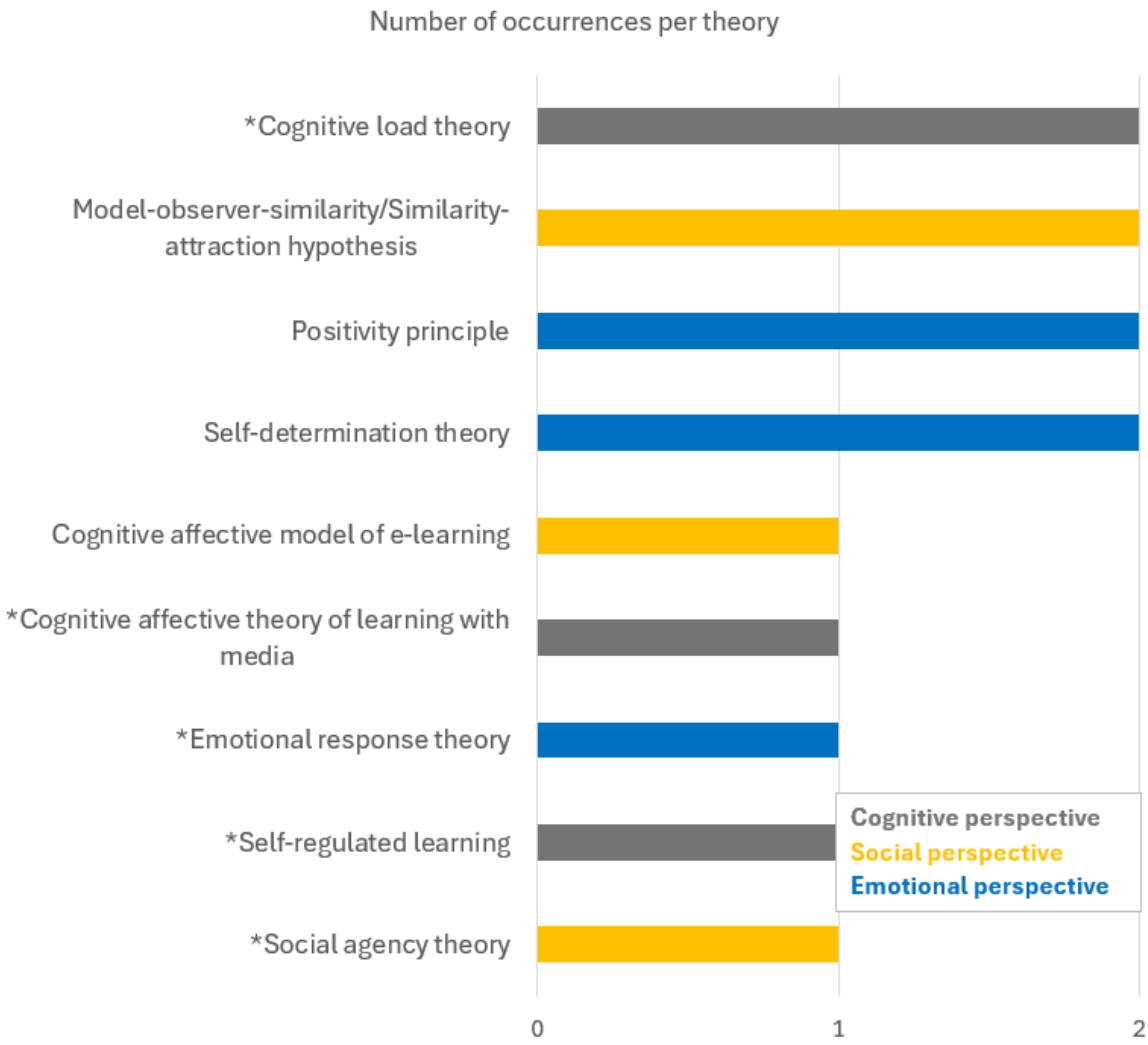



Figure 16 Number of occurrences per theory in the second phase

**Content - Cognitive perspective**

The content dimension is about what is learned. This provides a cognitive perspective as it can be many different things such as meaning, strategies, and opinions, but is often mentioned to be skills and knowledge. The learner develops functionality and constructs meaning and ability. (Illeris, 2008, 2018.) The theories introduced in this section emphasized the cognitive perspective.

**Cognitive load theory** was one of the most apparent theories in the umbrella review. In the second phase, the theory was discovered in two articles by Schneider et al. (2022) and Beege

and Schneider (2023). The former article, Schneider et al. (2022), was included in Wang et al.'s (2023) review which resulted in the theory being discovered in both phases. It is worth noting that the same authors, Beege and Schneider, were involved in both primary study articles.

Where Beege and Schneider (2023) studied the effects of cognitive load in the context of emotional design of pedagogical agents, the focus in Schneider et al.'s (2022) study was on gestures and facial expressions of pedagogical agents in video lectures. Schneider et al. (2022) studied how gestures and facial expressions would affect learning in attention to extraneous cognitive load. Interestingly, there were no significant differences in results, even if the body movements were not learning related. However, gestures were found to possibly increase intrinsic load. Schneider et al. (2022) indicate that pedagogical agents should behave naturally, making them more human-like. According to their results, gestures and facial expressions facilitate learning.

Beege and Schneider (2023) studied cognitive load in close connection to the emotional perspective with the Positivity principle and the social perspective with the Model-observer-similarity hypothesis. From the cognitive perspective, all three categories of cognitive load – extraneous, intrinsic, and germane – were involved. The results determined that an enthusiastic pedagogical agent reduced extraneous load and enhanced germane load. Moreover, the enthusiastic pedagogical agent with matching gender reduced intrinsic load whereas positive activation reduced extraneous load.

**Self-regulated learning theory** was found in one primary study, as well as discovered in an umbrella review in the first phase. Dever et al. (2023) elaborated on the use of the Self-regulated learning theory with the Complex systems theory as it was seen as necessary in self-organization, emergence, and interaction dominance. The study analyzed pedagogical agents' scaffolding in an intelligent tutoring system (ITS). This was the only study that included an ITS perspective. Scaffolds are tools and techniques in ITS, which help learners to monitor and regulate their learning process (Dever et al., 2023; Zeitlhofer et al., 2023). One method of scaffolding is using prompts, which support the activation of pre-existing

knowledge and the use of metacognitive processes (Zeitlhofer et al., 2023). Dever et al. (2023) used pedagogical agents for scaffolding.

In this versatile study, Dever et al. (2023) discovered promising findings. Pedagogical agents' scaffolding, with prompts and feedback, increased the learning outcomes and was significantly related to better content evaluation, prior knowledge activation, taking notes, judgment of learning, and summarizing which are all associated with cognitive and meta-cognitive strategies of self-regulated learning. However, all self-regulated processes, such as planning, did not appear in greater frequency. Overall, Dever et al. (2023) conclude that scaffolding by pedagogical agents merge learning outcomes and use of strategies, and also, contributes to better use of self-regulated learning systems.

**Cognitive affective theory of learning with media** (CATLM) was found in the study by Wang et al. (2022), who introduce how CATLM extends the Cognitive theory of multimedia learning by adding motivational and affective factors. The theory has the following three assumptions: motivation and affective cues forward learning by influencing cognitive engagement, meta-cognitive skills mediate learning through cognitive and emotional processes, and third, individual differences may influence the strength of multimedia learning. Wang et al.'s (2022) empirical study was included in Wang et al.'s (2023) meta-analysis found in the umbrella review.

Wang et al. (2022) studied affective pedagogical agents facilitating learning outcomes and cognitive processing. The study used CATLM and the Emotional response theory, which will be introduced later in this chapter, to explain the effectiveness of pedagogical agents. The results support that learners' intrinsic motivation improved and positive emotions were evoked due to pedagogical agents with enthusiastic tone in their voice and smiling facial expressions. However, there was no support that an affective pedagogical agent would have an effect on learning performance. The level of prior knowledge affected learners' experience of intrinsic and extraneous cognitive load, showing better performance in learners with high prior knowledge. Moreover, prior knowledge did not inhibit the effectiveness of pedagogical agents. Evidence that individual differences may influence learning with multimedia was provided.

**Interaction - Social perspective**

The interaction dimension is social, as it contributes impulses to conduct learning. Interaction can have multiple levels as it can happen in integration, situations, society, the environment, or other conditions. Interaction can be communication, action, cooperation, or other ways of influence. (Illeris, 2008, 2018.) The following theories emphasize the social perspective in the findings.

**Cognitive affective model of e-learning** has a strong stance on cognitive, social, and emotional perspectives. Unlike CATLM and its similar features, the Cognitive affective model of e-learning is categorized under the social perspective as the study by Lawson et al. (2021) discussing the theory focuses on the affective and social elements of e-learning.

Within a learning context, affective-cognitive models of learning aim to take the learners' emotional state into consideration while actively heading towards a learning outcome (Mayer, 2020). The theory extends the Cognitive theory of multimedia learning by focusing on affective and social factors from cognitive aspects. It is also close to CATLM, as both focus on affective processing (Mayer, 2024). Lawson et al. (2021) introduced how the Cognitive affective model of e-learning is designed for learning from on-screen instructors and online videos, and consists of a five step sequence. The predictions in their study are in line with the model's five events shown in Figure 17.

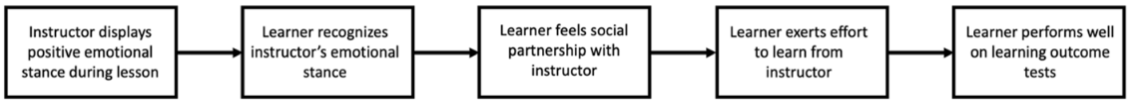



Figure 17 Steps of the Cognitive affective model of e-learning (A. P. Lawson et al., 2021)

Lawson et al. (2021) predicted that positive instructors are rated higher regarding positive emotions and vice versa with negative instructors/emotions, and positive instructors will be rated higher on the Agent Persona Index (agent's credibility, human-likeness, learning facilitation, and engagement). It was also predicted that positive instructors result in higher ratings of learner effort, motivation, and enjoyment. Fourthly, it was predicted that positive instructors lead to higher scores in posttests compared to negative instructors. The first three

predictions were supported by the study's results, indicating that the results were, to some extent, in line with the Cognitive affective model of e-learning. Agents' positivity is seen to affect the emotional state of the learner and lead to a feeling of social partnership, resulting in higher levels of learner motivation and performance.

Drawing on the **Similarity-attraction hypothesis** predictions by Berscheid and Hatfield Walster (1969), both real and digital learning partners attract learners if the characteristics and personality of the learner match those of the partner. Similarly, the **Model-observer similarity hypothesis** argues that the power of a modelling situation depends on how well the learner feels they match the model (D. H. Schunk, 1987), for example, an on-screen pedagogical agent.

Both hypotheses were discussed in the study by Beege and Schneider (2023), who emphasize the importance of model-observer similarity and similarity-attraction in social learning contexts. Based on their results, students found their learning material to be more manageable when initiated by an agent of the same gender, having a positive affect on learning. The most notable effects were seen with female students, who found enthusiastic female agents to be the most beneficial for learning.

While elaborating on these hypotheses, Beege and Schneider (2023) highlight the importance of focus on model-observer similarity and agent gender in future research. These elements can be used to nourish the benefits of pedagogical agents, as was seen with the social design implemented by Beege and Schneider (2023), resulting in higher levels of emotional processing and better learning outcomes.

The Similarity-attraction hypothesis was also discussed in the study by Huang et al. (2022), who focused on the perspective of children and their preferences regarding pedagogical agents. They tested the hypothesis by having middle school and college aged students select a virtual math tutor from choices with varying ethnicities and genders. The study was conducted with two different age groups, as it was anticipated that the attraction to similarity would be stronger with younger students due to their stage of psychosocial development. This was, to some extent, proven true by Huang et al. (2022). Their results showed that middle school aged students preferred agents with matching ethnicity, unlike with college

students. However, both age groups were found to be more attracted to agents with the same gender as them. The different psychosocial development stages were highlighted when weighing the differences in results between the two age groups.

**Social agency theory** was discovered in the umbrella review as one of the most appeared theories. In the recent empirical studies, the theory was discussed in the study by Li et al. (2022). Li et al. (2022) preface their research by stating that a social relationship between pedagogical agents and learners can affect the learning process and outcomes, according to the Social agency theory. The theory also emphasizes the role of the agent's social cues, for example, gestures and expressions, when trying to form a social connection with the learner. These predictions were partially proven true by Li et al. (2022), whose results supported the statement that embodied pedagogical agents lead to greater levels of cognitive processing, therefore, leading to better learning outcomes. These were anticipated to happen due to the formation of a social relationship between the learner and agent, however, there was not enough evidence in the study to support this claim.

Li et al. (2022) found support for the theory's expectation, which states that an agent exhibiting social cues results in the learner forming a social response, leading to higher levels of cognitive processing and better learning outcomes. This was done by measuring the learners' brain activity while interacting with agents. The discovered brain activation in the social processing areas of the brain is in line with the expectations of the Social agency theory.

**Incentive – Emotional perspective**

The incentive dimension is mainly emotional**,** as it relates to directing and providing mental energy for the learning process. It includes interest, motivation, and engagement. The incentive function is to develop a personal sensitivity and secure the mental balance of the learner. (Illeris, 2008, 2018.) Followingly introduced theories emphasized the emotional perspective.

**Self-determination theory** was found in two articles, and it was a new discovery of theories in the second phase. Self-determination theory focuses on the individual's motivation and persona in interaction with the social environment (Legault, 2017). Motivation relates to basic psychological needs – autonomy, competence, and relatedness (Jeon, 2022). Perceived autonomy and competence enhance intrinsic motivation, whereas external regulation

impacts extrinsic motivation (Bian & Zhou, 2022). The Self-determination theory has characteristics from all, cognitive, social, and emotional, perspectives, but it was categorized as emotional because of the focus on learners' experiences and motivation effects in learning with pedagogical agents in Bian and Zhou's (2022) and Jeon's (2022) studies.

The study by Bian and Zhou (2022) showed that affective pedagogical agents' positive feedback strategy led to a higher flow and better learning experience as well as higher intrinsic motivation. Choleric, rather than phlegmatic, affective pedagogical agents induced higher extrinsic motivation and personality type but did not significantly affect intrinsic motivation. Jeon (2022) found slight potential for self-directed interactive application, including the penguin character as a pedagogical agent, to be a beneficial tool in second-language learning. However, the conclusions in motivation revealed to be uncertain. The application did not motivate all users, and remarkably many users stopped using the application during the eight-week voluntary study. The 33 of the 120 users who continued usage were found to have satisfaction, enhanced motivation, and affection for the agent. One of the reasons to thwart motivation and relatedness was recognized to be if users experienced the agent as just a machine. The study found promising elements to implicate in self-directed interactive application design. Anyhow, further research was suggested, especially in the motivational factors with pedagogical agents.

**Emotional response theory** was found in the study by Wang et al. (2022) and, like CATLM, it was also discovered in the meta-analysis by Wang et al. (2023) in the umbrella review. The Emotional response theory consists of social, cognitive, and emotional elements. Wang et al. (2022) examined the effectiveness of pedagogical agents in learners' emotional responses. Results support that affective pedagogical agents affect learners' motivational and emotional states. The effect varied based on the strategy that learners used. Evidence was provided that learners who used the expressive suppression strategy achieved more positive influence on positive emotions.

**Positivity principle** was introduced in Lawson et al.'s (2021) study with the Cognitive affective model of e-learning, and in Beege and Schneider's (2023) study in the emotional design context. However, positivity was noticed as one variable in multiple other studies as

well. The Positivity principle indicates that positive emotions channelled via online learning materials or instructors enhance students' learning (A. P. Lawson et al., 2021; Zhao & Mayer, 2023).

Lawson et al. (2021) found evidence to support the Positivity principle as learners estimated pedagogical agents, which were positive instructors through voice and gestures, to be more thrustworthy and able to teach rather than negative instructors. Positive instructors were also rated more credible, human-like, engaging, and better at facilitating learning. However, it was recognized that further research is needed to specify the types of characters in voice and gesture that are considered positive. Beege and Schneider (2023) also found support that learners with an enthusiastic pedagogical agent have a higher positive activation rather than with a neutral pedagogical agent. However, it was only partially supported that also the learning outcomes are higher with enthusiastic pedagogical agents, as the transform performance was not influenced. Nonetheless, both studies conclude that positivity is a recommended factor to consider when designing multimedia learning.

### 5.2.2 Types of pedagogical agents and technologies

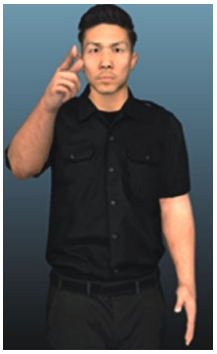
The following section aims to answer the following agent-related research questions: *What are the types of pedagogical agents found in these empirical studies?* and *What technologies are applied in the pedagogical agent context in these empirical studies?*

The types of pedagogical agents refer to the form in which agents are presented, for example, character agent or chatbot. Technology refers to the mechanisms and tools utilized to design and build the agents. The technological aspect was not discussed in many of the chosen articles, and, therefore, the introduction of used technologies remains rather limited.

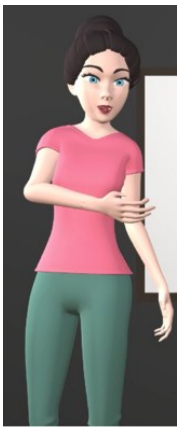
The pedagogical agents identified from the nine included studies are shown in Table 8, along with their type and technology, if mentioned. The table also includes the types of interaction that the agents are capable of providing. The possibilities for interaction depend on the type and used technology, as more advanced technology enables more opportunities for more complex interactions. On the other hand, different types of agents are used for different purposes, which affects the interaction requirements. For example, an agent that is only needed

to gesture and attract attention on an educational video requires fewer interactive qualities than an agent whose role is to prompt and guide the learner in real-time. Both examples, among others, are presented in the following table.

Table 8 Pedagogical agent types and technologies

| **Article** | **Type and technology (if mentioned)** | **Interaction capabilities** | **Example image** |
|---|---|---|---|
| A1 | Type: Animated and cartoon-like with only head moving, female and male versions.<br><br>Technology: Adobe Character Animator Version 3.2 | Used speech only, pre-recorded videos so no interaction from the learner |  |
| A2 | Type: Embodied, either choleric or phlegmatic, female and male versions<br><br>Technology: Implemented in a virtual learning enviorenment with VR technology | Agent gave feedback based on learner performance, also used gestures such as nodding, waving, and clapping |  |

| | | | |
|---|---|---|---|
| A3 | Type: 4 versions of talking heads, each agent had a different role in scaffolding/prompting, female and male versions.<br><br>Technology: Embedded in the hypermedia-based ITS MetaTutor | Verbal prompting to self-regulate by providing feedback, gives verbal and written feedback based on user inputs, prompts and scaffolds based on pre-defined conditions |  |
| A4 | Type: 8 versions of virtual math tutors, only upper body, female and male versions | Agents were presented to the students as images, so no interaction in either direction |  <br>  |
| A5 | Type: Animated penguin<br><br>Techology: Within PengTalk app on Android/Apple | Speaking activities including conversation with agent, speaking activities use NLU (natural language understanding) module based on a pretrained model, app gave feedback regarding, for example, pronunciation |  |

| | | | |
|---|---|---|---|
| A6 | Type: Animated and embodied instructor, only female | Behavior of instructor was based on a human actor giving the same math lesson in 4 varying emotional stances. Use of gestures, facial expressions, and body positioning to mimic the human actor's behavior. Pre-recorded videos, so no interaction from the learner |  |
| A7 | Type: Animated female instructor standing, from the waist up, only female<br><br>Technology: Animation was made using Flash C56 software | Used posture, eye gaze, and gesture to direct attention, lip synced. Pre-recorded lesson so no interaction from the learner |  |
| A8 | Type: Human agent, different versions with/without expressions/gestures, only female | Used body movements and facial expressions, learning content was pre-recorded and voice came from an audio tape. Pre-recorded and rehearsed material so no interaction from the learner |  |
| A9 | Type: Character agent, upper-half, 2 versions with different levels of enthusiasm and expression, only male<br><br>Technology: Videos were created using Flash CS6 software | Used tone of voice and different levels of expressions and enthusiasm to grab attention while teaching. Pre-recorded instructional videos so no interaction from the learner |  |

The types of agents used in the chosen studies were quite similar, as there were no chatbots or software components and instead, all of them were character agents. The type of embodiment differed among the agents, with some having more human-like physical characteristics than others. One agent was a real recorded human and, therefore, naturally had human-like qualities. However, as the human agent was part of a pre-recorded learning material, it could not interact with the learner. This was the case with many other agents as well. On the other hand, some agents were able to prompt and give feedback to the user based on their inputs, which enabled a higher level of interaction between the learner and the agent. However, all agent interaction was pre-defined and based on a set of rules, meaning that there was no utilization of, for example, generative AI or large language models.

Technologies behind the agents were not introduced in the majority of chosen articles, which perhaps results from the studies' lack of technological focus or from the commercial nature of agent development tools. Three agents out of nine were embedded in more complex learning environments with enhanced technology. These environments were the hypermedia-based ITS, PengTalk application, and the virtual learning environment with VR technology. However, the agents themselves were only a part of these environments. Nevertheless, these environments with more advanced technology inevitably affect the research due to the technological capabilities. For example, Jeon (2022) was able to gather data on learning analytics and conduct speaking activities due to the app's NLU module.

### 5.2.3 Summary

The aim of this systematic literature review was to answer the following research questions: *What learning theories are present in recent empirical studies of pedagogical agents and how have these theories been utilized?*, *What are the types of pedagogical agents found in these empirical studies?* and *What technologies are applied in the pedagogical agent context in these empirical studies?*

The systematic literature review provided an overview of learning theories and pedagogical agents represented in the nine empirical studies. A total of nine different learning theories, related principles and hypotheses were discovered, five of which were also included in the

first phase. The theory-related research question was answered based on the results of the chosen studies, with the support of theoretical background information from relevant research. The utilized learning theories from empirical studies were identified and introduced. Moreover, the identified theories' predictions and perspectives on pedagogical agent implementation were discussed to the extent that they were found in the studies. The learning theories were categorized based on Illeris' theoretical framework, under three dimensions: content (cognitive perspective), interaction (social perspective), and incentive (emotional perspective).

Each of the three dimensions of learning were represented in the findings of the second phase. It was noted that many studies had elements of multiple dimensions, for example Beege and Schneider (2023), who had all three perspectives included. Unlike in the first phase, the results of the studies were analyzed mostly from the aspect of smaller theories, principles, and hypotheses. It was noted that some empirical studies utilized theories from the first phase to set hypotheses and predictions for their research. For example, Li et al. (2022) used the Social presence theory and CATLM along with the Social agency theory as complementary theories to set the basis for their research, but only focused on the Social agency theory when analyzing results. Of the top three found theories in the umbrella review, Cognitive load theory and Social agency theory were also found in second phase. The third theory, Cognitive theory of multimedia learning, was not directly found as a theory of its own, but it was strongly present as CATLM and the Cognitive affective model of e-learning are extended from it, as well as the Positivity principle as its principle.

As disclosed earlier, three of the included empirical studies were also utilized in reviews included in the first phase. However, they provided additional value to this research as the prior reviews were conducted from a different research perspective. For example, Jeon's (2022) study was included in Zhang et al.'s (2023) review. Jeon's study discussed the Self-determination theory, which was not among Zhang et al.'s eight identified learning theories. This is most likely explained by the fact that Zhang et al.'s review strictly focused on chatbots, whereas Jeon's study focused on self-directed interactive applications.

The types, interaction capabilities, and technologies of pedagogical agents were also identified and documented in order to answer the pedagogical agent-related research questions to the extent that they were introduced in the studies. The studies predominantly utilized character agents, lacking chatbots or software components. Agent embodiment varied with some more human-like than others, including one agent being a recorded human but unable to interact directly due to its pre-recorded nature. While some agents could prompt and provide feedback based on user inputs, interactions were predefined, lacking AI or large language model utilization. It is noteworthy that in the research setting, the interaction between the user and the pedagogical agents was sometimes simpler than it would be in actual use.

The technological specifics behind the agents were often omitted, possibly due to the studies' focus or the commercial nature of development tools. However, three agents were embedded within advanced learning environments, such as hypermedia-based ITS, PengTalk application, and VR-based virtual environments. As these environments enhanced technological capabilities, they facilitated activities like data gathering on learning analytics and conducting speaking exercises, exemplified by Jeon (2022).

The found learning theories are summarized in Table 9 by categorizing them based on how they were supported by the studies' findings. Theories were found to be supported if their predictions and expectations were in line with the studies' results. Mixed results stemmed from partial alignment of predictions and results. This was due to the lack of sufficient evidence needed for proving learning theory related hypotheses, or to the differing results from studies related to the same theory.

Table 9 Support for identified learning theories in the second phase

| **Support/no support/mixed results** | **Theories** |
|---|---|
| Support | Emotional response theory |
| No support | - |
| Mixed results | Cognitive load theory, Self-regulated learning theory, CATLM, Cognitive affective model of e-learning, Similarity-attraction hypothesis/model-observer similarity hypothesis, Social agency theory, Self-determination theory, Positivity principle |

Table 9 illustrates how all theories except one received only some degree of support, and these theories were categorized as having mixed results. In most cases, the majority of theory related hypotheses were supported. An example of mixed results is the Cognitive affective model of e-learning, where three out of four predicitions based on the model's own hypotheses were supported. Another example of mixed results is the Similarity-attraction principle, which only received full support from the younger participant age group and not the older ones. On the other hand, the Emotional response theory was found to be fully supported by the evidence provided in Wang et al.'s (2022) study. The significant presence of mixed results highlights the necessity for further research on learning theories in the realm of pedagogical agents, given the multiple variables influencing the degree of support for different learning theories.

# 6 Discussion and conclusions

The purpose of the study was to explore the integration of learning theories within research on pedagogical agents, while also identifying the diverse types and technologies of these agents employed in existing studies. Its core goal was to gain insight into the current scene of pedagogical agent research from the perspective of learning theories, highlighting both implications and areas in need of further investigation. Organized as a two-phased systematic literature review, the first phase investigated the utilization of learning theories in prior systematic reviews and meta-analyses concerning pedagogical agents (spanning 2013-2023). Subsequently, the second phase, a systematic literature review, focused on the implementation of learning theories within pedagogical agent studies. In addition, an exploration of the types and technologies utilized in the most recent empirical investigations (covering 2021-2023) was conducted. To analyze learning theories, the study adopted Illeris' framework outlining the three dimensions of learning.

The umbrella review incorporated eight systematic reviews with a total of 17 identified learning theories, while the systematic review examined nine empirical studies, identifying nine learning theories. As presented in Table 10, out of these nine theories, five were overlapping between the two reviews. The results of the study incorporated all three dimensions of learning – content (cognitive perspective), interaction (social perspective), and incentive (emotional perspective), with the identified theories holding varying roles within their respective studies. It is worth noting that there was a difference in the emergence of perspectives between the first and second phases. In the first phase, almost half (8 out of 17) of the theories were presented from the cognitive perspective, whereas in the second phase the perspectives were equally represented, with each perspective being represented in three of the nine theories found. It was also found that the theories from the cognitive perspective in the second phase were all found in the first phase. However, there were new discoveries of theories from the social and emotional perspective in the second phase. As mentioned throughout the study, Illeris (2008, 2018) emphasizes the need for all three dimensions in learning, aligning with the multidimensional nature of many identified learning theories within this study. Moreover, the multidimensional representation within studies was further achieved by utilizing theories from different dimensions.

Table 10 Summary of found theories from both phases

| Perspective | First phase only (occurrence) | Second phase only | Both phases (sum of occurrence) |
|---|---|---|---|
| **Cognitive** | Cognitive theory of multimedia learning (3), Constructivism (1), Interference theory (1), Output hypothesis (1), Split attention and modality principles (1) | | Cognitive load theory (4+2), Cognitive affective theory of learning with media (1+1), Self-regulated learning theory (2+1) |
| **Social** | Collaborative learning (2), Activity theory (2), Situated/contextualized learning theories (1), Social presence theory (1) | Model-observer-similarity and similarity-attraction hypotheses (2), Cognitive affective model of e-learning (1) | Social agency theory (4+1) |
| **Emotional** | Emotional contagion theory (1), Flow theory (1), Motivation theory (1) | Self-determination theory (2), Positivity principle (2) | Emotional response theory (1+1) |

It was discovered that in the first phase, the Social agency theory and the Cognitive load theory were both found in four of the eight reviews, resulting in a 50 % occurrence rate. Both theories were found in the second phase as well. Moreover, in the first phase, the Cognitive theory of multimedia learning was found in three reviews, also resulting in about 40 % of occurrence rate. Although, the Cognitive theory of multimedia learning was not directly found as a theory of its own in the second phase, but it was strongly present as three of all of the found theories were based on it. CATLM and the Cognitive affective model of e-learning are extended from it, as well as the Positivity principle as one of its principles. The Cognitive load theory was also recognized as a pivotal theory, as it enabled in-depth analysis through its three cognitive load types – intrinsic, extraneous, and germane. The Cognitive load theory and the Cognitive theory of multimedia learning were identified as central pillars within pedagogical agent research, giving rise to numerous smaller theories, hypotheses, and principles.

Notably, the ratio of minor theories to more comprehensive ones was higher in the second phase of the study. In the second phase, all studies had elements from multiple dimensions, for example, Beege and Schneider's (2023) study included theories from all three perspectives. This suggests a preference for smaller theories, hypotheses, and principles in empirical studies, whereas extensive theories tend to be utilized when synthesizing large amounts of information.

The systematic literature review investigated the types, interaction capabilities, and technologies of pedagogical agents across the included empirical studies. Character agents were identified as the most common agent type, containing varied characteristics and interactive features. A VR-enabled virtual learning environment, an interactive application with a NLU module, and the hypermedia-based ITS MetaTutor were highlighted as more advanced technology, although these primarily reflected the environments in which the agents operated rather than the technologies within the agents themselves.

The lack of generative AI utilization in the included studies was not in line with what was anticipated in the beginning of this research process. The advancements in technology and generative AI, particularly evident in the development of large language models, were not reflected in the studies and agents included in this review. Notably, Yang and Kyun's (2022) systematic literature review on language learning, incorporated within the umbrella review, provided implications and recommendations for utilizing generative AI in language learning contexts. However, the second phase of the study did not result in any agents with generative AI functionalities. On the other hand, the rapid pace of technological advancement may impact research opportunities. Conducting high-quality research requires rigorous planning and a systematic approach, and, therefore, keeping up with the latest technology can pose challenges.

Positivity as both a design principle and a theoretical approach was highlighted in multiple studies as an element to enhance learning. It was concluded by Lawson et al. (2021), incorporated in the systematic literature review, that positivity as a concept is not unambiguous, requiring further research on what learners consider positive in terms of gestures and voice. This sheds light on the complexity of pedagogical agent design, as the learner's personality

plays a vital role in the usefulness of the agent, resulting in the need for more adaptive technologies. Furthermore, this uncertainty aligns with the interpretation of learning theories and understanding their support within the pedagogical agent research. The identified theories of both phases were weighed based on whether they were found to be supported in the studies. This classification was done by combining the results of the included studies with own interpretations of the learning theories, inevitably affecting the study's generalizability.

## 6.1 The validity of research

In systematic reviews, the validity of the research consists of both the qualitative use of the research method and the fact that the studies included are qualitative (Vilkka, 2023). To fulfill the systematic approaches well, the seven-step Fink model (Fink, 2019) was used in both phases. Documentation and reporting were carried out following the PRISMA 2020 guidelines (Page et al., 2021). For the validity assessment of this review and the studies included, the JBI quality assessment checklist and guidance (Aromataris et al., 2024) was used. The validity assessment of this research will be explained with the JBI checklist of 11 questions (see Figure 6 in Chapter 3).

First (1), the research questions were presented and argumentation was provided. The research questions were formed in the early stages of the research process, although, they were adjusted as the research process evolved. Next (2), the inclusion criteria for studies: *context educational, role of learning theory more than just mentioned, use of pedagogical agent and type of study,* were argued and in line with the research questions, aiming to include relevant studies. Then (3), the research strategy was considered and documented for both phases. The inclusion criteria of language (English) was recognized as a risk of possible language bias. It was considered more important that the language used was consistent throughout the research. Fourth (4), for attempting to reach extensively the available evidence, there were four databases used for searches and even more tested. This aspired to minimize the risk of database bias. However, some of the databases did not support complex searching, or they functioned differently compared to others. This might increase the risk of errors and unreliability of the results. A solution to this was to document the queries and processes in different databases thoroughly, so the search could be replicated correctly.

Then (5), the criteria for the appraised studies were directed by inclusion/exclusion criteria, appropriate context, and recognized research and publication type. Followingly (6), unlike the sixth question recommends, the critical appraisal was conducted by two reviewers, but not fully independently. As both reviewers were new to the systematic review approach, extensive cooperation, discussion and double-checking was performed. Two researchers conducting the study was considered as a strength and provided more resources. The risk of problems regarding the scope of research can be minimized by conducting the study with multiple researchers, as done in this review.

Seventh (7), the methods used to minimize errors in data extraction were applied. The reference management and data storage was planned and structured, as well as spreadsheet tools were utilized for gathering the information. A generative AI tool was tested to assist in the screening process, but excluded because it was not reliable for its intended use. In total, only 17 studies were included in the study, which allowed both reviewers to become familiar with all the studies and necessary information. Having more than one reviewer can increase the reliability of the study, as more than one reviewer can go through the same material or data, minimizing any errors due to misunderstanding or interpretation. These same considerations were taken into account when (8) synthesizing the evidence from the studies, which is pondered in the eighth question. However, the synthesis was provided based on theoretical background. In addition, the field of research was multidimensional, so adequate information about the source studies was deliberately provided.

Ninth (9), the likelihood of bias was considered through the search strategy but no statistical tests were applied as they are not applicable in qualitative reviews. Last questions, (10) the recommendation for policy and practice and (11) directives for new research were presented. Recommendations for policy and practice are careful as, like studies highlighted, learning is influenced by many variables. Overall, ensuring the validity of the research involved adhering to guidelines throughout the process, in addition to guidance and assistance from experienced research supervisors.

## 6.2 Limitations

As with all research, this study has its limitations. From the perspective of the research method, the researchers of this study had no prior experience in conducting a systematic literature review. This made the review process more time-consuming, and required an extensive use of resources to get familiarized with the method's requirements. Lack of experience comes with risks, however, these risks were minimized by replicating the search process multiple times by both researchers and comparing results. Also, the technical requirements of databases were tested using practice queries, simultaneously enabling the development of the query string. The decisions regarding databases and search terms determined the course of the review process. Although this is not necessarily a limitation, it does cause restrictions on the scope of results due to the emphasis on pedagogical elements. This can also be viewed from the perspective of the implemented framework, as Illeris' three dimensions of learning further delved into the foundations of learning theories. The decision on the chosen framework was made after conducting the umbrella review's search process and data extraction. By choosing the framework earlier, the data extraction phase could have been conducted and documented in a more systematic and productive manner.

Somewhat of a publication bias was noted when database searches showed results from South America, particularly Brazil, but the results were not included based on the language. The abstracts in English were promising, but the study was not available in English. In a more general sense, the used language might impact which studies have been published and peer-reviewed in terms of researchers' location and language. Furthermore, Schroeder (2013) presented concern that some meta-analyses have publication bias in the peer-reviewed journals as only ones reporting relatively high effect size get published. This is relatively difficult to confirm and no knowledge of whether it is still current, but after all, both reviews included under 10 studies. Nevertheless, all the studies included were comprehensive.

## 6.3 Implications and recommendations for further research

This study provided implications for both theory and practice, as well as for future research. Drawing on the implications of the included studies from both phases, positivity in terms of positive emotional tone and cues should be implemented in pedagogical agent design. Other practical implications are the inclusion of gestures, expressions, and enthusiastic voices as well as the consideration of differences in individual learners. These design suggestions were supported by theoretical implications from the included studies, as support was found for theories such as CATLM and Emotional response theory.

The use of pedagogical agents as an enhancement for language learning came across in multiple studies. These studies linked language learning with AI and the Output hypothesis, which promotes unlimited output attempts combined with real-time feedback from the agent. It is anticipated that the utilization of learning environments facilitating these interactions between learners and AI-enhanced agents will have a positive impact on learning outcomes, and could therefore be an interesting topic for further research.

This study prioritized the comprehensive representation of one or more learning theories within the included articles, which inevitably limited the emphasis on technology during the search process. This limitation stemmed from the formulation of the query string and the establishment of screening criteria. However, while technologies and agent-related data were collected, there remained a fascination towards a more technology-centric approach in this field of study. This shift in focus could potentially produce a deeper understanding of the technological aspect and provide the identification of learning theories rising from technology-focused research. In conclusion, the recommendation for further research is to include the learning theory as a notable variable in investigation of educational technology, especially pedagogical agents. Another shift in focus that could be considered for further research is focusing on the benefits of the pedagogical agents. While reviewing articles in both phases of this study, the pedagogical advantages of employing agents became apparent. For instance, agents were noted to enhance interaction, facilitate reaching a flow state, and offer opportunities for unlimited output training. These benefits are closely linked to learning

theories and could serve as a valuable area of research for gaining a deeper understanding of the role of pedagogical agents in learning.

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# Appendices

## A Evolution of query string in the first phase

| Database: Scopus, string, and result | Date: | Status: |
|---|---|---|
| Results: 2<br><br>(“pedagogical" OR "conversational" ) AND ( "agent" ) AND ( "learning theory" OR "educational theory" ) AND ( "systematic review" OR "systematic literature review" OR "meta-analysis" ) | 29.12.2023 | |
| Results: 7<br><br>("pedagogical") AND ("agent") AND ("theory") AND ("systematic review" OR "systematic literature review" OR "meta-analy*") | 29.12.2023 | |
| Results: 70<br><br>("pedagogical" OR “conversational”) AND ("agent") AND ("theory") AND ("systematic review" OR "systematic literature review" OR "meta-analy*") | 29.12.2023 | |
| Results: 27<br><br>("pedagogical") AND ("agent") AND ("theory") AND ("review" OR "meta-analy*") | 29.12.2023 | |
| Results: 40<br><br>("pedagogical") AND ("agent*") AND ("theor*") AND ("review" OR "meta-analy*") | 27.1.2024 | Final |

| **Database: ScienceDirect, string, and result** | **Date:** | **Status:** |
|---|---|---|
| Results: 4<br><br>("pedagogical") AND ("agent") AND ("theory") AND ("review" OR "meta-analy") | 30.12.2023 | |
| Results: 8<br><br>("pedagogical") AND ("agent" OR "agents") AND ("theoretical" OR "theory" OR "theories") AND (“review” OR “meta-analysis”) | 27.1.2024 | Final |
| **Database: EBSCOHost, string, and result** | **Date:** | **Status:** |
| Results: 6<br><br>AB pedagogical AND AB agent AND AB theory AND AB meta-analysis | 27.1.2024 | |
| Results: 7<br><br>AB pedagogical AND AB ( (agent OR agents) ) AND AB ( theory OR theories OR theoretical ) AND AB ( review OR meta-analysis ) | 27.1.2024 | Eliminated |
| **Database: Taylor and Francis, string, and result** | **Date:** | **Status:** |
| Results: 1<br><br>("pedagogical") AND ("agent") AND ("theory") AND ("review" OR "meta-analy*") | 5.1.2024 | |
| Results: 1<br><br>[Abstract: "pedagogical"] AND [[Abstract: "agent"] OR [Abstract: "agents"]] AND [[Abstract: "theory"] OR | 13.2.2024 | Final |

| | | |
|---|---|---|
| [Abstract: "theories"] OR [Abstract: "theoretical"]] AND [[Abstract: "review"] OR [Abstract: "meta-analysis"]] | | |
| **Database: ERIC, string, and result** | **Date:** | **Status:** |
| Results: 2<br><br>("pedagogical") AND ("agent") AND ("theory") AND ("review" OR "meta-analy") | 9.1.2024 | |
| Results: 0<br><br>abstract:(("pedagogical") AND ("agent" OR "agents") AND ("theory" OR "theories" OR "theoretical") AND ("review" OR "meta-analysis")) pubyearmin:2013 pubyearmax:2023 | 13.2.2024 | Final |

## B Evolution of query string in the second phase

| **Database: Scopus, string, and result** | **Date:** | **Status:** |
|---|---|---|
| Results: 240<br><br>( "pedagogical" ) AND ( "agent*" ) AND ( "theor*" ) | 27.1.2024 | Final |
| **Database: ScienceDirect, string, and result** | **Date:** | **Status:** |
| Results: 46<br><br>("pedagogical") AND ("agent" OR "agents") AND ("theoretical" OR "theory" OR "theories") | 27.1.2024 | Final |
| **Database: Taylor and Francis, string, and result** | **Date:** | **Status:** |
| Results: 36 | 20.2.2024 | Final |

| | | |
|---|---|---|
| [Abstract: "pedagogical"] AND [[Abstract: "agent"] OR [Abstract: "agents"]] AND [[Abstract: "theory"] OR [Abstract: "theories"] OR [Abstract: "theoretical"]] | | |
| **Database: ERIC, string, and result** | **Date:** | **Status:** |
| Results: 18<br><br>abstract:(("pedagogical") AND ("agent" OR "agents") AND ("theory" OR "theories" OR "theoretical")) pubyearmin:2013 pubyearmax:2023 | 20.2.2024 | Final |