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RESEARCH ARTICLE

Pedagogical AI conversational agents in higher education: a conceptual framework and survey of the state of the art

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Abstract

The ever-changing global educational landscape, coupled with the advancement of Web3, is seeing rapid changes in the ways pedagogical artificially intelligent conversational agents are being developed and used to advance teaching and learning in higher education. Given the rapidly evolving research landscape, there is a need to establish what the current state of the art is in terms of the pedagogical applications and technological functions of these conversational agents and to identify the key existing research gaps, and future research directions, in the field. A literature survey of the state of the art of pedagogical AI conversational agents in higher education was conducted. The resulting literature sample (n = 92) was analysed using thematic template analysis, the results of which were used to develop a conceptual framework of pedagogical conversational agents in higher education. Furthermore, a survey of the state of the art was then presented as a function of the framework. The conceptual framework proposes that pedagogical AI conversational agents can primarily be considered in terms of their *pedagogical applications* and their *pedagogical purposes*, which include *pastoral*, *instructional* and *cognitive*, and are further considered in terms of *mode of study* and *intent*. The *technological functions* of the agents are also considered in terms of *embodiment (embodied/disembodied)* and *functional type* and *features*. This research proposes that there are numerous opportunities for future research, such as, the use of conversational agents for enhancing assessment, reflective practice and to support more effective administration and management practice. In terms of technological functions, future research would benefit from focusing on enhancing the level of personalisation and media richness of interaction that can be achieved by AI conversational agents.

Keywords Pedagogy · Education · Higher education · Conversational agents · Chatbots · Human computer interaction · Artificial intelligence

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Introduction

With the majority of higher education students being under the age of 40 (Higher Education Statistics Agency, 2022; McCann, 2022), an ever increasing proportion of these students are considered to be digital natives, i.e., individuals that have relatively high competency and skill in using information technology (Wang et al., 2013). Higher education providers, particularly in developed countries, have noted this fact and have increased budgets to enable investment in technology to promote, advance, compliment and progress education within their institutional remits (Nagel, 2022). Furthermore, with governmental and global change towards digital transformation, there is additional incentive, and pressure, for higher education providers to establish research that seeks to deploy educational technologies for innovation. Additionally, as posited by Mladenova et al. (2020), the Covid-19 pandemic in 2020 further accelerated the digital strategy and transformation within higher education, and caused higher education providers to implement digital changes in education within weeks, which would normally have been implemented over years. According to a policy paper by the British (UK) Government (2022), the education sector faces various challenges that can be addressed through the use of technology. This includes reducing the burden of work on teachers, increasing efficiency, making education more accessible and inclusive, promoting exceptional teaching practices, and enhancing student achievement. Among the many educational technologies that exist, the exploration of using artificial intelligence (AI) to progress education has grown in recent years, primarily due to the evolution of the internet with Web3, a globally connected era, and the prevalence of immersive technology wherein human beings can interact with virtual technologies which can function with humanistic and anthropomorphic tendencies (Grudin, 2021). A common theme within AI is the scientific study of human–computer interaction (HCI), i.e. how humans interact with computers. According to Stephanidis et al. (2019), HCI has traditionally been the study of how technology can serve human interests but has in more recent years evolved into the establishment of a deeper psychological connection between humans and computers. The ability for human beings to have dialogue and converse with computers using natural language has been the primary objective within the field of contemporary AI (Lowe et al., 2016). A well established and growing technology explored within HCI and higher education is AI conversational agents.

An AI conversational agent is a computer system that imitates natural conversation with human users through image, written, or spoken language (Laranjo et al., 2018). The idea of conversing with a computer as though it is a human being is said to have come from Alan Turing in 1950, who conducted the Turing test wherein human participants were observed when conversing with a text-based computer system, to identify and evaluate whether they realised that their interlocutor was an artificial agent (Turing, 1950). The first chatbot to be built was in 1966, with the development of ELIZA, a first-computer rule-based programme which allowed conversation between a human being and a computer (Weizenbaum, 1966). Since then, with the evolution of information sciences, research within the domain of AI, widespread use of digital capabilities and construction of machine learning technologies, conversational agents can go beyond simple rule-based input–output interactions. Current modern-day conversational agents are able to imitate human beings in aesthetic and voice, identify the intent of the user through minimal interactions and access various data sources to output conclusions, assumptions and decisions, sometimes upon which to take actions (Adamopoulou & Moussiades, 2020). Examples of such uses of interactive and emotionally aware conversational agents can be demonstrated by Github's Co-pilot (Sobania

et al., 2021), wherein a conversational agent can act as a pair-programming colleague, and Microsoft Xiaoice, wherein a conversational agent can stimulate emotional responses in humans by satisfying their need for social interaction (Zhou et al., 2022).

With the evolution of conversational agents as aforementioned and a need for digital transformation within higher education, naturally, the use of conversational agents has, in recent years, been explored for pedagogical applications to advance teaching and learning. Conversational agents have been demonstrated to supplement and advance education in various forms, such as providing assessment of learners work (Maryadi et al., 2017), increasing peer dialogue (Wang et al., 2020), providing a context for education, for example in coordinating role-play in healthcare education (Shorey et al., 2019), and answering student queries (Gonda & Chu, 2019). A conversational agent can support teaching and learning within any pedagogical context wherein there is interaction between a human being and other matter, hence the popularity and acceptance of conversational agents within education.

There are many pedagogical applications of conversational agents developed by using a wide array of technologies. Furthermore, the agents come in various forms, such as embodied and disembodied conversational agents, with differing functionalities, such as voice, emotional intelligence and ambient sensory information. Given the variety of forms that conversational agents can take, coupled with the range of functionality, technologies, and pedagogical settings that they can be applied to, there is a need to establish, and better understand, what the state of the art is in this field and identify key opportunities for future research in this field.

Purpose of the study

Although numerous reviews have been conducted within the field of conversational agents, these investigations have been for specific applications of conversational agents, for example within the domain of health (Montenegro et al., 2019), or business (Bavaresco et al., 2020). There have been some mapping of pedagogical conversational agents, such as the study by Paschoal et al. (2020), however, such studies are limited to mapping the constructs of pedagogical conversational agents, such as evaluating the years of publications or the level of pedagogical application. Other studies include the research by Diederich et al. (2022) that explores conversational agents in various contexts, such as private and professional and focuses on the human interaction and anthropomorphic qualities that agents exhibit. The systematic review by Kuhail et al. (2023) surveys conversational agents used within the domain of education and presents a quantitative overview of uses in terms of the studies themselves, such as defining the subjects and type of use. The literature review by Pérez et al. (2020) investigates the use of conversational agents in education, drawing on a range of topics such as implementational problems in context, teachers' perceptions of use and architectures used for deployment. The review by Rodrigues et al. (2022) explores various conversational agents in the domain of education and highlights the main strengths and weaknesses of the agents. The study by Wahde and Virgolin (2022) explores conversational agents briefly in the specific domain of education, and generally looks at the more technical elements of the agent design. Furthermore, the study by Allouch et al. (2021) explores an overview of the concepts and building blocks of conversational agents in various domains, and agents are categorised according to their abilities and main application domains. To the best of our knowledge, there is no existing research that surveys and categorises contemporary research studies across the full range of pedagogical AI

conversational agents, specifically in the higher education landscape based on both, their pedagogical and technological functions.

While this review focuses primarily on literature that falls within a pre-defined and specific set of search criteria, it is important to acknowledge that important and relevant pedagogical agent studies exist outside of this. Such studies provide valuable foundational insights and findings that should also be considered and reflected upon in relation to the findings of the current study. Therefore, we consider such studies in the discussion section (Sect. "Findings in relation to existing pedagogical agent frameworks") of this paper. These wider findings are analysed and reflected upon in terms of how they support or contrast the outcomes of the current study, thereby providing a more comprehensive understanding of pedagogical conversational agents in higher education than could be captured by the survey alone.

Research aims

In light of the need to better understand the state of the art in pedagogical AI conversational agents implemented for higher education, this study provides a comprehensive literature review of the state of the art for pedagogical AI conversational agents in higher education. This literature study aims to answer the following research questions:

RQ1) How are pedagogical AI conversational agents being utilised in higher education?
RQ2) What are the pedagogical and technological functions and features of AI conversational agents for higher education, and how are they organised conceptually?
RQ3) What examples exist within the state-of-the-art higher education literature that provide evidence of the various pedagogical and technological functions and features identified in RQ2?
RQ4) Which domains within higher education do the pedagogical and technological functions and features of AI conversational agents appear to remain underexplored and/or present opportunities for further future research?

The remainder of this study is structured as follows, Sect. "Research method" presents the research methods used to conduct the literature survey. Sect. "Pedagogical AI conversational agents, a conceptual framework" presents a conceptual framework and its component parts are explained. Sects. "Pedagogical applications of conversational agents in higher-education" and "Technological functions of pedagogical conversational agents" present the literature survey of the state of the art. Sect. "Discussion" discusses the findings of the survey and proposes future research recommendations based on the findings. Sect. "Conclusions" concludes the study.

Research method

This section reports on the review methods utilised for this study. The steps taken to carry out a survey of the state of the art, and to produce the literature dataset on which the findings of this study are based, is illustrated in Fig. 1, and are explained in more detail throughout the course of this section.

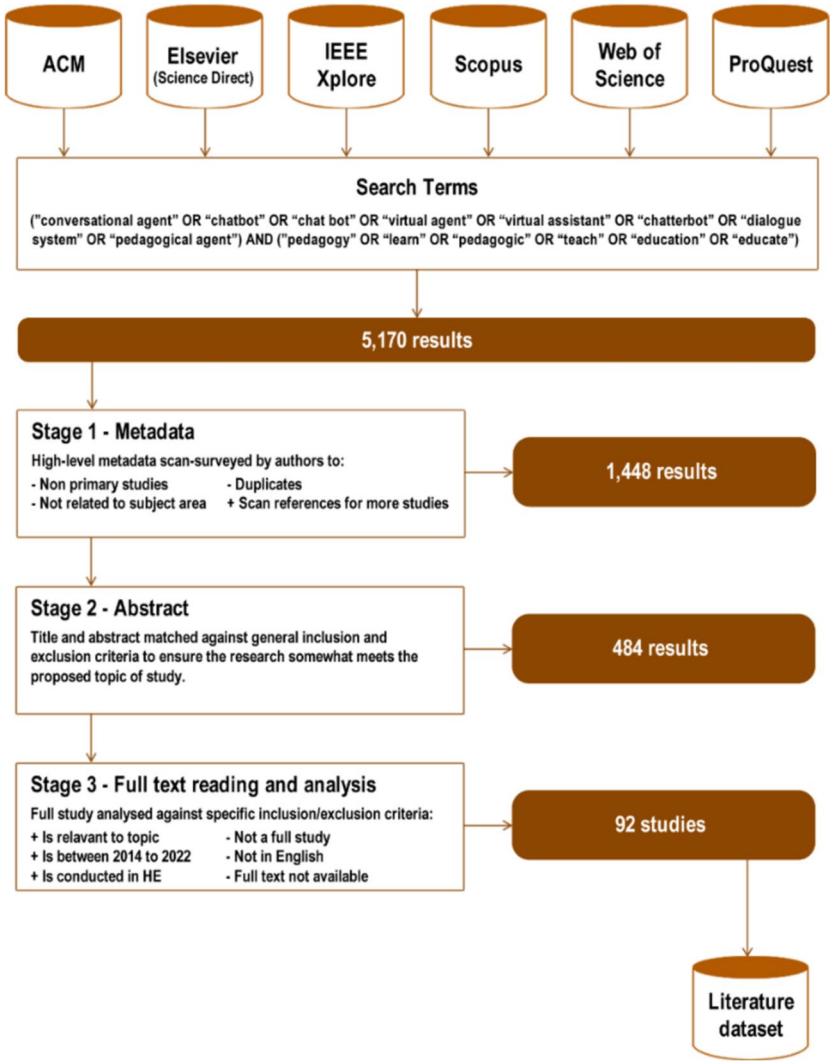


Fig. 1 Search Strategy

Literature search strategy

The review process of this study is partially conducted based on the conventions and guidelines applied by Petersen et al. (2008). Based on the background and context, and the problem statement defined, the aim of this research is to provide a holistic overview of pedagogical conversational agents and draw conclusions therefrom. This study aims to analyse previous research on conversational agents used for pedagogical purposes. It will examine if the studies mention the use of conversational agents for pedagogy, the pedagogical context, the hypothesis tested, and the configurations of the conversational agents in a pedagogical setting. The databases selected for the survey are presented in

Table 1 Databases used in the search

Database	Source
ACM Digital library	http://portal.acm.org
Elsevier (Science direct)	http://www.sciencedirect.com
ProQuest	https://www.proquest.com/
IEEE xplore	http://ieeexplore.ieee.org
Scopus	http://www.scopus.com
Web of science	https://webofknowledge.com

Table 1, and were selected as they are the most relevant sources for computer-related studies (Dyba et al., 2007; Kitchenham & Charters, 2007).

The search terms were defined in order to ensure that a wide search is conducted to traverse and find studies related to answer the research questions. The primary terms used were "conversational agent" and "pedagogy", and the secondary terms derived therefrom by way of synonyms to ensure coverage of the survey, as illustrated in Table 2.

The search string was created based on Table 2, generated by the databases built in advanced search facility which is based on the conjunction and disjunction connectives of Boolean operators in propositional logic, to ensure synonyms of search terms were included:

("conversational agent" OR chatbot OR "chat bot" OR "virtual agent" OR "virtual assistant" OR chatterbot OR "dialogue system" OR "pedagogical agent") AND (pedagogy OR learn OR pedagogic OR teach OR education OR educate OR "higher education").

Inclusion and exclusion criteria were created as shown in Table 3, in order to ensure that the primary studies found are relevant to the specialism defined, to ensure suitability to the research questions defined, as aforementioned. The criterion created was used by the authors to identify the parameters of the studies found, as a tool to objectify studies to narrow the survey to studies that are reliable and relevant. In order to ensure the survey was inclusive, yet relevant the survey was limited to the period between 2014 and 2022 (including).

It is important to note that while the primary focus of this review is to consider literature that falls within the specific search criteria, additional relevant and important studies that were not identified by the search have been included and considered in the discussion (Sect. "Findings in relation to existing pedagogical agent frameworks") of this study to provide foundational context, and a comprehensive overview where applicable.

Table 2 Search terms

"Conversational agent"	"Pedagogy"
Chatbot	learn
Chat bot	education
Virtual assistant	educate
Pedagogical agent	teach
Virtual agent	pedagogic
Dialogue system	higher education
Chatterbot	

Table 3 Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
1. The study discourses the establishment, application, use and/or evaluation of a conversational agent as a pedagogical tool, to aid and/or support teaching and learning	1. The study is a technical report or a document which is available only in summary format, is a presentation, a call for papers or a summary of a conference
2. The study was conducted between 2014 to 2022 (including)	2. The main language of the study is other than in English
3. The study was conducted within a Higher Education/ University setting	3. The study is not available online, due to a lack of digital indexing by the publisher and/or lack of institutional availability
4. The study was published in either a journal or conference proceeding	

The search and selection of the primary studies, based on the search string defined above was processed in linear stages, which is shown in Fig. 1.

Stage 1. The search was conducted using the Brunel University London's library database search facility, with all the databases listed above selected following the search string aforementioned. This resulted in 5170 initial search results. The high-level metadata of the search results, including the title, summary, discipline, publication date and keywords were scan-surveyed by the authors to eliminate results that were not primary studies, and not related to the subject area being explored, namely pedagogical conversational agents. The matched results were exported into EndNote[1] wherein duplicates were removed. Upon successful completion of this stage, 1448 studies remained.

Stage 2. From the remaining 1448 studies, each study was more carefully analysed using lower-level metadata, including the abstract and publication type to match the studies against the inclusion and exclusion criterion defined (first round), thereafter 484 studies remained.

Stage 3. The authors carefully read, in full, the remaining 484 studies post-stage 2 to analyse whether the study matched the inclusion and exclusion criteria and only studies related to the research area remained. Post-completion of this stage, only 92 studies remained.

Stage 4. The 92 studies that were not excluded in the first three stages of the selection process were analysed and information extracted thereof, such as the data analysis method used, participants included, pedagogical context, technology used for the development, and/or use of a conversational agent for the experimentation, which was mapped in a spreadsheet in order for the review process to take place and conclusions to be derived therefrom, for the purpose of answering the research questions posed.

It must be noted that the selection, extraction, and analysis processes are not an exact science as there are no absolute rules, nor container in the proposed research domain to follow or adhere to, hence the results may have elements of subjective research.

[1] More information about the tool can be obtained at: https://www.endnote.co.uk/

Literature analysis

After analysing and surveying the *literature dataset* identified from deploying the literature search strategy explained above, a thematic analysis of the *literature dataset* was then performed in order perform a categorisation of the studies that were included. Thematic analysis is a qualitative method for searching, identifying, analysing, organising and reporting themes and sub-themes found within a data set (Marks & Yardley, 2004). In order to analyse the *literature dataset*, the following steps were implemented. Firstly, following on from the fourth stage of the literature search strategy as explained above, the *literature spreadsheet* was restructured to ensure that studies were organised in terms of spreadsheet layout and data views, so that the spreadsheet could be used as a data management tool with the aid of Power Query.[2] After the studies were formatted appropriately and the *literature spreadsheet* was ready for analysis, each study was analysed and the educational purpose of the conversational agent was extracted as a set phrase which were created from the number of total extractions minus duplications, which was then recorded and coded as part of the *thematic coding* cycle. There was only one coder involved in the process and therefore interrater reliability consideration was not required. Once all the studies were analysed, the codes were then examined to identify repeated *overarching themes* that emerged from the dataset. Previous research conducted in the realm of pedagogical applications of educational technology, such as the study by Kumar (2021), were used as a basis for ensuring the *overarching themes* related to educational tasks carried out by educational chatbots. The themes identified were recorded in the *literature spreadsheet*, which worked as a *thematic coding* frame for conducting the thematic analysis. This process of finding categorisation themes was iterated four times until finally two *sub-themes* were developed. During this iterative and reflective process, a series of *splitting and joining* the themes, associated phrases and codes was common to ensure the *overarching themes* and *sub-themes* were appropriate, comprehensive, and inclusive of the studies in the *literature dataset*. Any anomalies found (such as where a study would not be identified within a set a theme) or other irregularities and inconsistencies were rectified through *validation*, which ensured that all the studies in the *literature dataset* found a home in each of the thematic layers, finally arriving at a *consensus* pool of *overarching themes* and *sub-themes* that set the foundation on which the findings of this study are based.

Pedagogical AI conversational agents, a conceptual framework

Through the application of thematic analysis of the *literature dataset*, a thematic map consisting of the *consensus* pool of *overarching themes* and *sub-themes* was constructed. The characteristics of AI conversational agents were organised into two overarching themes, namely *pedagogical applications* and *technological functions* of AI conversational agents. A range of sub-themes emerged within each of these two high-level themes. *Pedagogical applications* refer to the educational use and impact of the AI conversational agents on teaching and learning, and relate to the areas of pedagogical psychology and educational methodology, whereas the *technological functions* relate to the technical and

[2] Power Query is a part of Microsoft Excel and allows the import and connection of external data, and has various tools to shape data based on views and queries.

computational abilities of the agents, which relate to the fields of software engineering and computer science. Both of these overarching themes complement each other, as increased technological functions can enable a wider range of pedagogical applications, and more specified pedagogical applications often require more specialised technological functions. The *overarching themes* and *sub-themes* (presented in Sects. "Pedagogical applications" and "Technological functions"), and associated thematic coding frame, served as the foundation for developing the conceptual framework of pedagogical conversational agents. The framework was developed to provide a synthesised visual summary of the full range of themes and sub-themes that emerged from the literature analysis, and in line with (Jabareen, 2009), serves as an interpretative visual representation of how these themes may be organised conceptually. Figure 2 presents the resulting conceptual framework for pedagogical conversational agents. Sects. "Pedagogical applications of conversational agents in higher-education" and "Technological functions of pedagogical conversational agents" (and Tables Table 4-Table 7) provide detailed descriptions, which are mapped to the surveyed literature of the full range of pedagogical applications and technological functions that were identified as a result of the thematic analysis and are subsequently presented in the conceptual framework.

Pedagogical applications

The pedagogic section of the framework presents three tiers of categorisation for the pedagogical functions of conversational agents. The first and highest level of categorisation identified as *pedagogical purposes* is an overarching primary function of pedagogical application, stated as *instructional*, *pastoral* and *cognitive*. Studies of AI conversational agents used for *instruction* aid teaching and learning through instruction or via building on knowledge of core competencies. The students receive some form of instruction from the conversational agent, and therefore are effectively taught artificially. The AI conversational agents categorised within the *pastoral* domain aid educational administration tasks to reduce staff workloads and increase efficiency, or build motivation and/or self-efficacy of students. These students do not necessarily receive instruction from the conversational agent, but rather gain information or motivation through some form of artificial guidance. Finally, the *cognitive* AI conversational agents build the metacognitive functions of students by promoting creative thinking, facilitating experiences or reducing their psychological natural responses.

The second level of categorisation is the *mode of study* which is classified based on the type of delivery style. Upon a review of the studies in the literature dataset, it was evident that each study related to an AI conversational agent being used to aid a programme of study which is delivered by *distance-education*, which includes online, self-study and e-learning delivery modes, or *face-to-face education*, which includes in-person delivery within a classroom or theatre. From the studies reviewed, around half of the conversational agents were used in a *distance-education* programme delivery and the other half were used in a *face-to-face* programme delivery. According to Yarmak et al. (2021), due to the recent global Covid-19 pandemic in 2020, distance education has significantly increased in many higher educational institutes (HEI) and has become the normal standard, and therefore it is possible that future research trends of pedagogical AI conversational agents may be more-so in the domain of *distance-education*, as distance based educational programmes give students' increased accessibility, flexibility and can be cost effective due to a lack of commute. Furthermore, although studies relate to aiding programmes in either of the two

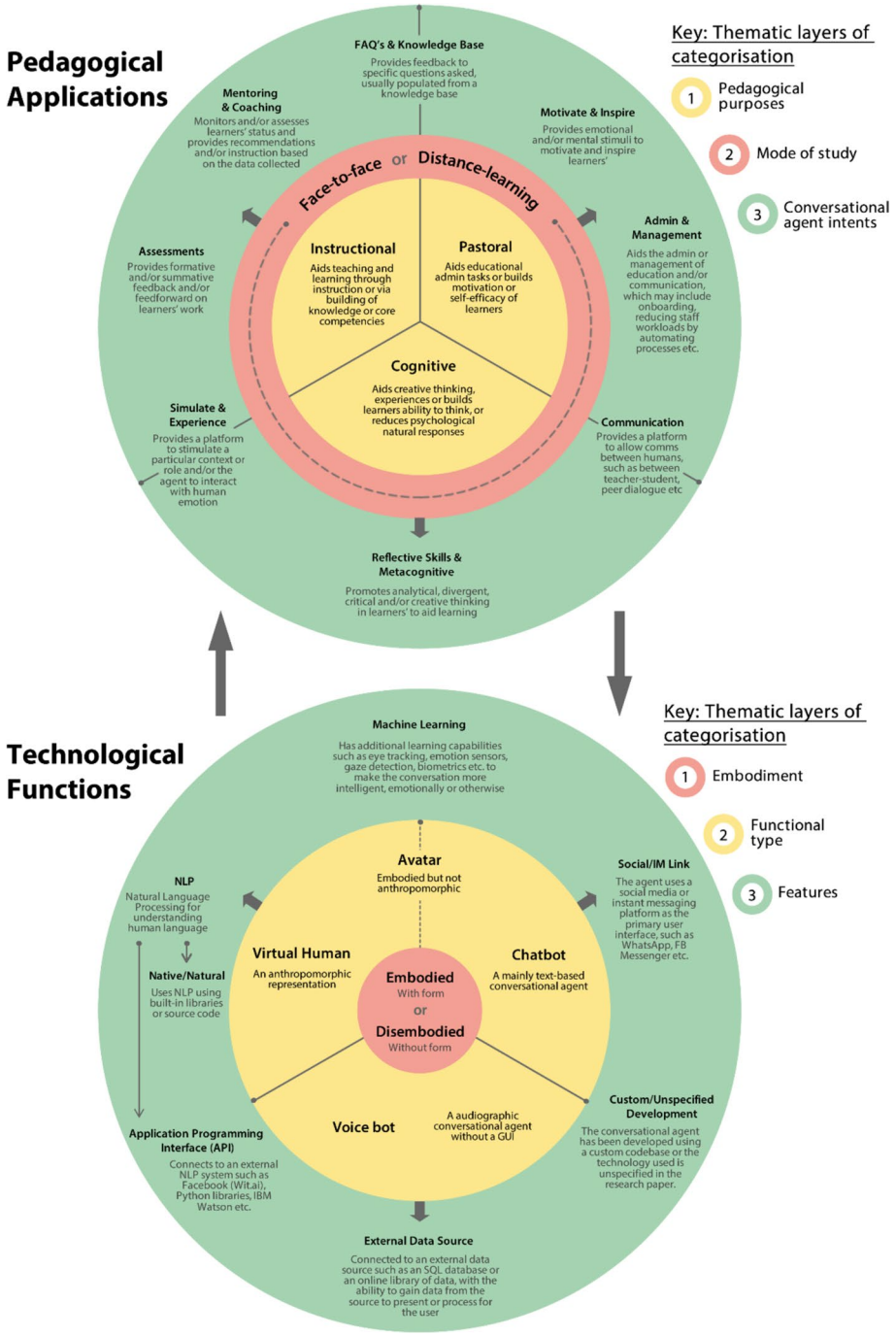


Fig. 2 Conceptual Framework for Pedagogical conversational agents

Table 4 Number of total studies

Thematic layer of categorisation	Descriptor	Number (n) n = 92
Mode of study	Face-to-face	50
	Distance	42
Pedagogical purposes	Cognitive	14
	Pastoral	37
	Instructional	41
Conversational agent intents	FAQ's & knowledge base	14
	Motivate & inspire	17
	Admin & management	3
	Communication	10
	Reflective skills & metacognitive	4
	Simulate & experience	15
	Assessments	3
	Mentoring and coaching	26

modes of delivery, the findings of the studies can be intermingled as the benefit of the experiments are not limited to the mode in which they are placed.

The third and lowest level of categorisation depicted as *conversational agent intents* indicates a deeper and specific pedagogical application, ranging across the various second-level categories. This layer of categorisation includes eight sections; (1) *FAQ's & Knowledge Base* where the conversational agent provides feedback to specific questions asked, usually populated from a knowledge base, (2) *Motivate & Inspire* where the conversational agent provides emotional and/or mental stimuli to motivate and inspire learners', (3) *Admin & Management* where the conversational agent aids the administration or management of education and/or communication, which may include onboarding reducing staff workloads by automating processes etc., (4) *Communication* where the conversational agent provides a platform to allow communication, such as between teacher-student, peer dialogue etc., (5) *Reflective Skills & Metacognitive* where the conversational agent promotes analytical, divergent, critical and/or creative thinking in learners' to aid learning, (6) *Simulate & Experience* where the conversational agent provides a platform to stimulate a particular context or role and/or the agent to interact with human emotion to some degree, for example as a patient in healthcare education, (7) *Assessments* where the conversational agent provides formative and/or summative feedback and/or feedforward on learners' work, and (8) *Mentoring & Coaching* where the conversational agent monitors and/or assesses learners' status and provides recommendations and/or instruction based on the data collected (e.g. counselling, teaching etc.).

Technological functions

Similar to the pedagogic applications mentioned in Sect. "Pedagogical applications", the technological section of the framework also presents three tiers of thematic categorisation. The first and highest level of categorisation is *embodiment*, in which every AI conversational agent is labelled as either *embodied*, wherein the agent has some degree of visual or

humanistic form, or *disembodied*, in which the agent is command line or text based, without visual form.

The second level of categorisation identified as *functional type* relates to the specific type of AI conversational agent design, in terms of its aesthetic interface, which can be *virtual human* which is an anthropomorphic representation, *avatar* which is an embodied creature but not completely anthropomorphic or human-like, *chatbot* which is a text based communicational agent, or *voice bot* which is an audio based agent, allowing only verbal communication or dialogue, without a graphical user interface.

The third and lowest level of categorisation depicted as *features* indicates the implementation of a specific type of technology. This layer of categorisation includes five sections; (1) *Machine Learning*, wherein the AI conversational agent has additional learning capabilities such as eye tracking, emotion sensors, gaze detection, biometrics etc. to make the conversation more intelligent, emotionally, or otherwise, (2) *Social/IM Link* which uses a social media or instant messaging (IM) platform as the primary user interface, such as WhatsApp, FB Messenger etc., (3) *External Data Source*, wherein the agent is connected to an external data source such as an SQL database or an online library of data, with the ability to gain data from the source to present or process for the user, (4) *Natural Language Processing* (NLP) for understanding human language, which can have two sub-categories, firstly *Application Programming Interface* (API) wherein the agent connects to an external NLP system such as Facebook (Wit.ai), Python libraries, IBM Watson etc. and secondly *Native/Natural* NLP wherein the agent uses NLP using built-in libraries or source code, and lastly (5) *Custom/Unspecified Development* wherein the conversational agent has been developed using a custom codebase, or that the technology used is unspecified in the study.

The following Sect. "Pedagogical applications of conversational agents in higher-education" presents an overview solely of the pedagogical applications of AI conversational agents and Sect. "Technological functions of pedagogical conversational agents" presents their technological functions.

Pedagogical applications of conversational agents in higher-education

In this study, the literature plays a pivotal role in delineating the various categories within the conceptual framework, which are developed from the themes and sub-themes that emerged as part of the thematic analysis. This section presents a detailed walkthrough of how the literature defines the various categories and aspects of the conceptual framework, through giving examples and showcasing how the literature shaped and contributed to the development of the conceptual framework. Table 4 below shows a breakdown of the number of studies considered for this research.

The overview presented in this section has been sorted by the first-level thematic categorisation of *pedagogical purposes* and contains only an analysis of the pedagogical applications of AI conversational agents, as the technological functions are analysed in Sect. "Technological functions of pedagogical conversational agents".

Cognitive agents

Cognitive agents build the metacognitive functions of the students by promoting creative thinking, giving experiences or reducing the psychological natural responses. Being the smallest sample in this research, it has been the first explained. Table 5 below presents an

Table 5 Cognitive agents

Cognitive agents	Pedagogical apps					Technological functions							
Thematic level of categorisation	Mode of study		Conversational agent intents			Embodiment		Functional type	Features				
Citation *Key: Virtual human (Vh), Avatar (Av), Chatbot (Cb) or Voice bot (Vb)	Face-to-face	Distance-education	Communication	Reflective skills & metacognitive	Simulate & experience	Embodied	Disembodied	Type of agent*	Social/IM link	NLP	Machine learning	External data source	Custom/unspecific dev
Number (n)	8	6	3	4	7	4	10	–	1	7	2	4	4
Hamzah et al. (2021)		x	x				x	Cb	x	x			
Bhartiya et al. (2019)		x		x			x	Cb	x	x			x
Chang et al. (2022)		x		x			x	Cb					x
Hsu et al. (2021)	x				x		x	Cb				x	
Jin et al. (2019)	x				x	x		Vh				x	
Lee et al. (2015)	x				x	x		Av			x		

Table 5 (continued)

Cognitive agents	Pedagogical apps					Technological functions							
Thematic level of categorisation	Mode of study		Conversational agent intents			Embodiment		Functional type	Features				
Citation *Key: Virtual human (Vh), Avatar (Av), Chatbot (Cb) or Voice bot (Vb)	Face-to-face	Distance-education	Communication	Reflective skills & metacognitive	Simulate & experience	Embodied	Disembodied	Type of agent*	Social/IM link	NLP	Machine learning	External data source	Custom/unspecific dev
Morris and Chen (2021)	x				x		x	Vb		x			
Morris and Chen (2020)	x				x		x	Vb		x			
Ralston et al. (2019)		x	x				x	Cb		x			
Song et al. (2017)		x	x				x	Cb				x	
Trappey et al. (2022)	x				x		x	Cb		x	x		
Wang et al. (2021)	x				x	x		Vh					x

Table 5 (continued)

Cognitive agents	Pedagogical apps					Technological functions							
Thematic level of categorisation	Mode of study		Conversational agent intents			Embodiment		Functional type	Features				
Citation *Key: Virtual human (Vh), Avatar (Av), Chatbot (Cb) or Voice bot (Vb)	Face-to-face	Distance-education	Communication	Reflective skills & metacognitive	Simulate & experience	Embodied	Disembodied	Type of agent*	Social/IM link	NLP	Machine learning	External data source	Custom/unspecific dev
Xiao et al. (2019)		x		x			x	Cb				x	x
Yılmaz et al. (2018)	x			x		x		Av		x			

overview of the AI conversational agents that have been categorised within the *Cognitive* agents' pedagogical purpose.

In terms of *mode of study*, these agents tend to be deployed as face-to-face systems. For example, the study by Hsu et al. (2021) uses an agent to compliment language education and increase scores in an in-class test. The research by Lee et al. (2015) tests the use of an AI conversational agent with a group in live sessions and Wang et al. (2021) experiments the use of an agent in undergraduate multimedia sessions. Agents used for *distance-education* tend to be chatbots that are aimed at increasing student satisfaction through the promotion of student engagement (Bhartiya et al., 2019; Chang et al., 2022; Ralston et al., 2019; Xiao et al., 2019).

Regarding *conversational agent intents,* the majority agents tend to have intents focused on the *simulate and experience* category (Hsu et al., 2021; Jin et al., 2019; Lee et al., 2015; Morris & Chen, 2020, 2021; Trappey et al., 2022; Wang et al., 2021). Within the *simulate and experience* label, all the conversational agents are used for *face-to-face* educational programmes, with the aim of providing context to education for an improved student experience. For example, the study by Jin et al. (2019) improves the student experience by reducing learners' shyness, and the study by Hsu et al. (2021) improves the student experience by providing a learning practice platform.

The studies labelled under *reflective skills and metacognitive* (Bhartiya et al., 2019; Chang et al., 2022; Xiao et al., 2019; Yılmaz et al., 2018) tend to also be applied to programmes categorised as *distance-education*, however some studies in this domain are also applied in *face-to-face* contexts. The aim of the conversational agents within this category is to promote thinking skills and reflection to ultimately build student self-efficacy and satisfaction. For example, the study by Chang et al. (2022) promoted learners to think deeply about the impact of their learning in healthcare to patient's needs.

Within the categorisation label *communication*, the agents are all used for *distance-education*, due to their ability to increase the level of interaction between individuals for remote education and e-learning, whereas generally, such communication is naturally occurring in face-to-face education (Hamzah et al., 2021; Ralston et al., 2019; Song et al., 2017). For example, the study conducted by Song et al. (2017) promotes learners meaningful interaction through the use of conversational agents in online courses to graduate-level students. The primary aim of the studies under the *communication* label is to promote participation and/or interaction of students through engagement with the conversational agent.

Cognitive AI conversational agents also have various technological functions, which are explored and analysed in Sect. "Technological functions of pedagogical conversational agents".

Instructional agents

Studies of conversational agents used for *Instruction* aid teaching and learning through instruction or via building on knowledge of core competencies. Table 6 shows a breakdown of the *instructional* studies considered in this research.

Regarding the *mode of study*, the majority of studied are categorised as *face-to-face* which could be due to the nature of instruction in traditional HEI's. Due to the uptake of *distance-education* programmes by HEI's, which has seen accelerated growth due to the coronavirus pandemic as mentioned in Sect. "Pedagogical applications", the number of *distance-education* AI conversational agents within the *instructional* category is likely to increase in the future.

Table 6 Instructional agents

Instructional agents	Pedagogical apps						Technological functions							
Thematic level of categorisation	Mode of study		Conversational agent intents				Embodiment		Functional type	Features				
Citation *Key: Virtual human (Vh), Avatar (Av), Chatbot (Cb) or Voice bot (Vb)	Face-to-face	Distance-education	FAQs & knowledge base	Simulate & experience	Assessments	Mentoring and coaching	Embodied	Disembodied	Type of agent*	Social / IM link	NLP	Machine learning	External data source	Custom/ unspecific dev
Number (n)	26	15	4	8	3	26	18	23	–	3	20	6	12	13
Aguilar-Mejia and Tejeda (2020)	x					x		x	Cb			x		
Asquer and Krachkovskaya (2022)		x				x		x	Cb					x

Table 6 (continued)

Instructional agents	Pedagogical apps						Technological functions							
Thematic level of categorisation	Mode of study		Conversational agent intents				Embodiment		Functional type	Features				
Citation *Key: Virtual human (Vh), Avatar (Av), Chatbot (Cb) or Voice bot (Vb)	Face-to-face	Distance-education	FAQs & knowledge base	Simulate & experience	Assessments	Mentoring and coaching	Embodied	Disembodied	Type of agent*	Social / IM link	NLP	Machine learning	External data source	Custom/ unspecific dev
Ba et al. (2021)	x					x	x		Vh					x
Bickmore et al. (2016)	x			x			x		Vh					x
Briel (2021)		x	x					x	Cb		x	x		
Campillos-Llanos et al. (2021)	x			x			x		Vh		x		x	

Table 6 (continued)

Instructional agents	Pedagogical apps						Technological functions							
Thematic level of categorisation	Mode of study		Conversational agent intents				Embodiment		Functional type	Features				
Citation *Key: Virtual human (Vh), Avatar (Av), Chatbot (Cb) or Voice bot (Vb)	Face-to-face	Distance-education	FAQs & knowledge base	Simulate & experience	Assessments	Mentoring and coaching	Embodied	Disembodied	Type of agent*	Social / IM link	NLP	Machine learning	External data source	Custom/ unspecific dev
Vázquez-Cano et al. (2021)		x				x		x	Cb		x			
Chang et al. (2021)	x			x				x	Cb				x	x
Chen et al. (2022)	x					x		x	Cb		x			
Maicher et al. (2017)	x			x			x		Vh		x			

Table 6 (continued)

Instructional agents	Pedagogical apps						Technological functions						
Thematic level of categorisation	Mode of study		Conversational agent intents				Embodiment		Functional type	Features			
Citation *Key: Virtual human (Vh), Avatar (Av), Chatbot (Cb) or Voice bot (Vb)	Face-to-face	Distance-education	FAQs & knowledge base	Simulate & experience	Assessments	Mentoring and coaching	Embodied	Disembodied	Type of agent*	Social / IM link	NLP	Machine learning	External data source	Custom/ unspecific dev
Gonda and Chu (2019)	x		x					x	Cb		x		x	
Gonda et al. (2018)	x				x			x	Cb		x			
González et al. (2022)	x		x					x	Cb				x	x
Gupta and Chen (2022)	x					x		x	Cb		x			

Table 6 (continued)

Instructional agents	Pedagogical apps						Technological functions							
Thematic level of categorisation	Mode of study		Conversational agent intents				Embodiment		Functional type	Features				
Citation *Key: Virtual human (Vh), Avatar (Av), Chatbot (Cb) or Voice bot (Vb)	Face-to-face	Distance-education	FAQs & knowledge base	Simulate & experience	Assessments	Mentoring and coaching	Embodied	Disembodied	Type of agent*	Social / IM link	NLP	Machine learning	External data source	Custom/ unspecific dev
Halan et al. (2014)	x			x			x		Vh					x
Jha et al. (2020)		x				x	x		Vh		x	x		
Kaur et al. (2021)	x			x				x	Cb					x
Lahav et al. (2020)		x				x	x		Vh			x		x

Table 6 (continued)

Instructional agents	Pedagogical apps						Technological functions						
Thematic level of categorisation	Mode of study		Conversational agent intents				Embodiment		Functional type	Features			
Citation *Key: Virtual human (Vh), Avatar (Av), Chatbot (Cb) or Voice bot (Vb)	Face-to-face	Distance-education	FAQs & knowledge base	Simulate & experience	Assessments	Mentoring and coaching	Embodied	Disembodied	Type of agent*	Social / IM link	NLP	Machine learning	External data source	Custom/ unspecific dev
Latorre-Navarro and Harris (2015)		x				x		x	Cb		x		x	
Lee and Fu (2019)	x				x			x	Cb	x				
Li et al. (2020)	x					x		x	Cb		x		x	
Li et al. (2021)	x					x		x	Cb				x	x

Table 6 (continued)

Instructional agents	Pedagogical apps						Technological functions							
Thematic level of categorisation	Mode of study		Conversational agent intents				Embodiment		Functional type	Features				
Citation *Key: Virtual human (Vh), Avatar (Av), Chatbot (Cb) or Voice bot (Vb)	Face-to-face	Distance-education	FAQs & knowledge base	Simulate & experience	Assessments	Mentoring and coaching	Embodied	Disembodied	Type of agent*	Social / IM link	NLP	Machine learning	External data source	Custom/ unspecific dev
Lin et al. (2020)	x					x	x		Cb		x			x
Maryadi et al. (2017)		x			x		x		Vh		x			
Mokmin and Ibrahim (2021)		x	x					x	Cb	x				
Moon and Ryu (2021)	x			x			x		Vh			x		

Table 6 (continued)

Instructional agents	Pedagogical apps						Technological functions							
Thematic level of categorisation	Mode of study		Conversational agent intents				Embodiment		Functional type	Features				
Citation *Key: Virtual human (Vh), Avatar (Av), Chatbot (Cb) or Voice bot (Vb)	Face-to-face	Distance-education	FAQs & knowledge base	Simulate & experience	Assessments	Mentoring and coaching	Embodied	Disembodied	Type of agent*	Social / IM link	NLP	Machine learning	External data source	Custom/ unspecific dev
Neumann et al. (2021)		x				x		x	Cb				x	
Nguyen et al. (2021)		x				x		x	Cb			x		
Resch and Yankova (2019)		x				x		x	Cb	x				
Rodríguez et al. (2021)	x					x	x		Vh		x			

Table 6 (continued)

Instructional agents	Pedagogical apps						Technological functions							
Thematic level of categorisation	Mode of study		Conversational agent intents				Embodiment		Functional type	Features				
Citation *Key: Virtual human (Vh), Avatar (Av), Chatbot (Cb) or Voice bot (Vb)	Face-to-face	Distance-education	FAQs & knowledge base	Simulate & experience	Assessments	Mentoring and coaching	Embodied	Disembodied	Type of agent*	Social / IM link	NLP	Machine learning	External data source	Custom/ unspecific dev
Scholten et al. (2019)		x				x	x		Av					x
Schroeder and Craig (2017)	x					x	x		Vh					x
Shorey et al. (2019)	x			x			x		Av		x			
Song and Kim (2020)		x				x		x	Cb		x			

Table 6 (continued)

Instructional agents	Pedagogical apps						Technological functions							
Thematic level of categorisation	Mode of study		Conversational agent intents				Embodiment		Functional type	Features				
Citation *Key: Virtual human (Vh), Avatar (Av), Chatbot (Cb) or Voice bot (Vb)	Face-to-face	Distance-education	FAQs & knowledge base	Simulate & experience	Assessments	Mentoring and coaching	Embodied	Disembodied	Type of agent*	Social / IM link	NLP	Machine learning	External data source	Custom/ unspecific dev
Tamayo et al. (2019)		x				x		x	Cb					x
Tan et al. (2021)	x					x		x	Cb					x
Tegos et al. (2016)	x					x	x		Av		x		x	
Tegos et al. (2015)	x					x	x		Av		x		x	

Table 6 (continued)

Instructional agents	Pedagogical apps						Technological functions						
Thematic level of categorisation	Mode of study		Conversational agent intents				Embodiment		Functional type	Features			
Citation *Key: Virtual human (Vh), Avatar (Av), Chatbot (Cb) or Voice bot (Vb)	Face-to-face	Distance-education	FAQs & knowledge base	Simulate & experience	Assessments	Mentoring and coaching	Embodied	Disembodied	Type of agent*	Social / IM link	NLP	Machine learning	External data source	Custom/ unspecific dev
Tegos et al. (2014)	x					x	x		Av		x		x	
Winkler et al. (2020)		x				x		x	Cb		x			
Yilmaz and Yilmaz (2020)	x					x	x		Av				x	

In terms of the *conversational agent intents*, the largest category to be explored by researchers is *mentoring and coaching* (n = 26, 28%). All the studies within this area aim to provide teaching and learning to some degree, either by direct instruction, aid in mentoring/coaching or encouraging students to explore topics, and agents can be used in both *distance-education* (n = 12/26, 46%) and *face-to-face* education (n = 14/26, 54%) (Aguilar-Mejia & Tejeda, 2020; Asquer & Krachkovskaya, 2022; Ba et al., 2021; Chen et al., 2022; Gupta & Chen, 2022; Jha et al., 2020; Lahav et al., 2020; Latorre-Navarro & Harris, 2015; Li et al., 2020, 2021; Lin et al., 2020; Neumann et al., 2021; Nguyen et al., 2021; Resch & Yankova, 2019; Rodríguez et al., 2021; Scholten et al., 2019; Schroeder & Craig, 2017; Song & Kim, 2020; Tamayo et al., 2019; Tan et al., 2021; Tegos et al., 2014, 2015, 2016; Vázquez-Cano et al., 2021; Winkler et al., 2020; Yilmaz & Yilmaz, 2020). For example, the study by Aguilar-Mejia and Tejeda (2020) uses an agent to increase the conceptual understanding of topics, the study by Asquer and Krachkovskaya (2022) uses an agent to mentor students' on a particular case study within their curriculum, the study by Jha et al. (2020) uses an agent to act as a student support mentor, the study by Lin et al. (2020) uses an agent to instruct learners.

Similar to the *cognitive* high-level category, the conversational agents within the high-level *instructional* category labelled as *simulate and experience* are also used for *face-to-face* educational programmes, however they are used for an instructional teaching and learning purpose to build student knowledge, as opposed to the *cognitive* high-level category wherein they are assisting the cognitive functions of students, such as psychological improvements (Bickmore et al., 2016; Campillos-Llanos et al., 2021; Chang et al., 2021; Halan et al., 2014; Kaur et al., 2021; Maicher et al., 2017; Moon & Ryu, 2021; Shorey et al., 2019). Most studies within this label are used in healthcare-based education programmes, and are medical technology (MedTech) based research studies. For example, the study by Bickmore et al. (2016) uses an embodied conversational agent as co-presenter in a classroom setting, the study by Halan et al. (2014) and Campillos-Llanos et al. (2021) use an embodied agent to roleplay a patient in healthcare education, the study by Chang et al. (2021) use an agent to provide instruction in learning human anatomy by creating new experiences in nursing education, and the study by Shorey et al. (2019) uses an agent to provide a platform for students to practice counselling skills in nursing education.

Within the *FAQ's and knowledge base* category, all conversational agents aim to increase student participation by answering student queries, and are used in both *distance-education* and *face-to-face* education (Briel, 2021; Gonda & Chu, 2019; González et al., 2022; Mokmin & Ibrahim, 2021). For example, the studies by Gonda and Chu (2019), González et al. (2022) and Mokmin and Ibrahim (2021) use a simple rule-based conversational agent as a teaching assistant to answer students' questions.

Finally, the studies that fall in the remit of the *assessment* category explore a conversational agent for assessing learners work, either on an individual level or in groupwork (Gonda et al., 2018; Lee & Fu, 2019; Maryadi et al., 2017). The aim of the agent is to provide feedback to learners, as can be observed in the study by Maryadi et al. (2017) which uses a conversational agent to provide automatised and personalised feedback on students' work, and the study by Lee and Fu (2019) which uses a conversational agent to support peer assessment. Studies within this domain tend to vary in agent type and mode of study, and is not as explored as other categorisations within the framework hence a smaller sample.

Instructional AI conversational agents also have various technological functions, which are presented in detail in Sect. "Technological functions of pedagogical conversational agents".

Pastoral agents

The conversational agents categorised within the *Pastoral* domain aid educational administration tasks to reduce workloads and increase efficiency or build motivation and/or self-efficacy of students.

Concerning the *mode of study* categorisation, most agents within the pastoral group are labelled as *distance-education*, which shows a contrasting overview to the *instructional* group, mainly since *pastoral* AI conversational agents supplement and support teaching and learning as opposed to direct in-class instruction. For example, the study by Gunadi et al. (2019) utilises a virtual assistant to collect responses from prospective new students following an orientation event, Table 7 shows a breakdown of the *pastoral* studies considered in this research.

Concerning the *mode of study* categorisation, most agents within the pastoral group are labelled as *distance-education*, which shows a contrasting overview to the *instructional* group, mainly since *pastoral* AI conversational agents supplement and support teaching and learning as opposed to direct in-class instruction. For example, the study by Gunadi et al. (2019) utilises a virtual assistant to collect responses from prospective new students following an orientation event, and the study by Lee et al. (2020) makes use of an agent to act as an online tutor.

In terms of the *conversational agent intents*, the largest category to be explored by researchers is *Motivate & Inspire* label, wherein most conversational agents (n = 13/17, 76%) are used within *face-to-face* education programmes while some (n = 4/17, 23%) are used in *distance-learning* programmes (Ayedoun et al., 2019; Ceha et al., 2021; Feng et al., 2017; Fidan & Gencel, 2022; Krämer et al., 2016; Kumar, 2021; Liew & Tan, 2016; Liew et al., 2017; Nelekar et al., 2022; Paschoal et al., 2018; Ramachandiran et al., 2019; Shiban et al., 2015; Tan et al., 2020; Tanaka et al., 2020; Valdivieso & Luzón, 2021; Xie et al., 2021; Yin et al., 2021). All the agents used within the studies aim to build the level of motivation and self-efficacy of students by inspiring and/or prompting them to learn, participate and engage in some form of educational activity. The agents within this category tend to have anthropomorphic aesthetic characteristics. The study by Ayedoun et al. (2019) uses a conversational agent to motivate second language learners to engage with learning languages, the research by Ceha et al. (2021) uses an agent to inspire students through fun and humour, the study by Fidan and Gencel (2022) uses an agent that has peer feedback mechanisms to intrinsically motivate students, the study by Nelekar et al. (2022) uses an agent to motivate students by reducing stress for foreign students, the study by Paschoal et al. (2018) uses an agent to inspire students by acting as a study aid and the research by Xie et al. (2021) uses a conversational agent to motivate distance learning students by engaging them in collaborative learning activities.

Similar to the *Cognitive* high-level category, the conversational agents within the high-level *Pastoral* category labelled as *Communication* are also used for *distance-learning* programmes, however they are used for pastoral support purposes to aid the learning process by engaging students, as opposed to the *Cognitive* high-level category wherein they are used as a tool for interaction between students (Abbas et al., 2022; Belhaj et al., 2021; Carayannopoulos, 2018; Dibitonto et al., 2018; Gaglio et al., 2019; Lee et al., 2021; Wang et al., 2020). For example, the study by Abbas et al. (2022) and Carayannopoulos (2018) use conversational agents to communicate with new students transitioning into their first year of higher education, to engage and support

Table 7 Pastoral agents

Pastoral agents	Pedagogical apps						Technological functions							
Thematic level of categorisation	Mode of study		Conversational agent intents				Embodiment		Functional type	Features				
Citation *Key: Virtual human (Vh), Avatar (Av), Chatbot (Cb) or Voice bot (Vb)	Face-to-face	Distance-education	FAQs & knowledge base	Motivate & inspire	Admin & management	Communication	Embodied	Disembodied	Type of agent*	Social / IM Link	NLP	Machine learning	External data source	Custom/ unspecific dev
Number (n)	16	21	10	17	3	7	13	24	–	7	18	6	4	8
Ayedoun et al. (2019)	x			x			x		Vh		x	x		
Carlos et al. (2021)		x	x					x	Cb	x				
Valdivieso and Luzón (2021)	x			x				x	Cb				x	
Ceha et al. (2021)	x			x				x	Cb		x			
Feng et al. (2017)	x			x			x		Vh			x		

Table 7 (continued)

Pastoral agents	Pedagogical apps						Technological functions							
Thematic level of categorisation	Mode of study		Conversational agent intents				Embodiment		Functional type	Features				
Citation *Key: Virtual human (Vh), Avatar (Av), Chatbot (Cb) or Voice bot (Vb)	Face-to-face	Distance-education	FAQs & knowledge base	Motivate & inspire	Admin & management	Communication	Embodied	Disembodied	Type of agent*	Social / IM Link	NLP	Machine learning	External data source	Custom/ unspecific dev
Mikic-Fonte et al. (2018)	x		x					x	Cb				x	
Fidan and Gencel (2022)		x		x				x	Cb		x			
Gunadi et al. (2019)		x	x					x	Cb					x
Gonçalves et al. (2022)		x	x					x	Cb		x			x
Hayashi (2020)	x				x		x		Av			x		

Table 7 (continued)

Pastoral agents	Pedagogical apps						Technological functions							
Thematic level of categorisation	Mode of study		Conversational agent intents				Embodiment		Functional type	Features				
Citation *Key: Virtual human (Vh), Avatar (Av), Chatbot (Cb) or Voice bot (Vb)	Face-to-face	Distance-education	FAQs & knowledge base	Motivate & inspire	Admin & management	Communication	Embodied	Disembodied	Type of agent*	Social / IM Link	NLP	Machine learning	External data source	Custom/ unspecific dev
Hien et al. (2018)		x	x					x	Cb	x				
Ismail and Ade-Ibijola (2019)		x	x					x	Cb		x			
Krämer et al. (2016)	x			x			x		Vh					x
Kumar (2021)	x			x				x	Cb		x			
Lee et al. (2021)		x				x	x		Vh			x		
Lee et al. (2020)		x	x					x	Cb		x			

Table 7 (continued)

Pastoral agents	Pedagogical apps						Technological functions							
Thematic level of categorisation	Mode of study		Conversational agent intents				Embodiment		Functional type	Features				
Citation *Key: Virtual human (Vh), Avatar (Av), Chatbot (Cb) or Voice bot (Vb)	Face-to-face	Distance-education	FAQs & knowledge base	Motivate & inspire	Admin & management	Communication	Embodied	Disembodied	Type of agent*	Social / IM Link	NLP	Machine learning	External data source	Custom/ unspecific dev
Liew and Tan (2016)		x		x			x		Vh		x			
Liew et al. (2017)	x			x			x		Vh		x			x
Dibitonto et al. (2018)		x				x		x	Cb	x				
Zubani et al. (2022)		x	x					x	Cb		x			
Belhaj et al. (2021)		x				x		x	Cb	x				
Nelekar et al. (2022)	x			x			x		Vh			x		

Table 7 (continued)

Pastoral agents	Pedagogical apps						Technological functions							
Thematic level of categorisation	Mode of study		Conversational agent intents				Embodiment		Functional type	Features				
Citation *Key: Virtual human (Vh), Avatar (Av), Chatbot (Cb) or Voice bot (Vb)	Face-to-face	Distance-education	FAQs & knowledge base	Motivate & inspire	Admin & management	Communication	Embodied	Disembodied	Type of agent*	Social / IM Link	NLP	Machine learning	External data source	Custom/ unspecific dev
Abbas et al. (2022)		x				x		x	Cb		x			
Paschoal et al. (2018)	x			x				x	Cb				x	
Ramachandiran et al. (2019)		x		x			x		Vh			x		
Gaglio et al. (2019)		x				x		x	Cb		x			
Shiban et al. (2015)	x			x			x		Vh					x

Table 7 (continued)

Pastoral agents	Pedagogical apps						Technological functions							
Thematic level of categorisation	Mode of study		Conversational agent intents				Embodiment		Functional type	Features				
Citation *Key: Virtual human (Vh), Avatar (Av), Chatbot (Cb) or Voice bot (Vb)	Face-to-face	Distance-education	FAQs & knowledge base	Motivate & inspire	Admin & management	Communication	Embodied	Disembodied	Type of agent*	Social / IM Link	NLP	Machine learning	External data source	Custom/ unspecific dev
Singh et al. (2019)		x	x					x	Cb	x				
Carayannopoulos (2018)		x				x		x	Cb	x				
Tegos et al. (2021)		x			x			x	Cb		x		x	
Tan et al. (2020)		x		x			x		Vh		x			x
Tanaka et al. (2020)	x			x			x		Av		x			x
Wambsganss et al. (2020)	x				x			x	Cb		x			

Table 7 (continued)

Pastoral agents	Pedagogical apps						Technological functions							
Thematic level of categorisation	Mode of study		Conversational agent intents				Embodiment		Functional type	Features				
Citation *Key: Virtual human (Vh), Avatar (Av), Chatbot (Cb) or Voice bot (Vb)	Face-to-face	Distance-education	FAQs & knowledge base	Motivate & inspire	Admin & management	Communication	Embodied	Disembodied	Type of agent*	Social / IM Link	NLP	Machine learning	External data source	Custom/ unspecific dev
Wang et al. (2020)		x				x	x		Vh		x			
Villegas-Ch et al. (2021)		x	x					x	Cb	x				
Xie et al. (2021)	x			x				x	Cb		x			
Yin et al. (2021)	x			x				x	Cb					x

their learning, the study by Belhaj et al. (2021) uses an agent to communicate with and engage students in completing surveys that provide feedback on their learning experiences, and the research by Gaglio et al. (2019) uses a conversational agent to communicate effectively for students living on a university-campus.

Furthermore, similar to the *Instructional* high-level category, the conversational agents within the high-level *Pastoral* category labelled as *FAQ & Knowledge Base* are mostly used for *distance-learning* programmes (n = 9/10, 90%) to aid student learning and/or act as a student support mechanism, as opposed to the *Instructional* high-level category wherein they are used as a tool for increasing student participation by answering student queries (Carlos et al., 2021; Gonçalves et al., 2022; Gunadi et al., 2019; Hien et al., 2018; Ismail & Ade-Ibijola, 2019; Lee et al., 2020; Mikic-Fonte et al., 2018; Singh et al., 2019; Villegas-Ch et al., 2021; Zubani et al., 2022). The studies by Carlos et al. (2021), Gunadi et al. (2019) and Ismail and Ade-Ibijola (2019) use conversational agents as a personal assistant to answer student questions with the aim of supporting learning, the research by Lee et al. uses an agent to answer student queries in the form of an online constantly-available tutor to support learners and the study by Zubani et al. (2022) uses a conversational agent to support students using pre-defined answers relating to a subject in a knowledge base to answer student queries, which it understands through deep natural language processing.

Conversational agents within the *Admin & Management* category have been used for both *face-to-face* and *distance-education* programmes for the purpose of administering or managing the education process (Hayashi, 2020; Tegos et al., 2021; Wambsganss et al., 2020). For example, the studies by Tegos et al. (2021) and Hayashi (2020) use conversational agents to facilitate and manage peer-collaboration on behalf of faculty staff, and the study by Wambsganss et al. (2020) uses an agent to gain course feedback from students post completion, to evaluate the effectiveness of the course in replacement of standard module evaluation questionnaires (MEQ).[3] Although this low-level category is less explored within the criterion set in Table 3, with the prevalence of home working for many staff within the higher education sector, especially within the professional and support workforce in HEI's post the Covid-19 pandemic, it is possible that in subsequent years more research will be conducted within this category.

Pastoral AI conversational agents also have various technological functions, which are presented in detail in Sect. "Technological functions of pedagogical conversational agents".

Technological functions of pedagogical conversational agents

Conversational agents used for pedagogical purposes in higher education come in many forms as discussed in Sect. "Pedagogical applications of conversational agents in higher-education", but also come with various technological features and functions which can vary, such as the ability to connect to external data sources, machine learning capabilities. It is important to discuss the technological functions when discussing educational and pedagogical conversational agents because these functions determine the capabilities and limitations of the agent. Furthermore, the technological functions also impact the user experience, which is a critical factor in determining the success of educational conversational agents. This section is based on the results of the dataset aforementioned

[3] Typical feedback surveys provided to students in higher education.

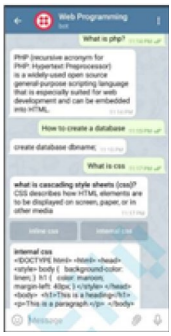
as part of the survey and focuses on the technological features and functionality of conversational agents used in higher education. The secondary and lower part of the conceptual model in Fig. 2 shows a diagrammatic overview of the technological functions of pedagogical conversation agents.

Embodiment

The highest-level categorisation of the technological functions is the cyber-physical and visual embodiment of the conversational agents which, based on the thematic analysis conducted, has been classified as *embodied* and *disembodied*. An example of an *embodied* and a *disembodied* agent can be seen in Fig. 3.

Every pedagogical agent analysed within the remit of this survey can be considered within the construct of embodiment. This research has adopted the view stipulated by Ziemke (2023) which posits that *embodied* conversational agents have *"organismic"* and physical attributes which make them anthropomorphic based on their visual aesthetic and/or ability of interaction with users, such is the study by Ayedoun et al. (2019) which presents a conversational agent that is life-like, as shown in Fig. 3. As is evident from this example study, the conversational agent is developed to impersonate a human being for the purpose of emotional reassurance to the user, as is the primary objective of embodiment. *Disembodied* conversational agents generally lack bodily form and thus, are centred on a text-based graphical user interface. Such conversational agents are more common in pedagogical contexts due to being easier to develop, requiring less visual programming expertise and computational power for rendering media outputs. The lack of a humanoid figure does not necessarily mean lack of emotional intelligence in the agent, for example the study by Chen et al. (2022) presents a *disembodied* conversational agent that uses intelligent questioning and natural language processing (NLP) algorithms to identify user intentions which can gather user data for the purpose of emotionally engaging students. The distinction of embodiment is vital to consider as a high-level theme in terms of technological functionality as both notions have various differing conversational types, linked to further features.

(a) Embodied agent



(b) Disembodied agent

Fig. 3 **a**: example of embodied agent (Ayedoun et al., 2019), **b**: example of disembodied agent (Hamzah et al., 2021)

Table 8 Identified functional types of agents

Short code	Type	Number (n)
Cb	Chatbot	56
Vh	Virtual human	24
Av	Avatar	10
Vb	Voice bot	2

Functional type

Further to the consideration of embodiment, the second-level categorisation of technological functions is the *functional type*. Pedagogical agents come in many forms, each with differing technological characteristics. From the survey conducted as part of this research, the types of conversational agents identified include *virtual humans*, *avatars*, *chatbots* and *voice bots*, as shown in Table 8.

Virtual human conversational agents are always *embodied* agents and span over all three pedagogical purposes (*cognitive*, *instructional* and *pastoral*). For example, the instructional study by Halan et al. (2014) uses a *virtual human* agent to act as a patient in healthcare education, for medical students to assess and find a diagnosis. Most *virtual human* agents are developed using powerful graphical rendering software such as iClone, Unity, Unreal, Media Semantics, Flash etc. which is common in video game development, and then linked to an algorithmic programming sequence to enable conversation, such as in Node.js (Ayedoun et al., 2019). Some are then then linked to external NLP systems via API's such as DialogFlow (Shorey et al., 2019) to create advanced communicative dialogue. *Avatar* conversational agents are those that are not anthropomorphic to the extent that they can be deemed as *virtual humans*, but do possess some degree of embodiment and thud cannot be categorised as disembodied chatbots. *Avatar* agents also span over all three pedagogical purposes and make use of stop motion animation tools, such as MikuMD[4] (Tanaka et al., 2020) which, written in C++uses frames, layers and loop based timeline animation techniques to create animated characters. The most common functional type of agent is the *chatbot*, which is sometimes *embodied* (Scholten et al., 2019; Xie et al., 2021) but mostly presents as a *disembodied* agent, having a text-based inputs and outputs. *Chatbots* have a range of features, such as connecting to external data sources, connecting to NLP servers, having machine learning capabilities etc. The last and least-popular functional type of pedagogical conversational agent is the *voice bot*, which is only used within the *cognitive* pedagogical purpose (Morris & Chen, 2020, 2021). *Voice bots* only accept verbal communication using a microphone and have voice based outputs, therefore not having a graphical user interface. It is not explored due to the various and obvious limitations of the *voice bot*, such as lack of visual engagement and dependence on a singular human sense, which also makes it less inclusive in terms of actual use.

Features

Further to the types of conversational agents, the consideration of the *features* and functionality of pedagogical agents is vital in order to understand the technological functions.

[4] MikuMikuDance – a 3D animation freeware.

As conversational agents can be created using many technologies and programming constructs, the framework has categorised the various technological features of pedagogical conversational agents into five categories, which include *Social/IM Link*, *NLP*, *Machine Learning*, *External Data Source* and *Custom/Unspecified Development*. The aim of this section is to explain these descriptors and the technologies that exist within these labels, based on the literature sample, within the remit of the survey conducted as part of this research.

The first technological function to be listed is *Social/IM link*, which includes any conversational agent bot that uses a social media or instant messaging platform as the user interface to interact with the user. *Social/IM link* tend to be disembodied chatbots that use platforms such as Telegram, WhatsApp and Facebook messenger, as such platforms are already used for communication between humans, hence the idea is to create the perception that when the user is communicating with the bot, it gives the impression that the user is communicating with a human being. For example, the study by Mokmin and Ibrahim (2021) makes use of both WhatsApp and Telegram while the study by Hamzah et al. (2021) is based solely on the Telegram platform.

The second function to be listed is Natural Language Processing (*NLP*), which allows the conversational agent to understand natural language inputted by the user, and make meaningful interactions therefrom. *NLP* libraries have designed algorithms which incorporate features such as sentence segmentation, lemmatisation and word tokenisation which can identify intents from inputted sentences as strings, and tools for predicting parts of inputted text via identifying noun phrases and entity recognition. From the pedagogical conversational agents surveyed, some used native *NLP* libraries such as the study by Hsu et al. (2021) that uses a custom Python library, but many agents linked to common and sometimes opensource *NLP* systems through API connections to services such as Google's DialogFlow (Gonda & Chu, 2019), Juji.ai (Gupta & Chen, 2022), NLP.js (Winkler et al., 2020), IBM's Watson (Gonda et al., 2018), Microsoft Luis and Facebook's Wit.ai (Zubani et al., 2022).

The third technological function listed is *Machine Learning*, which describes any conversational agent with emotional or intelligent learning capabilities, in addition to *NLP*. For example, the study by Feng et al. (2017) measures the stress level of the user by collecting their skin conductance levels using ambient sensors, the study by Hayashi (2020) uses video recording technology to measure the eye movement of the user which allows the agent to identify gaze movements to help understand the users emotional state, and the study by Lee et al. (2021) uses virtual reality to give the user a more realistic experience, which then tracks the users movements and reactions to certain situations, which collects data regarding their psychological natural responses.

The fourth technological function listed is *External Data Source*, which allows the conversational agent to draw information from any external source, such as a database or online repository of data. For instance, the study by Campillos-Llanos et al. (2021) permits the conversational agent to connect to a patient record database, to make conversations more informed to allow the agent to act as a patient for medical students, and the conversational agent designed by Tegos et al. (2021) connects to a MongoDB database to store session information to ensure the conversations are not lost and can be referred back to on subsequent conversations. Furthermore, the study by Jin et al. (2019) uses a conversational agent that asks the user questions from a bank of questions stored in an SQLite database.

The last and fifth listed technological function is Custom/Unspecified Development, which defines conversational agents that have been created using custom programming constructs and scripts, or those that have not been listed by the researcher, as the focus of

the research is on the pedagogical application of the conversational agent, as opposed to the computational functions. For example, the study by Chang et al. (2022) uses an agent created on a custom Android mobile application, and the study by Lahav et al. (2020) uses a conversational agent based on SimCoach, a custom-developed system.

Mode of study in relation to the technological functions

As aforementioned in Sect. "Pedagogical applications", the second level of pedagogical categorisation is the *mode of study*, which includes two sub-themes; *face-to-face education* and *distance-education*, which are concerned with the method of delivery of teaching and learning for which the AI conversational agent is being used. The AI conversational agents used for *distance-learning* are generally used by students in their own time (non-scheduled) and include mostly disembodied chatbots (Abbas et al., 2022; Asquer & Krachkovskaya, 2022; Belhaj et al., 2021; Bhartiya et al., 2019; Briel, 2021; Carayannopoulos, 2018; Carlos et al., 2021; Chang et al., 2022; Dibitonto et al., 2018; Fidan & Gencel, 2022; Gaglio et al., 2019; Gonçalves et al., 2022; Gunadi et al., 2019; Hamzah et al., 2021; Hien et al., 2018; Ismail & Ade-Ibijola, 2019; Latorre-Navarro & Harris, 2015; Lee et al., 2020; Mokmin & Ibrahim, 2021; Neumann et al., 2021; Nguyen et al., 2021; Ralston et al., 2019; Resch & Yankova, 2019; Scholten et al., 2019; Singh et al., 2019; Song & Kim, 2020; Song et al., 2017; Tamayo et al., 2019; Tegos et al., 2021; Vázquez-Cano et al., 2021; Villegas-Ch et al., 2021; Winkler et al., 2020; Xiao et al., 2019; Zubani et al., 2022), with some being embodied virtual humans (Jha et al., 2020; Lahav et al., 2020; Lee et al., 2021; Liew & Tan, 2016; Maryadi et al., 2017; Ramachandiran et al., 2019; Tan et al., 2020; Wang et al., 2020). The agents used for *face-to-face education* are generally guided by an instructor or facilitator and therefore tend to be more diverse in their embodiment and functional type, and accordingly this category can include chatbots (Aguilar-Mejia & Tejeda, 2020; Ceha et al., 2021; Chang et al., 2021; Chen et al., 2022; Gonda & Chu, 2019; Gonda et al., 2018; González et al., 2022; Gupta & Chen, 2022; Hsu et al., 2021; Kaur et al., 2021; Kumar, 2021; Lee & Fu, 2019; Li et al., 2020, 2021; Mikic-Fonte et al., 2018; Paschoal et al., 2018; Shorey et al., 2019; Tan et al., 2021; Tegos et al., 2014, 2015, 2016; Trappey et al., 2022; Valdivieso & Luzón, 2021; Wambsganss et al., 2020; Xie et al., 2021; Yin et al., 2021), virtual humans or avatars (Ayedoun et al., 2019; Ba et al., 2021; Bickmore et al., 2016; Campillos-Llanos et al., 2021; Feng et al., 2017; Halan et al., 2014; Hayashi, 2020; Jin et al., 2019; Krämer et al., 2016; Lee et al., 2015; Liew et al., 2017; Lin et al., 2020; Maicher et al., 2017; Moon & Ryu, 2021; Nelekar et al., 2022; Rodríguez et al., 2021; Schroeder & Craig, 2017; Shiban et al., 2015; Tanaka et al., 2020; Wang et al., 2021; Yilmaz & Yilmaz, 2020; Yılmaz et al., 2018), and voice-bots (Morris & Chen, 2020, 2021).

Discussion

Pedagogical AI conversational agents sit within the research area of educational technology (EdTech), which is a research specialism that is situated within the study of philosophy, education and the computer sciences. However, studies within this remit tend to focus on either the pedagogical impact of their agents, or the technological advancement of their agent, but both are equally important in developing emotionally aware, pedagogically able, intelligent conversational agents. In summary, taking

a broader view of the AI conversational agents included in this study, and considering their pedagogical applications as depicted in Table 4, the largest proportion (n = 41) of agents used to advance teacher and/or learning within higher education are used for instructional (direct teaching) purposes. Furthermore, many AI conversational agents (n = 37) are used for pastoral purposes, which support educational providers in teaching and learning. Within these instructional and pastoral domains, the majority of AI conversational agents focus on providing knowledge to students, building student motivation and engagement, or answering student queries. In reference to the technological functions, the majority of AI conversational agents exploit NLP capabilities to ensure users can effectively and easily communicate with the agents and have provisions for connecting to various data sources to draw meaningful conversations.

Although this is the case with AI conversational agents used within education, the trends with conversational agents outside of the education sector tend to have more focus on leveraging machine learning techniques, utilising cutting edge technological concepts such as neural networks, internet of things (IoT) and advanced API's to create more powerful and advanced conversational agents (Allouch et al., 2021; Modrzejewski & Rokita, 2018) such as Alexa (Amazon) and Siri (Apple). One rapidly emerging technology is the use of large language models (LLMs) for the development of AI conversational agents. LLMs use deep learning algorithms and neural networks that can enable a conversational agent to perform a range of NPL tasks such as allow agents to converse and deliver information, generate text, and conceptualise data in real-time, drawing on the world wide web as it's data source. One such AI conversational agent is ChatGPT (also known as GPT-3 by OpenAI) which emerged in November 2022 and has shown noteworthy potential that has drawn significant press coverage and ignited debates of its use in many settings. Due to its recent inception, there is a lack of research that focuses on the use of LLMs for pedagogical purposes. The relatively small amount of pedagogical LLM research that does exist focuses on understanding and regulating LLM agents (Hacker et al., 2023), and their roles or implications in scientific writing or research (Alkaissi & McFarlane, 2023; Patrick & Treutlein, 2023). The use of LLMs is likely to become much more common in light of new vendors developing AI conversational agents using this approach (Dilmegani, 2023). For example, BERT by Google is soon to be released, as is TuringNLG by Microsoft, XLM-RoBERTa by Meta, and NeMoLLM by NVIDIA.

Within developed countries, and especially in a post-Covid United Kingdom, education focused applications appear to be slower in adopting the latest advancements in digital transformation technologies and gaining investment in cutting-edge technologies, while sectors such as finance and pharma appear to benefit more from public sector investment (Bell, 2023; Hacker & Dreifus, 2017; Johnson et al., 2023). When taking a bird's eye view of the current state-of-the-art in the field of pedagogical AI conversational agents considered in this study, the trend appears to focus on the development of instructional and pastoral applications, specifically using disembodied chatbots. There appears to be a lack of focus on cognitive agents in general and instructional agents specifically focusing on assessment. This presents an opportunity for new educational-based research to focus on further development of conversational agents within these specific pedagogical purposes and intents, and also with a focus on optimising the function of these agents via the use of cutting-edge AI technologies.

Findings in relation to existing pedagogical agent frameworks

Reflecting on the findings of this literature survey, there is value in comparing the findings from the current study with prominent findings and pedagogical agent frameworks published in the wider literature. Sect. "Purpose of the study", considered and discussed knowledge from prominent contemporary pedagogical agent frameworks published in recent years and outlined how the focus of this study compliments, and is distinct from, contemporary pedagogical agent frameworks. However, there is a range of prominent knowledge, and frameworks, published prior to the survey window which should also be considered in light of the findings of the current study. Accordingly, the remainder of this section explores several prominent conversational agent frameworks and key findings presented in the broader literature. It provides a synthesis of the findings presented in the form of five key themes (Sub-Sects. "Role-based functions and educational support models"—"Strategic frameworks for higher education") and considers what the similarities and differences are between these themes compared with the conceptual framework of pedagogical agents presented in this study (the current study).

Role-based functions and educational support models

A central approach in pedagogical agent research involves categorising agents by educational roles, assigning functions such as tutor, mentor, or motivator to enhance specific learning outcomes. This theme examines various frameworks that define agents by these roles, each contributing to a nuanced understanding of how role-based functions support learner engagement and outcomes.

Kim and Baylor (2006) classify pedagogical agents into three roles: Expert, Mentor, and Motivator. The Expert agent provides knowledge, aligning with traditional teaching methods; the Mentor agent organises learning activities based on learner preferences; and the Motivator agent supports learners emotionally, enhancing engagement and learning. Marín (2014) emphasises agents' roles in fostering social interaction and emotional support, suggesting that virtual peer interactions contribute to empathy and social equality among learners, thereby improving learning outcomes. Tao et al. (2008) propose that agents should switch flexibly among roles such as knowledge provider, emotional stimulator, and organiser to better meet diverse student needs, enhancing adaptability in learning contexts. They explore agents in e-learning roles, indicating that tailored support can create a more supportive environment for learners' cognitive and emotional development. Taking a broader view across these sources, a shared emphasis on social interaction and emotional engagement emerges, with all recognising the Motivator role's importance in supporting learner engagement. However, while Kim and Baylor (2006) categorise roles statically, Tao et al. (2008) advocate for a more flexible, dynamic role adaptation. Marín (2014) introduces a social dimension, suggesting that emotional and social aspects are as crucial as cognitive support in the learning process.

The conceptual framework presented in this study expands upon traditional role-based functions by integrating the categorisation of roles through overarching purposes, including as pastoral, instructional, and cognitive support, specifically tailored for higher education contexts. This broader categorisation allows for a more nuanced understanding of how pedagogical agents can address the complex needs of learners in higher education. The current study emphasises adaptability and the strategic targeting of support roles, which aligns with the perspective on role flexibility by Tao et al. (2008), and it incorporates a

more comprehensive view of emotional and social support, similar to the findings of the study by Marín (2014). This integrated approach advances the field by offering a broader, more adaptable model that can effectively support the complex and varied requirements of higher education. The emphasis on adaptability and the inclusion of pastoral roles further develops the understanding of how pedagogical agents can be leveraged to create supportive and effective learning environments.

Psychological, social, and motivational influence

The psychological, social, and motivational dimensions of pedagogical agents play a critical role in fostering learner engagement and rapport. This theme explores frameworks that position agents as facilitators of psychological support, examining how agents' motivational and social capabilities impact learning.

Tao et al. (2008) propose a framework that integrates psychological incentive mechanisms, suggesting that Expert, Mentor, and Motivator agents stimulate learners' internal motivation. Zhao et al. (2014) emphasise agents' ability to adapt to learners' emotional states, noting that timely feedback can enhance learner motivation. Fakinlede et al. (2013) highlight agents as virtual companions, not only providing academic support but also fostering positive learning environments that mitigate isolation. Across these studies, there is a shared recognition of the importance of motivation and social rapport in learning. Each study acknowledges that agents can provide emotional support and foster a positive learning environment. They highlight the need for agents to adapt to individual learners' emotional and motivational needs, suggesting that personalised interactions can lead to better educational outcomes. However, each study provides a unique perspective. Tao et al. (2008) provide a structured framework categorising agents based on their functions, focusing on the interplay between psychological mechanisms and agent roles. Zhao et al. (2014) delve deeper into the social dynamics, emphasising the importance of rapport and emotional adaptability in agent-learner interactions, and Fakinlede et al. (2013) concentrate on the motivational aspects, particularly how agents can mitigate feelings of isolation and enhance emotional engagement through companionship.

The conceptual framework presented in this study builds upon the insights from these sources by integrating psychological, social, and motivational elements into a comprehensive model tailored for higher education. The current study incorporates strategies for fostering motivation and social rapport, aligning with the findings from (Fakinlede et al., 2013; Zhao et al., 2014). Furthermore, the current study advances the concept of emotional support by applying it across diverse learning contexts, ensuring that instructional, cognitive and pastoral needs are met. This holistic approach is particularly relevant in higher education, where students often face complex challenges. The current study positions itself within the broader context of higher education by addressing the strategic educational needs of students through a balanced approach to psychological and social engagement, through the iteration of its levels of categorisation. By integrating motivational and communicative support, the framework proposes the development of pedagogical agents that employ adaptive learning which can cater to the diverse needs of learners.

Technological features, embodiment, and interaction quality

Technological design and interaction quality are vital for effective pedagogical agents, influencing learner engagement and perceptions of these digital tools. This theme reviews

frameworks that examine embodiment, multi-modal interaction, and feedback in enhancing educational interactions.

Komatani et al. (2006) emphasise multi-threaded dialogue management, showing how agents' ability to manage multiple conversation threads enhances user engagement. Min et al. (2019) and Mayer and DaPra (2012) discuss embodiment, with findings indicating that human-like gestures improve interaction quality and foster social presence. Lemon et al. (2002) highlights natural language processing capabilities as crucial for creating an immersive learning environment. Across these studies, a shared theme is the emphasis on embodiment as essential for enhancing user engagement and interaction quality. All sources recognise that human-like gestures and facial expressions contribute to a more relatable and effective learning experience. Regarding embodiment, both (Komatani et al., 2006; Min et al., 2019) highlight the importance of gestures and expressions, with Komatani et al. (2006) focusing on dialogue management, while Min et al. (2019) emphasises user engagement. Mayer and DaPra (2012) further support this by linking embodiment to cognitive processing and learning outcomes, suggesting that the quality of interaction directly impacts educational effectiveness. With respect to multi-modal interaction, Min et al. (2019) specifically address how enabling users to interact through various means enhances overall engagement. In contrast, Lemon et al. (2002) focus on the technical features that support these interactions, particularly natural language processing. Lastly, regarding dialogue management, Komatani et al. (2006) make a unique contribution by detailing how multi-threaded dialogue management improves interaction quality, a feature not explicitly addressed in the other studies. This approach is vital for maintaining context and ensuring that users feel understood throughout interactions.

The conceptual framework developed in this study expands on existing research by categorising conversational agents to address specific pedagogical and technological needs within higher education. This structure supports both personalised and scalable educational interactions tailored to diverse student needs. Technologically, the framework categorises agents by embodiment, functional types, and features. This layered approach enables a clearer understanding of how agents can enhance interaction quality and media richness in educational contexts, addressing the distinct demands of higher education. In conclusion, this study presents a comprehensive model that captures the pedagogical and technological applications of conversational agents in higher education, guiding future research to advance assessment, reflective practices, and administrative support. This structured framework lays a foundation for developing agents that transform learning experiences through enhanced personalisation and engagement.

Cognitive and pedagogical impact on learning

Pedagogical agents significantly impact cognitive processes and learning outcomes through design and engagement strategies. This theme examines how frameworks address agents' cognitive impacts, such as managing cognitive load, improving comprehension, and enhancing engagement.

Moreno (2004) focuses on cognitive processing, proposing that agents aid in organising learning materials and managing cognitive load. Mayer and DaPra (2012) integrate social agency, arguing that agents can enhance comprehension through rapport-building, while Zhao et al. (2014) highlight the adaptability of agents in providing personalised support. Across these studies, a common theme emerges regarding the cognitive load management facilitated by agents. The studies recognise that agents can help reduce extraneous

cognitive load, allowing learners to focus on essential content. Moreno (2004) emphasises instructional methods that promote active processing, while the study by Mayer and DaPra (2012) highlight the importance of social cues in motivating learners. Zhao et al. (2014) contribute by discussing the role of real-time feedback and personalised support, which further enhances cognitive engagement. While the study by Moreno (2004) primarily focuses on cognitive processes, Mayer and DaPra (2012) introduce the social dimension of learning, suggesting that rapport-building is essential for cognitive engagement. Zhao et al. (2014) uniquely contribute by examining the adaptability of agents in various contexts, emphasising their role in providing tailored support to learners.

The conceptual framework presented in this study builds on the existing body of literature on cognitive support and pedagogical strategies, particularly within the context of higher education, by focusing on agents designed to enhance instructional, cognitive, and pastoral support. By aligning with foundational concepts like real-time feedback, cognitive engagement, and tailored support highlighted in the literature, this framework integrates these elements into a model that emphasises personalised and multi-modal learning experiences. For example, by addressing cognitive load and fostering engagement through simulations and collaborative experiences, it provides a comprehensive approach to improve student comprehension and retention. The current study uniquely emphasises the importance of diverse, context-specific applications for conversational agents in higher education. It extends beyond traditional cognitive support to address administrative efficiency and student motivation, acknowledging the multi-dimensional needs within academic environments, including the mode of study. Through categories such as reflective skills, assessments, and personalised interactions, the framework accounts for the varied roles conversational agents can play in enhancing both academic and non-academic support structures. This approach not only synthesises insights from current research but also anticipates future applications by proposing pathways for advancing agent capabilities in adaptability, interaction richness, and context-appropriate feedback.

Strategic frameworks for higher education

Strategic application of pedagogical agents in structured educational environments is critical for achieving scalable and effective learning outcomes. This theme evaluates frameworks that emphasise adaptability, scalability, and task coordination.

Nakano et al. (2008) focus on the development of strategic frameworks that address multi-domain tasks within educational environments. Their contribution lies in emphasising scalability, allowing pedagogical agents to operate across various educational contexts and disciplines. The framework supports task coordination by enabling agents to manage complex interactions among multiple stakeholders, including students, educators, and administrative staff. This adaptability is crucial for addressing the diverse needs of learners and facilitating instructional goals in a structured manner. As previously discussed, Lemon et al. (2002) focus on adaptable dialogue systems, and Marín (2014) provides structured role definitions across educational contexts. Each framework addresses task coordination uniquely, contributing to an understanding of how agents support instructional goals. When comparing these studies, several shared themes emerge regarding strategic implementation in educational contexts, such as scalability and task management. All these studies recognise the importance of scalability in deploying pedagogical agents across various educational settings. Nakano et al. (2008) emphasise multi-domain applicability, Lemon et al. (2002) focus on adaptable dialogue systems, and the taxonomy by Marín (2014) provides

a structured approach to defining agent roles. Furthermore, in terms of task management, the frameworks address task coordination, although from different angles. The research by Nakano et al. (2008) highlights the management of complex interactions, while Lemon et al. (2002) focuses on structured dialogue management, and Marín (2014) clarifies agent roles to enhance instructional support. Unique elements include emphasis on multi-domain tasks, which allows for broader applicability across disciplines by Nakano et al. (2008) and a detailed approach to dialogue management that enhances user engagement by Lemon et al. (2002). Furthermore the framework by Marín (2014) provides taxonomy for understanding agent roles in educational contexts.

The conceptual framework presented in this study builds upon strategic elements from existing frameworks, emphasising the role of agents in fulfilling both academic and emotional support functions at a comprehensive level within higher education. Drawing on insights into scalability, adaptability, and structured task management, the framework aligns specifically with the multi-layered demands of higher education institutions. It extends current strategic models by presenting an adaptable approach tailored to institutional needs, which includes support for both instructional and pastoral functions, thereby addressing diverse student requirements. A distinctive contribution of this study is its flexibility in supporting varied academic structures while aligning with the strategic educational objectives unique to higher education. By integrating functionalities such as mentoring, reflective practice, and administrative support, the framework is structured to operate across face-to-face and distance learning modalities. This multi-functional approach ensures that conversational agents can provide personalised and context-appropriate support, further enhancing scalability and adaptability within complex educational settings. By facilitating emotional and academic engagement through diverse agent roles, the framework positions itself as a forward-thinking, holistic model for optimising future conversational agent-controlled learning environments.

Conclusion

The comparison of these frameworks reveals both similarities and differences between existing knowledge and the conceptual framework developed in the current study, highlighting the diverse approaches to categorising and understanding pedagogical conversational agents. The frameworks share a common goal of enhancing educational outcomes through the strategic use of conversational agents, yet they differ in their focus areas, ranging from psychological and social dynamics to cognitive processes and technological functions. The conceptual framework developed in the current study distinguishes itself from frameworks presented in the wider literature to date by offering a comprehensive approach that integrates both pedagogical applications and technological considerations, making it particularly suited to the complexities of higher education. While role-based frameworks, such as those proposed by (Kim & Baylor, 2006; Marín, 2014) provide valuable insights into the specific functions of agents, the current conceptual framework offers a broader, more holistic perspective that more closely aligns with the strategic needs of higher education. Similarly, frameworks focused on psychological, social, or cognitive aspects, provide important contributions but are more narrowly focused than the comprehensive framework presented in this study (Fakinlede et al., 2013; Moreno, 2004; Tao et al., 2008).

In conclusion, the conceptual framework developed in the current study builds upon, and extends existing frameworks, by providing a comprehensive categorisation of pedagogical conversational agents that integrates both pedagogical applications and technological

functions. This broader perspective makes it particularly valuable and applicable to the strategic implementation of conversational agents in higher education, addressing the diverse and complex needs of this sector. The comparison of frameworks highlights the evolving nature of research in this domain and emphasises the need for continued investment in the development and refinement of pedagogical AI conversational agents to fully realise their potential as innovative and effective tools for enhancing education and learning.

Future pedagogical research recommendations

Based on the range of conversational agents considered in this study, a number of opportunities for future study have emerged from the analysis. This section presents recommendations for future research, according to the two key sections of the conceptual framework: (1) Pedagogical applications, and (2) Technological functions.

Pedagogical applications: future research directions

AI Conversational agents for assessment

One of the most important aspects of teaching and learning is assessment, as the successful teacher or instructor will consistently evaluate the knowledge of the student to ensure delivery, comprehension and retainment of learning using initial, formative, summative and ipsative assessment techniques, both formally and informally (Dunn et al., 2013). In addition to its vitality, assessment processes are one of the most cited factors linked to causing student stress and anxiety in higher education (McConlogue, 2020). Furthermore, assessment processes directly lead to grades, results, and degree classifications, which can have significant impacts on student progression, retainment, graduate destinations and in some cases on teacher reputation. Hence is it important that the sector as a whole focuses on ensuring assessments are fair, valid, reliable, authentic and current (Boud & Nancy, 2007). In many higher education institutes, teaching and faculty staff employ considerable time on assessment and feedback, *"…but have very little professional development in how to design assessments"* (McConlogue, 2020). Therefore, given the crucial role that assessment plays within the educational context coupled with the recent advancements in AI technologies, there appears to be real opportunities to explore how AI conversational agents can be used to support staff to optimise delivery of effective and appropriate assessments. Although its importance and impact in education, in terms of the pedagogical AI conversational agents within the remit of this survey conducted, this research has found very few agents are designed to support, automate, or strengthen assessment processes. In light of the findings of this literature survey, future research areas of consideration within pedagogical conversational agents supporting assessment processes would benefit from focusing research effort within the following areas:

Pedagogical recommendation 1: Automation of assessment processes using intelligent conversational agents.
Pedagogical recommendation 2: Reduction of stress and anxiety (psychological natural resources) for students in educational assessment processes using emotionally intelligent conversational agents.

Pedagogical recommendation 3: Methods of self-assessment using artificial intelligent conversational agents.
Pedagogical recommendation 4: A comparison of the impact of teacher-based and agent-based assessment processes on students within higher education.

AI conversational agents for reflection

Another crucial aspect of learning is reflection, especially in higher education (Harvey et al., 2016; Moon, 2004). Students consistently need to reflect on their knowledge, methods of learning and revision techniques to build better memory retention, gain a better understanding of their subject matter, and avoid unconscious biases from directing their critical judgement through implicit assumptions (Brookfield, 2021). Many pedagogical instructional theories are based on the process of reflection, for instance Experiential Learning Theory which posits that learning happens through experimentation, reflection, thought and action (Kolb, 1984). Furthermore, reflections are also an important tool for the teacher or instructor, as reflective practice allows progress in pedagogical ability, by reflecting on sessions and identifying areas of weakness and implementing perpetual improvements, consistently (Tay et al., 2023). The development of metacognitive skills, specifically the ability to perform reflection and make decisions based on reflective processes aids students, in addition to their academic learning, in their civil and personal development by preparing them to become critical and creative thinkers. This is a key tool for the promotion of individualism in students, allowing them to cultivate into freethinking, confident beings (Brookfield, 2021). While the ability to reflect is a key area of cognitive development in higher education, technological innovations within this area are not widespread, perhaps because the ability to change thought and metacognition is difficult for human-instructors, and more-so for artificial agents. In terms of the conversational agents reviewed in this survey, this research has found very few agents designed to promote or encourage students to use reflective thinking. Therefore, in consideration of these findings, this research recommends future areas of research may benefit from focusing on:

Pedagogical recommendation 5: The use of artificial intelligent conversational agents to promote students' reflective skills.
Pedagogical recommendation 6: Development of questions to encourage reflection-in-action, through the use of intelligent conversational agents.
Pedagogical recommendation 7: The development of intelligent conversational agents which can automate logging of key points, and using the data from the logs to promote reflection in students as part of homework studies.
Pedagogical recommendation 8: Emotionally intelligent conversational agents to assess students' ability to reflect and provide areas of improvement, through exemplifying reflective methodologies.

AI conversational agents for administration and management

Academic and faculty staff satisfaction in higher education is an area of interest for universities as it is linked to staff effectiveness and retainment (Gillespie et al., 2001). A major factor in faculty staff dissatisfaction is occupational stress, a primary cause of which is *"exposure to high numbers of students, especially tuition of postgraduates, strongly predicts the experience of burnout"* (Watts & Robertson, 2011). When analysed, it is apparent

that a cause of stress and burnout is not necessarily having a high number of students, but rather the lack of management tools available to handle a high number of students. Furthermore, in addition to staff satisfaction, the ability to manage the learning journey appropriately, with clear communication between the faculty department and the student also impacts on student satisfaction. Student satisfaction is a key performance indicator for universities, and in many countries such as the UK, institutions have a legal responsibility to declare student satisfaction results to regulatory bodies, and student satisfaction also affects legalities related to student-university relationship in contract law (Gaffney-Rhys & Jones, 2010). Since the 1990s, virtual learning environments (VLE) and learning management systems (LMS) have been implemented in higher education as a means for supporting lecturers and teachers with educational technology tools to manage and enable their classes, however innovation has been lacking in this area (Arabie, 2016). Aside from VLE's such as Moodle, Blackboard, Teams and otherwise, the use of technological tools to manage students in terms of learning progression, educational journey recording, student–teacher communication, requests for help and logistical variables are scarce. Furthermore, in terms of the conversational agents reviewed in this survey, the results of this study indicate that very few conversational agents have been designed to aid and support the management of education. Therefore, with respect to these findings, this research suggests that future areas of research may benefit from focusing on:

Pedagogical recommendation 9: The development of conversational agents to bridge student–teacher and teacher-teacher communication during and after sessions.
Pedagogical recommendation 10: Intelligent conversational agents to gather student feedback on module delivery during and post-completion of studies.
Pedagogical recommendation 11: Emotionally aware conversational agents to gather formative feedback on student emotional state through the use of emoticons to aid teacher reflection-in-action.
Pedagogical recommendation 12: The development of intelligent conversational agents to organise group and team working tasks for students in higher education labs and workshops.

Future technological research recommendations

From a technological perspective, this study has found many disembodied chatbots having NLP capabilities, which creates an intelligent agent, as the agent is able to identify users' intentions from verbal cues in natural language. However, beyond NLP, the majority of the conversational agents do not have further intelligent abilities or emotional awareness. This paper recommends that future research in this area explores agents with more data input steams than just text-based response, such as collecting the users facial and body-language recognition, perspiration levels, oxygen levels, heart rate, emotional state using verbal and non-verbal emotional intelligence, and psychological natural response state, using ambient and medical sensors to accumulate data, and the development of algorithms to interpret the data and draw therefrom intelligent conclusions in the form of reactions by the conversational agent. Through the use of these added data streams, the conversational agent could become more emotionally aware and exemplify empathy, which in turn, could support its pedagogical purposes. Furthermore, recent developments in generative AI video

automation technologies, such as Elai[5] and Gen-1[6] have shown potential in allowing users to create media (videos and images) based on textual inputs, which could be explored synonymously with embodied AI conversational agents to create better experiences for students. This may expand to AI conversational agents being used in additional areas such as educational counselling, mental health assessments for education, mentoring and coaching strategies or direct instruction through intelligent presentations, and so on. Therefore, this paper recommends that future research may benefit from focusing on the following technological characteristics of AI conversational agents:

Technological Recommendation 1: Personalisation technology via the development of algorithms specifically focused on personalisation of the interactions of the conversational agent with individual students based on their individual needs and learning styles.
Technological Recommendation 2: Multimodal interactions that incorporating rich multimedia elements, such as images and videos, into conversational interactions to improve the engagement and understanding of the students.
Technological Recommendation 3: Development of conversational agents that are more integrated with Learning Management Systems (LMS), in addition to external data sources, so that agents can provide teachers with data on student performance and progress and allow for personalised feedback.
Technological Recommendation 4: Conversational agents equipped with adaptive testing capabilities, allowing them to assess student understanding in real-time and adapt the learning experience accordingly.
Technological Recommendation 5: Incorporating gamification technologies that include game-like elements into conversational interactions to increase student engagement and motivation.
Technological Recommendation 6: Integrating of voice recognition technologies to make conversational agents more accessible and user-friendly, especially for younger students.
Technological Recommendation 7: Integration with virtual and augmented reality (VR/AR) to provide students with more immersive and interactive learning experiences.

Conclusions

This research has carried out a literature survey of the state of the art of pedagogical AI conversational agents and conducted a thematic analysis based on the resulting literature dataset, from which a conceptual framework was developed. The conceptual framework presented in this study has two overarching themes which include the *pedagogical applications*, and *technological functions* of pedagogical AI conversational agents. *Pedagogical applications* of AI conversational agents were found to belong to one of three *pedagogical purposes*; (1) *pastoral*, (2) *instructional* or (3) *cognitive*, and specify into one of two *modes of study*, *face-to-face* or *distance-education*. The agents were also found to belong to one of eight sub-types; (1) *mentoring and coaching*, (2) *assessments*, (3) *simulate and experience*, (4) *reflective skills and metacognitive*, (5) *communication*, (6) *administration and*

[5] Elai.io: https://elai.io/
[6] Gen-1 by RunwayML: https://research.runwayml.com/gen1

management, (7) *motivate and inspire*, or (8) *FAQ's and knowledge base*. The *technological functions* of AI conversational agents were found to be either *embodied* or *disembodied*, and belong to one of four functional types; (1) *virtual human*, (2) *avatar*, (3) *chatbot* or (4) *voice bot*, and to have one (or more) of five technological functions; (1) *machine learning*, (2) *natural language processing*, 3) *external data source*, (4) *social and instant messaging link* or (5) *custom and/or unspecified development*. The conversational agents that exploit natural language processing systems also fall into one of two sub-types; *native and natural* or *application programming interface* systems.

Despite there being a range of valuable contributions and existing conversational agents presented in the existing research literature, this paper recommends a number of future research recommendations both relating to the development of future pedagogical applications and the technological functions of these future applications. More specifically, in term of pedagogical applications, there is a need to focus future research on the development of AI conversational agent to support assessment processes, reflective practice, and to support more efficient and effective administration and management practice. In terms of technological functions, future research would benefit from focusing on enhancing the level of personalisation and media richness of interaction that can be achieved by AI conversational agents.

In conclusion, this literature review and conceptual framework has demonstrated the growing trend and potential benefits of using AI conversational agents for pedagogical purposes in higher education. The review has highlighted the diverse applications of these agents in various educational contexts. The conceptual framework developed in this study provides a comprehensive understanding of the key components and design principles of pedagogical AI conversational agents and offers a useful framework for future research and development in this field. Ultimately, this review emphasises the need for continued investment in the development of pedagogical AI conversational agents to fully realise their potential as innovative and effective tools for enhancing education and learning.

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