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Conversational Agents in Education – A Systematic Literature Review

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Research Paper

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Abstract

Conversational Agents (CAs) are widely spread in a variety of domains, such as health and customer service. There is a recent trend of increasing publications and implementations of CAs in education. We conduct a systematic literature review to identify common methodologies, pedagogical CA roles, addressed target groups, the technologies and theories behind, as well as human-like design aspects. The initially found 3329 records were systematically reduced to 252 fully coded articles. Based on the analysis of the codings, we derive further research streams. Our results reveal a research gap for long-term studies on the use of CAs in education, and there is insufficient holistic design knowledge for pedagogical CAs. Moreover, target groups other than academic students are rarely considered. We condense our findings in a morphological box and conclude that pedagogical CAs have not yet reached their full potential of long-term practical application in education.

Keywords: Conversational Agents, Chatbots, Pedagogical Conversational Agents, Education, Learning, Literature Review.

1 Introduction

Due to the technological progress in artificial intelligence (AI), conversational agents (CAs) are applied in a variety of contexts (Feidakis et al., 2019), e.g., as everyday facilitators as in the case of Apple's Siri or Amazon's Alexa, in health care, or customer service (McTear et al., 2016). CA is an umbrella term for software that uses natural language to interact with its user, either text-based (as chatbots) or speech-based (as virtual assistants) (McTear et al., 2016; Gnewuch et al., 2017). An emerging application and research area for the deployment of CAs is the educational sector (Al Muid et al., 2021). CAs in education provide the advantages of being permanently available, scalable, and location-independently accessible, leveraging the potential to address multiple concerns of learners simultaneously while

adapting to their individual needs (Vu et al., 2016; Adel et al., 2016; Hobert and von Wolff, 2019; Elshan and Ebel, 2020). Despite recent cross-domain literature reviews on the adoption and design of CAs (e.g., Diederich et al., 2022) and on selective aspects such as trust (Zierau, Engel, et al., 2020), so far, a structured *holistic overview* of the scientific literature of CAs in the educational context is lacking. However, generating a holistic overview of the state of the art is relevant to reveal existing scientific gaps and to streamline future research directions that are currently underrepresented (Webster and Watson, 2002; Grover et al., 2019). For instance, existing literature reviews on CAs in education refer to specific use cases by focusing on individual roles such as tutors (e.g., Hobert and von Wolff, 2019; Ashfaque et al., 2020), include only text-based CAs (e.g., Pérez et al., 2020; Smutny and Schreiberova, 2020), or limit themselves to specific target groups like higher education learners (e.g., Sjöström and Dahlin, 2020; Karrenbauer et al., 2021). Therefore, we conducted a systematic literature review (SLR) on CAs in education, following the procedure of Webster and Watson (2002), Page et al. (2021), and Schoormann et al. (2021) to answer the following **research question (RQ**) to contribute to structuring a holistic knowledge base: W*hat is the status quo on research regarding CAs in the educational context, and which research streams arise therefrom?* By answering the RQ, we aim to provide an overview of the opportunities to support learners through pedagogical CAs, to identify promising streams for further research in this area, and to help structure research on pedagogical CAs in the Information Systems (IS) domain, and thus facilitate the research process (Grover et al., 2019). To answer this RQ, we used a two-step process, consisting of an explorative-inductive category definition during the analysis of the abstracts in the first step, and a subsequent deductive coding, guided by a code manual (Mayring, 2015, 2020). We exploratively identified five major research areas for our deeper analysis: *(1) research design and design paradigms, (2) roles and target groups of the analysed CAs, (3) aspects of Human-Computer-Interaction, (4) application of psychological concepts and learning theories, and (5) technological implementation.* The remainder of this paper is structured as follows: First, we elaborate on the trends of CAs in education as well as the evolution of CAs towards virtual companions, which form the foundation for the focus areas set in this SLR (chapter 2). Then, we provide our methodological approach for the SLR in chapter 3. Thereupon, chapter 4 describes the results of the SLR based on the five focus areas, leading to the identification of future research streams (chapter 5). Finally, we provide a summary of the main findings in chapter 6.

2 CAs in Education and Virtual Companions as Emerging Trends

CAs evolve significantly due to the development of AI and natural language processing (NLP), which is reflected by the fact that they become increasingly intelligent and better at understanding human language (Russell and Norvig, 2016; Knijnenburg and Willemsen, 2016; Brown et al., 2020). A developing area is the use of *"pedagogical CAs"* which are e-learning systems, that "interact with learners using natural language dialogs" (Hobert and von Wolff, 2019, p. 301). Pedagogical CAs address the learners' concerns by providing personalised support (Gupta et al., 2019; Winkler et al., 2019; Gubareva and Lopes, 2020). They can e.g., help students with organisational issues (Currie et al., 2016; Herrera et al., 2019) or assist them regarding time management (Gubareva and Lopes, 2020). This personal support is often enhanced by machine learning algorithms, e.g., by suggesting learning content adapted to the users' individual learning preferences and styles (Gubareva and Lopes, 2020; Sharef et al., 2020; Filho et al., 2021). Furthermore, with the development of novel language models, such as GPT-3 (e.g., known from Google's LAMDA project) open conversations with a CA become possible, enabling human-like interactions and individualised facilitation (Brown et al., 2020; Collins and Ghahramani, 2021).

Users seem to perceive this human-like interaction with computers as pleasant (Nass et al., 1995; Becker et al., 2007; Young et al., 2008; Tsiourti, 2018). This finding is supported by the theory of Nass et al. (1994) and Moon (2000), which states that people tend to treat *"computers as social actors"* (CASA) if they exhibit human-like characteristics. In general, human-associated characteristics, such as interactivity, natural language use, or human appearance, are encountered with social attributions and

elicit social responses and behaviour (Fogg, 2002). The CASA paradigm is a foundation of the field of CA research in the information system (IS) discipline (e.g., Pfeuffer et al., 2019; Elshan and Ebel, 2020; Wambsganss, Janson, et al., 2021), and is therefore referred to as a kernel theory (Gregor, 2002; Kuechler and Vaishnavi, 2008). We consider this course for analysing the humanoid design of pedagogical CAs. If CAs are perceived as social entities, it should be possible to build long-term relationships between the CA and its users (Qiu and Benbasat, 2009; Krämer et al., 2011; Lee et al., 2021). This can be seen in the examples of popular CAs such as Replika (Luka, Inc., 2021) or Microsoft's XiaoIce (Zhou et al., 2020), which are referred to as *"virtual companions"* that build friendships with their users since they enable the establishment of a collaborative bond (Nißen et al., 2022; Skjuve et al., 2021; Ta et al., 2020). In contrast to many existing CA approaches, which merely act reactively and have preconceived conversational paths (Seymour et al., 2018), virtual companions act proactively, resulting in far more engaging interactions (Krämer et al., 2011; Strohmann et al., 2019). Designing CAs with companionship elements holds the advantage that they are perceived as pleasant by their users due to their personalized interaction behaviour (Strohmann, 2021; Nißen et al., 2022). Furthermore, a long-term orientation of CAs is essential to ensure recurrent usage and thus the sustainable success of CA projects (Nißen et al., 2022). Moreover, this long-term orientation offers the advantage of novel training data collection through the repeated interaction of the user with the CA and consequently, the CA iteratively becomes better in its language understanding and enables the provider to offer an improved service (Inaba et al., 2015; Janssen et al., 2021). Since several authors (Strohmann et al., 2019; Ta et al., 2020; Xie and Pentina, 2022; Nißen et al., 2022; Ahmad et al., 2022) from both, the IS and the HCI context, point out that CAs are evolving towards relationship-oriented virtual companions, we analyzed the potential future trend in education.

3 Methodology

To contribute to future research, we conducted an SLR based on Webster and Watson (2002), Page et al. (2021), and Schoormann et al. (2021). We included scientific journal articles, conference papers, and book chapters. To collect high-quality contributions of interdisciplinary research domains (IS, Computer Science, Education & Pedagogy), we queried the following databases: *Scopus, ACM Digital Library, AIS eLibrary, IEEE Xplore Digital Library, ERIC, Taylor & Francis, and the International Conference on Artificial Intelligence in Education (AIED)*. Scopus was chosen since it contains more than 80 million documents and refers to itself as the "largest abstract and citation database for peer-reviewed literature" (Elsevier, 2021). ACM Digital Library, AIS eLibrary (including the *"basket of eight"*), and IEEE were selected based on Levy and Ellis' (2006) recommendation since relevant IS conferences and journals are indexed here. ERIC and Taylor & Francis were added as they aggregate publications with a focus on education and pedagogy. The international conference AIED supplements articles linking AI and education. The SLR was performed in June 2021. The search phrase contains synonyms for the context of education and CAs, and was applied to the title, abstract, and keywords:

TITLE-ABS-KEY ("Learning" OR "Education" OR "E-learning" OR "Instruction") AND TITLE-ABS-KEY ("Conversational Agent" OR "Collaborative Agent" OR "Chatbot" OR "Virtual Assistant" OR "Virtual Companion" OR "Interactive Agent")

The search query resulted in a total of 3891 hits. Figure 1 presents the search and selection process in a PRISMA flow diagram as proposed by Page et al. (2021). The column in the middle enumerates the number of reviewed publications during each step, the column on the right lists the documents additionally added via backward search, while the left column illustrates the successive removal of excluded publications after each process step. The exclusion was guided by pre-defined criteria, to ensure the fit with our RQ and the topicality of the contributions examined. The following exclusion criteria were applied: missing educational context, no relation to CAs, another language than English or German, duplicates, language learning or health focus, as well as publications before 2016. A peer-reviewed screening process was applied to strengthen the objectivity of the SLR. In this way, the abstract, as well as the title screening, was double-checked by pairing with another author of the research

team, and the authors agreed on the inclusion and exclusion of an article in a joint discussion in case of differing opinions.

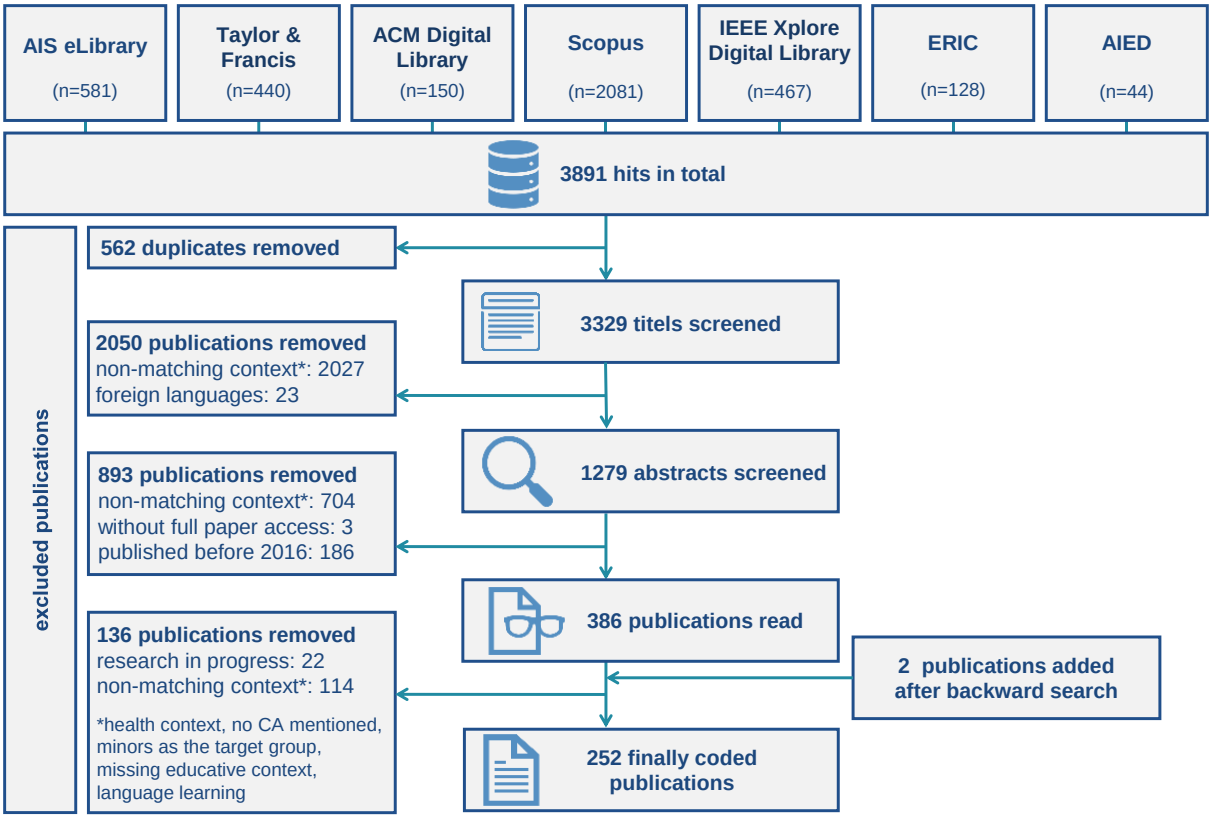

Figure 1. PRISMA flow diagram

To check the timeliness, we analysed the yearly number of publications based on the remaining papers after the title and abstract screening. We decided to focus on papers published after 2016, as we identified a research trend, marked by a strong increase in the publication output, as illustrated in Figure 2. The cut-off was chosen because along the Gartner Hype Cycle the topic of CAs increased in relevance, particularly from this point onwards (Forni and van der Meulen, 2016), and novel advances in digitization and AI outlined above enabled CAs to be developed far more intelligently (cf 4.5). For that reason, we excluded 186 publications published before 2016 and proceeded with the remaining 386 articles for further analysis.

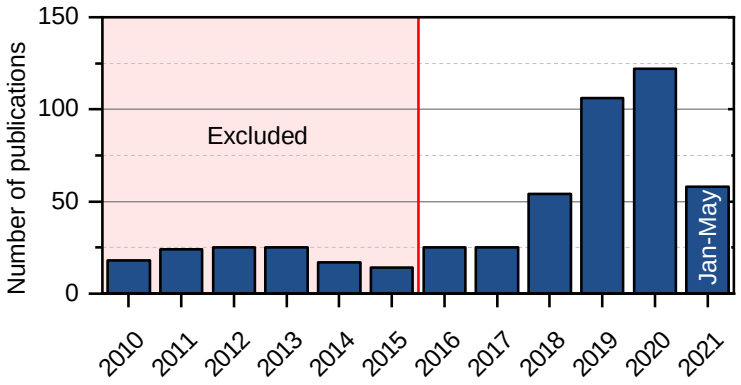

Figure 2. Distribution of remaining publications from '10-'21 after the abstract screening

Based on the pre-defined exclusion criteria, we finally reduced the data set to 252 articles that were fully analyzed by five coding scientists using the software MAXQDA as suggested by Bandara et al. (2015). The coding system was developed iteratively: First, we coded all abstracts in an exploratory-inductive process, meaning that an open coding of the literature progressively led to the emergence of our code system (Miles et al., 2014; Mayring, 2020). Second, the code system was finalised after a joint discussion among the authors, so that a coding manual following Mayring (2015) was created which ensured a shared understanding for attributing codes during the further deductive analysis. The coding guide contains individual sub-categories (up to 3 levels) for the different foci, with definitions, anchor examples, and coding rules for each sub-category to ensure correct coding (Mayring, 2015). The coding took place over the period from August 2021 until the beginning of October 2021, with the individual coders combining their results at weekly intervals (after each coding cycle), and also finally condensing them to reduce complexity. In addition, a *"codebook author"* was defined, who checked the conformity along with the coding manual during the entire coding process. Figure 3 visualizes the coding process.

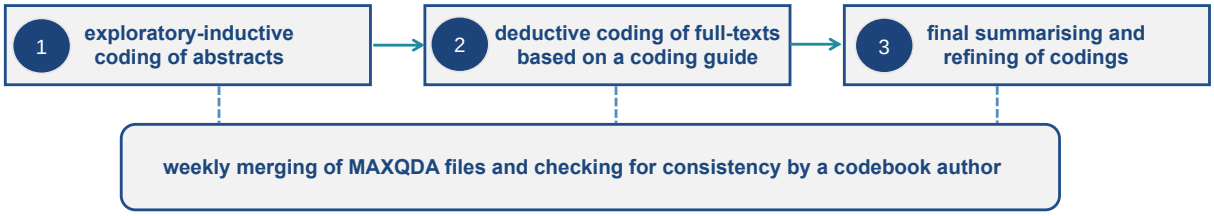

Figure 3. Coding Process

4 Results

Following Mayring (2020, 2015), the explorative coding resulted in the five following focus areas:

(1) Research designs and paradigms: We analysed the research designs and paradigms of the identified sources to assess the quality and rigour of previous studies in the field of CAs in education. We explored patterns in the methodological approaches and identified underrepresented study designs that should be given greater consideration in the future.

(2) Roles and target groups of the analysed CAs: Following Gubareva and Lopes (2020), Hobert (2019a), and Wellnhammer et al. (2020), our screening and analysis revealed, that pedagogical CAs can take on different roles, e.g., as tutors or to assist students in organizing their curriculum. Furthermore, research in different application contexts (e.g., high school as well as academic students) could be identified. Consequently, the roles of CAs, as well as the addressed target groups were considered in more detail.

(3) Aspects of Human-Computer-Interaction: Computers can be seen as social actors (Nass et al., 1994; Nass and Moon, 2000), allowing relationships between humans and CAs to arise (Qiu and Benbasat, 2009; Krämer et al., 2011; Lee et al., 2021; Nißen et al., 2022). Thus, we examined human-like design aspects in the interaction of pedagogical CAs with its users and analysed the extent to which virtual companions approaches (see chapter 2) were already considered in pedagogical CA literature.

(4) Application of psychological concepts and learning theories: As it is crucial for the successful design of IT artefacts to ground on scientific theories (Gregor, 2002; Hevner, 2007; Kuechler and Vaishnavi, 2008), we analysed to what extent a theoretical foundation has been established. Due to the focus on the educational context, the reference to psychological and learning theory concepts is particularly relevant.

(5) Technological implementation: We assessed the technological status quo of existing publications to derive implications regarding the technological realisation of pedagogical CAs.

Based on the previously elaborated focus areas, we derive a morphological box (cf. Table 1) grounded on Ritchey (2011). It provides design variants (*characteristics*) for the use, implementation, and research regarding pedagogical CAs for every sub-section of chapter 4. The related *dimensions* condense the key findings and provide a categorization scheme as a summary for the status quo on CAs in education (RQ).

Sub-chapter and Dimension		**Characteristic**				
4.1	Research methods	Empirical study	Prototype	Literature review	Experiment	
	Research paradigms	Design Science Research		User-centred design		
4.2	Roles	Tutor	Motivator	Organizer	Mentor	Moderator
	Target groups	Academic students	(High-) school students	Teachers	Professionals	
4.3	Humanoid design	Embodiment	Communication style	Personality		
	Adaptability and adaptation	User preferences	Personality	Emotions	Context	
4.4	Learning concepts	Cognitive approaches	Incremental learning	Collaborative and social learning	Media and technology usage	
	Other concepts	Relationship	Social interaction	Trust building	Motivation	
4.5	Extend of AI usage	Minor/none	NLP	User adaptation		
	Building platforms	Google Dialogflow	IBM Watson Assistant			
	Integration	LMS	Messenger	Virtual worlds		
	Messenger	Facebook Messenger	Telegram	WhatsApp		

Legend: 4.1: Research designs and methodological approaches to design CAs; 4.2: Roles and target groups of the analysed CAs; 4.3: Aspects of Human-Computer-Interaction; 4.4: Application of psychological concepts and learning theories; 4.5: Technological implementation; Abbreviations: LMS (Learning Management System) and NLP (Natural Language Processing);
For the sake of clarity, the morphological box does not include residual categories of just occasionally mentioned aspects in the analysed pedagogical CA research.

Table 1. Morphological box of CA research in education

In the following sections, the results for these foci are elaborated in detail.

4.1 Research designs and methodological approaches to design CAs

The research design and methodology are assessed to provide an overview of the approaches and practices used to design and evaluate CAs in education. Therefore, we consider (1) the research design (i.e., empirical study, prototype/IT artefact development, experimental setting, case study, literature review) and dive deeper into the empirical character of the conducted studies (qualitative; quantitative; mixed-methods). Furthermore, we examine, whether a specific design paradigm (2) is mentioned (i.e., Design Science Research, user-centred).

(1) Research methods: Concerning the applied research methods, 95 papers use prototype development (e.g., Sjöström and Dahlin, 2020; Al Muid et al., 2021). For the evaluation of the developed artefacts, researchers use mainly a quantitative approach (61 articles), and less frequently a qualitative (18 articles) or mixed methods (18 articles) approach. 82 studies include an experimental setting to test their assumptions (e.g., Winkler, Hobert, Salovaara, et al., 2020; Wambsganss, Winkler, et al., 2020). Furthermore, the majority of the studies have a small sample size, so the representativeness of the results must be further examined. Only 15 studies have a sample

size ≥ 250 (e.g., Hobert and Berens, 2020; Kim et al., 2020; Wang et al., 2021). We identified 30 papers, which solely provide a literature review (e.g., Smutny and Schreiberova, 2020; Ashfaque et al., 2020; Ashok et al., 2021). In addition, 10 publications are case studies (e.g., Akcora et al., 2018; Amado-Salvatierra and Rizzardini, 2018; Aljameel et al., 2019). Another observation is the rareness of long-term observations in the selected contributions: Only five studies out of 252 articles reported on long-term studies (Shi et al., 2018; Hobert and Berens, 2020; Wolfbauer et al., 2020; Wang et al., 2021; Song and Kim, 2021). 25 studies apply other methods, e.g., accuracy analyses of the proposed CA (Hien et al., 2018; Kowsher et al., 2019).

(2) Research paradigms: With regards to the applied research paradigm, we found 18 papers explicitly mentioning a user-centred design approach (e.g., Sharef et al., 2020; Lembcke et al., 2020; Herrmann-Werner et al., 2021). Moreover, 12 publications explicitly follow the Design Science Research approach, whereof 6 derive design principles (e.g., Rodriguez et al., 2019; Winkler and Roos, 2019; Elshan and Ebel, 2020), and 8 present an IT artefact (Hobert and Berens, 2020; Winkler, Hobert, and Appius, 2020; Wambsganss, Weber, et al., 2021), mostly as an instantiation of previously proposed design principles. Only one paper presents a (nascent) design theory as prescriptive design knowledge (Gregor, 2002; Gregor and Hevner, 2013), focusing on the advancement of argumentation skills as a specific application context (Wambsganss, Soellner, et al., 2020). Further design knowledge was gained, e.g., in the form of design characteristics or overarching recommendations (Meyer von Wolff et al., 2020).

4.2 Roles and target groups of the analysed CAs

The following chapter is divided into three sections. (1) deals with the roles and functions that a pedagogical CA can take and the distribution and typical overlaps of the fulfilled roles. Section (2) shows the distribution of target groups addressed by the corresponding CA. Section (3) reveals the consolidated results of both areas from (1) and (2).

(1) Roles and functions: We found functions of pedagogical CAs, which correspond to the roles identified by Gubareva and Lopes (2020) namely tutoring, organizing, motivating, and mentoring. Supplementary, we added the moderator function, because Gubareva and Lopes (2020) focused on academic student support and we covered a broader scope, also including the instructors' perspective (e.g., Mikic-Fonte et al., 2019; Sakr et al., 2021). The roles can be described as follows: The main objective of a tutoring CA is to provide learning content (e.g., Taoum et al., 2019; Winkler, Hobert, Salovaara, et al., 2020). The organizer targets academic integration i.e., by administrative support like university admission (e.g., Al Muid et al., 2021), course management (e.g., Priadko et al., 2020), or finding the right career opportunities (e.g., El Hefny et al., 2021). User's engagement to invest more time in learning is fostered by the CA as a motivator, which results e.g., from concepts like gamification (Krassmann et al., 2019) or strategies to overcome procrastination (Rodriguez et al., 2019). Nevertheless, CAs in the role of a motivator are rarely (6%) designed and developed based on motivation theories. The mentor accompanies the students and monitors their progress, above all by quizzes (e.g., Kita et al., 2018) and self-assessments (e.g., Durall and Kapros, 2020), whereas support on stress reduction was rarely found (e.g., Ranjbartabar et al., 2018). The moderator facilitates any kind of learning in groups, e.g., it supports group work (David et al., 2019), or collaborative learning and problem-solving environments (Graesser et al., 2018). The distribution of the roles is as follows: 31% tutor, 21% motivator, 21% organizer, 18% mentor, 9% moderator. Papers that did not refer to specific functions (n=42) focus e.g., on design principles for the communication style (e.g., Wolfbauer et al., 2020) or avatar design (e.g., Taoum et al., 2019). A single pedagogical CA can incorporate multiple functions. In 24 publications, the mentoring and tutoring functions were combined, i.e., when the virtual teacher makes use of quiz functions (e.g., Ruan et al., 2019) or additionally facilitates learning partnerships among students (e.g., Reinken and Greiff, 2021). The role as a motivator was combined with mentoring in 16 papers (e.g., Song et al., 2017), tutoring in 16 publications (e.g., Agada et al., 2019), and organizing in 15 articles (e.g., Mekni

et al., 2020). 24 contributions focused exclusively on motivation. The moderator role has by far the least overlaps and therefore reflects a more specialized and rare application of pedagogical CAs.

(2) Target groups: The target groups addressed by the CAs in the analysed sample are: 78% academic students (e.g., Mikic-Fonte et al., 2019; Sakr et al., 2021), 6% high school students or equivalent (e.g., Rodriguez-Gil et al., 2019; Nguyen et al., 2020), 6% teachers (e.g., Gonda and Chu, 2019), 5% professional development (e.g., Shi et al., 2018; Fang et al., 2019; Schouten et al., 2021), and 5% others such as parents of learners (e.g., El Hefny et al., 2021).

(3) Consolidated roles and target group results: The target group of academic students is overrepresented in pedagogical CA research. Transfer of results to other target groups is mostly not covered. Only 5% of the articles cover professional development in a non-academic context, although lifelong learning is tremendously important for all educational levels due to longer life expectancy, rapid technological advances, globalisation, and demographic change, but also unexpected circumstances like the COVID-19 pandemic (OECD, 2021). Shortage of time due to occupation is considered the main barrier for adult learning (formal and non-formal) (OECD, 2019). Nevertheless, none of the analysed articles covers the challenge of adult learning in parallel to one's employment. Over two-thirds of professional development articles deal with low literacy and thus with the lower educational class (e.g., Shi et al., 2018; Fang et al., 2019; Schouten et al., 2021).

4.3 Aspects of Human-Computer-Interaction

Derived from the CASA paradigm (see chapter 2), there is potential in designing CAs human-like. Even though there are already approaches to bundle these insights for different application contexts, e.g., through a nascent design theory for anthropomorphic enterprise CAs (Diederich et al., 2020), there is no consensus on the transferability of other contexts such as education. Thus, we examine the humanoid design of pedagogical CAs in detail (1). As various authors point out, a user-adaptive design and the adaptability of the CA is a prerequisite for users to perceive the machines as companion-like (Nass et al., 1995; Park et al., 2012; Strohmann, 2021). Therefore, we also discuss linked design aspects (2).

(1) Designing humanoid CAs: 80 among the analysed articles examined the human-like design of the CA's appearance and interaction. We determined that an essential way to implement anthropomorphism in a CA, is the use of *"social cues"*, in terms of "signals depicted by humans when interacting with each other" (El Hefny et al., 2021, p. 675). These characterise a CA's humanness by either verbal, visual, or invisible cues (ibid.). Wolfbauer et al. (2020) recognise social cues as a necessary design aspect to motivate learners for the usage of CAs. Specific features related to the design of human-like CAs were found in a variety of sub-categories: a human-like representation (e.g., Gamage and Ennis, 2018), communication style adaptation to the user's personality traits (e.g., Dennis et al., 2016; Iwase et al., 2021), human gestures (e.g., Agada et al., 2019; Hayashi, 2020), emotions and empathy (e.g., Fraoua et al., 2020; Wambsganss, Weber, et al., 2021), human-like interaction in colloquial scenarios such as small talk (e.g., De Medeiros et al., 2019; Tärning and Silvervarg, 2019), supported by an intuitive communication style adapted to the learner (e.g., Tärning and Silvervarg, 2019; Hobert and Berens, 2020). These design features build the foundation for a stable human-machine relationship, which is for instance characterised by building trust and acting in good faith (Herrmann-Werner et al., 2021). Although being mentioned in recent publications (see chapter 2), our SLR proves that the companion perspective as an evolutionary stage for designing pedagogical CAs is underrepresented in research. The explicit goal of building a friendship-like relationship between the CA and its learner is only taken up by the authors Krassmann et al. (2019), Iwase et al. (2021), and Heras et al. (2020). While the term *"chatbot"* was used in 167 publications and thus a majority of the 252 articles (85%) with a total of 5661 entries, the term *"virtual companion(ship)"* appeared in only 2 articles (< 1%) with 28 overall mentions (Souali et al., 2019; Cervantes Ramírez et al., 2020). However, some authors use the term *"learning companion"* instead, which is mentioned more often with a total of 5 contributions, even though still being underrepresented (Novick et al., 2019; Wiggins et al., 2019; Sandu and Gide,

2019; Tärning and Silvervarg, 2019; Schneider et al., 2019; Wu et al., 2020). Although research shows that CAs may act as collaborative partners to humans (see chapter 2), the term *"collaborative agent"* was just found once (Tomar and Sankaranarayanan, 2016).

(2) Relatedness through adaptability and adaptation: Consistent with several sources, the adaptability of the CA by the user may promote the perception of relatedness to the CA, e.g., when the avatar can be customized fitting to personal preferences (Park et al., 2012; Hanus and Fox, 2015; Kocaballi et al., 2019; Strohmann, 2021). In this context, Weisz et al. (2019) show in their studies that learners build genuine feelings towards adaptable pedagogical CAs and attribute human qualities, such as helpfulness to them. Accordingly, the development of an emotional relationship is targeted by several authors: Krassmann et al. (2019) specifically apply emotional behaviours (e.g., joyful gestures, disappointed reaction) with the CA to strengthen social interaction in learning. Ismail and Ade-Ibijola (2019) respond to emotional problems of the learner with personalised advice, whereas Kumar et al. (2018) apply sentiment analysis in text messages to co-convey emotions on the relationship level according to the situation, in addition to specifically adapting the interaction content (e.g., with emojis reacting to facial detection) to the user. Hobert and Berens (2020) argue that for such an emotional relationship, trust between the learner and the CA is required above all, which is consistent with the findings of other CA scientists (e.g., Benbasat and Wang, 2005; Feine et al., 2019; Lee et al., 2021). Herrmann-Werner et al. (2021) also draw on this trust-based relationship by introducing a CA that responds to learners' emotions and helps them feel less stressed; the authors, therefore, conclude that trust is necessary for the acceptance of this nascent technology. Overall, adaptation takes place not only to the user, but also to the entire context of the interaction, whereby according to Fischer (2012) such context-awareness can ensue, e.g., through a conscious adaptation to the associated situation, time, or place. Context-awareness is implemented by CAs in education, e.g., by the CA reacting to the user's emotional state (Griol et al., 2017), by generating situation-dependent quiz questions (Sreelakshmi et al., 2019), or by suggesting learning content (e.g., videos or articles) to the user that fits the place and situation, for instance, tailored for learning when commuting with public transportation (Abdelkefi and Kallel, 2016).

4.4 Application of psychological concepts and learning theories

In 136 of the reviewed publications, we identified theoretical reflections referencing psychological or learning pedagogical theories on the topic of CAs in the educational setting. The majority of mentioned theories (80%) stem from educational research. More precisely, they focus on four overarching concepts:

(1) Cognitive approaches about information processing and knowledge representation: In developing a CA that supports knowledge acquisition, some authors have integrated the assumption of cognitivism that knowledge is not always represented in the same form (e.g., Graesser et al., 2017; de Medeiros et al., 2019; Hattingh and Weilbach, 2020). Therefore, they refer to different theories of knowledge representation, such as *"deep and shallow knowledge"* (Graesser et al., 2017). Deep knowledge involves causal, logical reasoning, solving complex problems, and dealing with ambiguity; for that reason, the elaboration of deep knowledge is essentially more challenging (Bennet and Bennet, 2008; Chi, 2009; Graesser et al., 2017). Learning style theories have been developed in an attempt to adapt the learning setting to individual preferences (Felder and Silverman, 1988) and are to this day still very popular amongst practitioners even though discussed controversially (Willingham et al., 2015). 36 publications refer to literature on different learning styles, e.g., to the Felder and Silverman (1988) model that differentiates between four learning preferences cited in Aljameel et al. (2019), or the concept of Kolb (1984) who describes a four-stage cycle of learning styes, mentioned by Rajkumar and Ganapathy (2020).

(2) Didactical concepts about incremental learning: Several papers focused on concepts to break broad subjects down into incremental learning steps (e.g., Feidakis et al., 2019; Winkler, Hobert, Fischer, et al., 2020; Yin et al., 2021). For instance, micro-learning is a popular E-Learning strategy

that relies on breaking down learning content into short units consisting of the most important information on those sub-topics (Yin et al., 2021). Other theories emphasise the role of the teacher who needs to adapt to the student's learning progress to react accordingly (Huse and Le, 2016; Hayashi, 2018, 2019, 2020).

(3) Collaborative and social learning: In addition to supporting individual learning, various CAs have also been related to collaborative learning. On the one hand, the learner might interact with other peers in a group setting, e.g., on tasks of collaborative problem-solving (Graesser et al., 2018; Hayashi, 2018). On the other hand, the CA itself might be perceived as a learning partner or teacher with whom the learner can interact (Gonda et al., 2018). In this regard, several authors reference theories that explain the function of the CA as a feedback provider to the learner (e.g., Dennis et al., 2016; Hayashi, 2018; Gonda et al., 2018).

(4) Media and technology usage: There is a growing theoretical body on how to use media and technology in learning and teaching scenarios (e.g., Fang et al., 2019; Feidakis et al., 2019; Krassmann et al., 2019; Heras et al., 2020; Winkler, Hobert, Salovaara, et al., 2020). The *"Cognitive Theory of Multimedia Learning"* (Mayer, 2014) i.e., specifies five major cognitive processes in multimedia learning. Eventually, the choice of technical implementation (see chapter 4.5) also determines the possibilities of media use in learning scenarios.

Furthermore, 20% of the theories refer to broader psychological concepts that are not directly related to education. The largest part looks at relationships and social interactions (e.g., Dennis et al., 2016; Schöbel et al., 2019; Moussawi and Benbunan-Fich, 2020; Tai and Chen, 2020). In some cases, other theories from the broader psychological literature are cited, e.g., creativity enhancement (Vladova et al., 2019), motivation (Diachenko et al., 2019; Schöbel et al., 2019), trust (Moussawi and Benbunan-Fich, 2020), and self-regulation (Cabales, 2019; Durall and Kapros, 2020; Karrenbauer et al., 2021). However, these theories are underrepresented overall.

4.5 Technological implementation

In the following section, we will present salient findings on the technological status quo regarding the deployment of CAs (1) and their integration into existing platforms (2):

(1) Technological deployment: In the last decade, numerous building platforms emerged that support the design of CAs, promising to enable their deployment without in-depth programming knowledge (Diederich et al., 2019). To assist designers in conceptualisation as well as implementation, we analysed which platforms were mentioned most frequently: Google Dialogflow (37%) (e.g., Gonda and Chu, 2019; El Hefny et al., 2021) and IBM Watson Assistant (30%) (e.g., Ralston et al., 2019; Oliveira et al., 2019). Even though building platforms are simple approaches for the development of CAs, Diederich et al. (2019) emphasise that tools such as Google Dialogflow include intelligent functionalities, and can also be enhanced by developers through their own code fragments, leading to the possibility to integrate building platforms in an ecosystem of intelligent services (e.g., Hien et al., 2018; Oliveira et al., 2019; González-Castro et al., 2021). Such meta-architectures serve to interlink intelligent components and thus create a technological backbone for an engaging user experience. For instance, Hobert (2019b) presents a software architecture for a *"coding tutor"* connected to a backend with different intelligent components: NLP, management of the dialogue, a knowledge base (different databases with the learners' data), and an interpreter for the users' input. It is noteworthy that many authors give the CAs certain (human-like) names, e.g., *"Timmy"* (Elshan and Ebel, 2020) or *"Jimmy"* (Krassmann et al., 2019), although a large proportion of these software names are only referenced once, and have mostly not yet been further developed in subsequent publications. Thus, we assume that many pedagogical CAs are still in a prototypical stage and that relying on intelligent AI technologies for speech recognition is still rare since many CA instantiations control the conversation based on certain fixed conversational sequences, also referred

to as *"rule-based"* CAs (Seymour et al., 2018). An exception is the so-called *"AutoTutor"*, which was presented several times by different authors and occurs in total in 12 of the analysed publications, thus to be seen as a milestone in the emergence of CAs in education (e.g., Li and Graesser, 2017; Shi et al., 2018; Fang et al., 2019). However, some authors already present intelligent technologies with the aim that the CA adapts to the users' behaviour (see chapter 4.3), e.g., by considering users' emotions (e.g., Lallé et al., 2018; David et al., 2019; Fraoua et al., 2020), or suggesting learning content and recommendations to match specific learning styles (Crockett et al., 2017; Filho et al., 2021; Sharef et al., 2020). For these adaptative functions, AI is often applied, especially by algorithms to classify users based on certain characteristics, also referred to as *"classifications"* (Crockett et al., 2017). Examples of AI technologies used for this are neural networks (e.g., Lallé et al., 2018), naive bayes classifiers (e.g., Adel et al., 2016), or classification trees (e.g., Crockett et al., 2017).

(2) Integration: Concerning the integration of CAs into existing platforms, the distribution is as follows: 33 research papers deal with the integration into messenger services (e.g., Lee et al., 2020), 26 publications refer to Learning-Management-Systems (LMS) like Moodle (e.g., Laeeq and Memon, 2019), and 18 papers describe CAs in virtual worlds, e.g., by embedding a CA into a game-based learning context (e.g., Novick et al., 2019; Wiggins et al., 2019). Other mentioned services are Twitter (e.g., Huff et al., 2019), social media platforms such as LINE (e.g. Lee et al., 2020), or Google Drive (e.g., Hattingh and Weilbach, 2020). Messenger services utilized are particularly Telegram (e.g., Tsidylo et al., 2020), WhatsApp (e.g., Meyer von Wolff et al., 2020), or Facebook Messenger (e.g., Arun et al., 2019). One special use case identified links multiple CAs to interact with learners, also referred to as *"trialogues"* (e.g., Graesser, 2016; Fang et al., 2019; Hayashi, 2019).

5 Discussion and Further Research Streams

Furthermore, for a comprehensive answer to the RQ, we derive implications for broader future research streams based on the findings on the five elaborated focus areas, which are meant to provide guidance to the research community:

(1) Research designs and paradigms: Overall, we detected a deficiency of solidly validated studies of CAs. This is reflected in the lack of triangulation of quantitative and qualitative research (mixed-methods) targeting a multi-faceted evaluation (Ivankova et al., 2006). Moreover, a research gap emerges in long-term studies of CAs in education, which are, however, necessary to elicit the long-term effect on learning motivation and success (Salkind, 2010; Hobert, 2019a). It is not yet clear, whether and to what extent CAs in educational contexts can unfold their potential in terms of long-term and trust-based relationships with their users. We suggest, in conclusion, that researchers should engage in rigorous evaluation of pedagogical CA artefacts with a large as well as representative sample size. This includes eliciting a long-term effect on learning motivation using empirical models such as the ARCS model (Keller, 1987), learning success or knowledge gain (e.g., according to Brucks, 1985), perceptions of trust (e.g., Qiu and Benbasat, 2009), or even friendship-like relationships with users (e.g., Mendelson and Aboud, 2012). Examining the effects of using pedagogical CAs from validated constructs is crucial to make scientific implications about whether and to what extent pedagogical CAs might support learners and thus provide added value for them. Although the established paradigm of Design Science Research in the IS domain is already employed by some researchers, its application is still expandable, especially when building on design frameworks and theories with the potential of a holistic view on the design of pedagogical CAs (Gregor, 2002; Kuechler and Vaishnavi, 2008). By expanding the design knowledge base, other researchers, as well as developers, could be exposed to prescriptive recommendations for the design of pedagogical CAs, thus contributing to the entire research and practitioner community (ibid.). Moreover, only a few authors explicitly follow the user-centred design approach, although

considering the user perspective is crucial for the design of innovative artefacts (Norman and Draper, 1986; Abras et al., 2004). Consequently, future research opportunities arise from that gap.

(2) Roles and target groups of the analysed CAs: Theoretical foundation for prototype development, especially for the CA as a motivator is rather rare**.** CA researchers in education should consequently incorporate motivation theories and the derivation of theoretical design knowledge such as design principles (Gregor et al., 2020). Designing pedagogical CA based upon well-established scientific theories helps to ensure the rigour of the artefact design process (Gregor, 2002; Kuechler and Vaishnavi, 2008). While the academic context dominates research regarding CAs in education, other application areas supporting lifelong learning are rare to find, despite their growing importance (OECD, 2021). Studies with learners in continuing vocational education mainly relate to lower educational backgrounds, leading to the need for further research for all social strata.

(3) Aspects of Human-Computer-Interaction: The humanoid design of CAs as a further evolution of pure chatbots is already addressed in many articles, whereby often only scattered design aspects (e.g., social cues, or small talk behaviour) are considered. Thus, the design of human-like pedagogical CAs should be investigated more holistically. Despite some mature pioneers (e.g., Replika) that already embody an evolution from purely assistive CAs to virtual companions, this dimension is currently hardly considered in the educational context and requires further research, especially to exploit the potentials that might arise from a long-term relationship between the users and their CA. According to Gregor and Hevner (2013), this raises the opportunity to bundle these specific findings for the design of pedagogical CAs and to transfer them into prescriptive design knowledge, e.g., in the sense of a (nascent) design theory. In doing so, it could be investigated to what extent existing findings on the design of human-like CAs (e.g., Gnewuch et al., 2017; Ahmad et al., 2022) could be transferable to the educational context, thus contributing to the future evolution of pedagogical CAs.

(4) Application of psychological concepts and learning theories: Since the design of IT artefacts requires drawing on a sound knowledge base (Gregor, 2002; Hevner, 2007; Kuechler and Vaishnavi, 2008), we analysed the theoretical foundation of CA publications with an educational context. We found that a large number of authors do not base the design of their CA on scientific theories. The articles that are based upon psychological concepts and theories, however, usually only consider isolated aspects (e.g., CAs to promote improved multimedia learning), while a more diverse consideration of the knowledge base was hard to find. For this reason, we assume that existing CAs do not yet realise their full potential. We conclude that working in interdisciplinary research teams on the development and design of pedagogical CAs from multiple perspectives is advisable to address the topic in a multi-faceted manner.

(5) Technological implementation: The insufficient exploitation of potential is also evident in terms of technological implementation, with many CAs not progressing beyond prototype status or merely relying on rule-based conversational building blocks. This is surprising, as developments in the field of AI are advancing rapidly leading to a variety of intelligent services for the programming of CAs on the market (Diederich et al., 2019, 2022). Moreover, the positive example of the often-cited *"AutoTutor"* demonstrates that pedagogical CAs can also be implemented in diverse application contexts over a longer period (e.g., Cai et al., 2016; Fang et al., 2019). Since Janssen et al. (2021) proved that most CAs nevertheless fail within a short period, we reckon that this might particularly go back to the rare long-term orientation of the research projects outlined above. Consequently, we advocate researching CAs targeting long-term application, proceeding user-centred and holistically in the design, and consequently also evaluating and iteratively further developing the prototypes in real learning scenarios. A long-term research and development approach may contribute to the sustainable success of pedagogical CA projects and to moving the designed artefacts beyond the prototype phase.

The following limitations should be noted when interpreting the results. First, as is common for SLRs, the selection and analysis process is based on subjective decisions of the authors, which might have

influenced the results. Second, despite our extensive review of 252 publications, it is still possible that relevant publications might have been overlooked during the screening process, even though we included a variety of databases and search terms. Ultimately, as the field is evolving quickly, we can only provide the current state of the field and future searches on related topics might yield different results.

6 Conclusion

The objective of this scientific contribution was to conduct a structured literature review on the state of research on CAs in learning contexts to identify implications for research and practice. We reviewed 252 relevant articles, following the approaches of Webster and Watson (2002), Page et al. (2021), and Schoormann et al. (2021). Due to the complexity of the topic, we followed an exploratory-inductive approach during the screening and abstract coding, whereas the deeper analysis was conducted deductively (Mayring, 2015, 2020). As a result, we identified the following research foci (see chapter 4): applied research methods and paradigms, the roles of CAs and the addressed target groups, the interaction design between CA and learners, the underlying learning-theoretical foundation, as well as the technological implementation. We uncovered, that many publications deal with very specific aspects of CAs in the learning context. However, there is a lack of holistic (and theoretically well-founded) considerations. Furthermore, in contrast to cross-domain literature reviews (Zierau, Elshan, et al., 2020; Strohmann, 2021; Diederich et al., 2022), the knowledge base to be considered is broader: While the literature on CAs, in general, focuses mainly on HCI and corresponding psychological concepts, our literature review refers by ca. 80% to theories emerging from education research (e.g., collaborative and social learning). Moreover, unlike for CAs in general (Diederich et al. 2022), DSR approaches are still rare to find in the field of pedagogical CAs. At the same time, despite the rapid progress of AI in the past decade and the evolution towards intelligent companion approaches of CAs, the majority of CAs presented are still in an early and immature prototypical state. Thus, their potential has not yet been fully realised. Similar to Strohmann (2021) and Diederich et al. (2022), we found that scenarios of the long-term orientation of CAs have so far been rarely considered, which is reflected in the lack of long-term studies (Diederich et al. 2022). However, contrary to what cross-domain literature reviews reveal, there is a difference in the quality of existing studies: While for CAs in general, a plethora of empirical studies with validated constructs exist (Diederich et al., 2022), those are underrepresented in the educational domain - many publications lack evaluations with a solid sample size. Although the number of publications on CAs in education has been significantly increased in recent years (see chapter 3), research in this area is still immature. We presume great potential in the interdisciplinary and holistic consideration of CAs with studies on long-term effects.

In spite of inescapable limitations regarding subjectively driven decisions during the SLR, we purposefully undertook measures to reduce these through a peer-reviewed process in screening, two successive coding waves in an interdisciplinary research team, after querying seven scientific databases. Consequently, as our essential contribution, we provided a comprehensive overview of current literature on research in the field of CAs in learning contexts, presented a morphological box following Ritchey (2011), and ultimately revealed future research streams as an impetus for researchers and practitioners.

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