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TOPICAL REVIEW

Emotion-Related Pedagogical Agent: A Systematic Literature Review

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ABSTRACT Pedagogical agent is a software agent that provides guidance, feedback, or intervention to learners in digital environments. It has the potential to address issues in computer-based learning, particularly online learning, which often neglects affective aspects, such as the emotions of its users. Most systematic literature reviews (SLR) on pedagogical agent have focused on their visual design, types of feedback, and other empirical elements. However, what underlies these agents' ability to provide interventions personalized to learner's emotions has not been examined. So, this SLR explores how pedagogical agent has addressed learner's emotional needs. The study's research questions include: 1) To what extent does research exist on models, frameworks, or architectures for pedagogical agent, especially those related to emotions? 2) How are pedagogical agent represented, what types of interventions do they use, and how do they affect learner's emotions? 3) What kinds of inputs are used to activate the pedagogical agent's functions? This SLR applied the Kitchenham method to select reference sources from 2013 to 2023 and was indexed by Scopus in the Q1 to Q4 range. Our review revealed the absence of a specific model for mapping out interventions tailored to the learner's emotional needs. Most existing pedagogical agent provide learning interventions that are less adaptive and personalized based on the learner's emotional state and are applied to asynchronous learning systems such as e-learning. There are still very few pedagogical agents that use real-time input technology by utilizing artificial intelligence to recognize learner's emotion to trigger an adaptive and personalized intervention.

INDEX TERMS Pedagogical agent, learning intervention, emotion, education, learner.

I. INTRODUCTION

Digital learning, especially online learning, is increasingly being used nowadays. The Covid-19 pandemic has accelerated the application of online learning [1]. However, in general, online learning only gives attention to the cognitive aspects of the learner [2]. Meanwhile, the affective aspect, especially the learner's emotions, is also an essential factor in the learning process. One of the keys to successful effective learning is not only by transferring material content to students but also through social interaction, where meaningful emotions in learning aspects can be realized and maintained [3]. In addition, learner engagement built by learning strategies with positive psychology can improve learning outcomes and learner welfare [4]. Learners need learning that prioritizes personal experiences without eliminating social aspects [5]. Lack of social interaction, poor communication, and evaluation of the learner's emotional state to provide interventions are closely related to ineffectiveness in learning [6], [7]. Learning can be more effective by maintaining the 'human touch' [8]. One way to enhance the learning experience is to present agents in learning.

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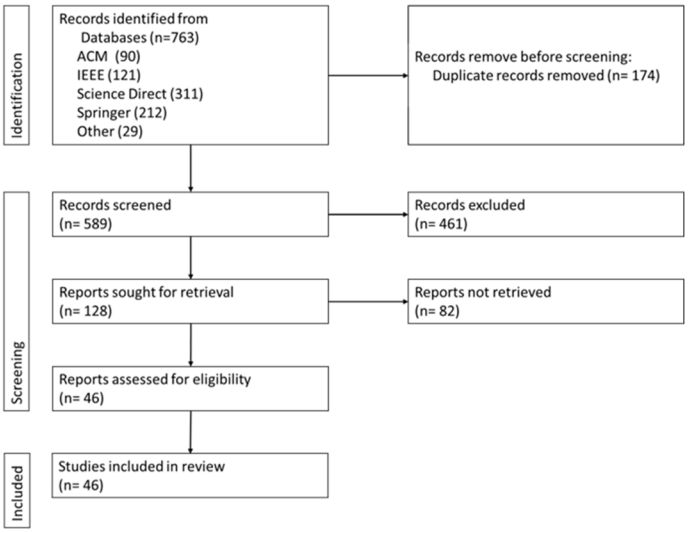

FIGURE 1. Methodology of systematic literature review.

Agents who provide interactive teaching about learning materials according to pedagogical strategies are called pedagogical agents [9]. A pedagogical agent is a software agent that provides assistance, guidance, or intervention to learners in digital environments, especially in learning multimedia or computer-based learning [10], [11], [12], [13]. Anthropomorphic agents with human-like appearance features are generally applied in e-learning to increase motivation and learning performance [14]. Through agents, interventions can be provided in computer-based learning systems [15].

Numerous studies have been conducted to develop pedagogical agents, including literature reviews. Most of the literature studies that have been made discuss the role, design, and representation of pedagogical agents such as facial expressions, movements, sounds, and gender and how the roles of pedagogical agents [10], [11], [16], [17]. More in-depth research is needed to investigate how a series of enigmatic factors influence the efficacy of pedagogical agents [18]. So far, there has been no literature review regarding pedagogical agents related to interventions or feedback from emotional aspects, despite the crucial roles of interventions and emotions in learning. Emotional feedback has an essential function in learning [19]. Therefore, this literature review was done to 1) find out the extent of models and frameworks for learning interventions by pedagogical agents; 2) explore various types of interventions and feedback provided by pedagogical agents based on their role and relation to emotions; 3) what types of inputs have been used to trigger interventions by pedagogical agents.

II. METHODS

The methods in this review use protocols from Kitchenham [20], as shown in Fig 1. The Kitchenham method is used because it is flexible and easy to use yet comprehensive [21], [22]. It is also the most popular method for conducting systematic literature reviews in computer science, especially in software engineering. This method consists of four stages: identification, screening, eligibility, and inclusion. Three research questions are as follows:

- RQ1: To what extent does research exist on models, frameworks, or architectures for pedagogical agents, especially those related to emotions?
- RQ2: How are pedagogical agents represented, what types of interventions do they use, and how do these interventions affect learner's emotions?
- RQ3: What kinds of inputs are used to activate the pedagogical agent's functions?

A. SEARCH AND SELECTION CRITERIA

The search was carried out on four main databases, i.e., ACM, IEEE, Science Direct, and Springer. Those databases were accessed through institutional access. Additionally, searches were conducted on Scopus and Google Scholar to enhance the search results. The search uses the search string by considering synonymous words or terms that may have similar meanings to broaden the search results. Search terms using (''pedagogical'' OR ''virtual'' OR ''teaching'' OR ''conversational'') AND (''agent'' OR ''bot'') AND ''learning''.

To select articles to be reviewed, a list of inclusion criteria and exclusion criteria is made. It is used as a parameter to help analysis from primary sources to be more objective, reliable, and accurate.

1. References discuss the characteristics of pedagogical agents according to the RQ that are made.
2. If articles with different titles discuss the same pedagogical agent, then only one of them will be taken according to selection criteria no. 1-5 or which is closest to the development stage.

3. References must be indexed in Scopus Q1-Q4 and in journal articles, not proceeding articles. This rule is used because we only want to include the results from reliable, complete, and comprehensive sources.
4. The primary sources are taken from 4 publishers: ACM, IEEE, Science Direct, and Springer.
5. Other additional sources are taken from Scopus and Google Scholar, which can be accessed openly.

The quality assessment in this study is based on the following predefined quality questions.

1. Are the aims of the research clear?
2. Does the article answer at least one of three research questions?
3. Does the article provide novelty or contributions in pedagogical agent?
4. Does the article clearly explain the pedagogical agent used?

B. SEARCH AND SELECTION RESULTS

There are 46 articles included in this review. The study should have been indexed in Scopus Q1-Q4; however, no Q4 articles met the selection criteria. Table 1 shows the articles that were included and their publisher and quartile.

TABLE 1. Final article result.

Publisher	Quartile	Paper
ACM	Q2	[23], [24], [25], [26]
IEEE	Q1	[27], [28], [29], [30], [31], [32], [33]
Science Direct	Q1	[34], [35], [36], [13], [33], [37], [38]
Springer	Q1	[39], [40], [41], [42], [43], [44], [45], [46], [47], [48], [49], [50], [51], [52], [53], [54], [18], [55], [56], [57], [58]
Others	Q1	[59], [60]
	Q2	[61], [62], [63], [64],
	Q3	[65], [66]

C. PROTOCOL LIMITATIONS

To maintain quality and reinforce search boundaries, the articles used as sources for study in this SLR only use sources indexed by Scopus in the range Q1 to Q4 and can be accessed legally. Due to these criteria, numerous articles discussing different pedagogical agents that did not meet the sorting criteria are not addressed in this SLR. Articles that discuss pedagogical agents with interesting features are still discussed in the discussion section as an additional elaboration of the main sources studied. However, not all articles that do not meet the criteria are used as additional sources in this discussion.

III. RESULTS

A. RQ1: TO WHAT EXTENT DOES RESEARCH EXIST ON MODELS, FRAMEWORKS, OR ARCHITECTURES FOR PEDAGOGICAL AGENTS, ESPECIALLY THOSE RELATED TO EMOTIONS?

Developers require models and frameworks as a foundation for conceptualization and reference when developing a system. However, among the selected sources used in this review, no model or framework specifically discusses pedagogical agents, let alone their role in emotions. Thus, the literature search results used to address RQ1 encompass not only specific models or frameworks for pedagogical agents but also methods and architectures related to pedagogical agents. Only seven articles from primary sources were selected to address RQ1.

1) LEARNING ENVIRONMENT

Of the seven sources found discussing models or frameworks. The application environment can be used in asynchronous or synchronous learning. The models or frameworks discussed in the articles are primarily designed for use in asynchronous learning environments [13], [27], [43], [50], [52]. Various types of asynchronous learning environments have been considered for implementing the discussed model or framework. In [27], the model is used for the learning system using a serious game, meanwhile [13] for video-based learning lectures, and [43], [50], [52] for chatbot. The sources primarily discuss models for chatbots. This is an interesting finding because, according to another article discussed in RQ2, the trend of developing pedagogical agents in the form of chatbots is far less than pedagogical agents for asynchronous video-based learning. Conversely, models or frameworks for pedagogical agents in synchronous environments are only addressed in [42] and [64], where [42] focused on Virtual Learning Environments and [64] focused on video-based synchronous online learning environments.

2) RELATED EMOTIONS

Almost all the sources used as references in this RQ1 discuss the emotions involved in the pedagogical agent model or framework. The emotions discussed also vary, ranging from those related to learner focus, such as attention or engagement [52], [64], [67], emotion-related to the intrinsic motivation of learners, such as enthusiasm, sympathy, reassurance, and self-confidence [50], [67], emotions related learning satisfaction [13], [67], to anxiety-related emotions [42]. Among all the sources discussing models or frameworks of pedagogical agents with emotions, none of them explore emotions based on widely recognized psychological theories, such as basic emotions, continuous emotions, or academic emotions [68]. Most of the emotions discussed here are the emotions that learners are expected to experience, not the emotions that a pedagogical agent might use to regulate the learner's state.

TABLE 2. Current model, framework, or architecture on pedagogical agent.

Paper	Framework/ Model/ Architecture	Environment	Related Emotion
[13]	Cognitive-affective model of learning with instructional video	Asynchronous	Happy, content, bored, frustrated
[27]	Extended ARCS Model to Support 3D Collaborative Educational Games through PAs	Asynchronous (Serious Game)	N/A
[42]	Pedagogical Emphatic Agent	Synchronous (3D Virtual Environment)	Anxiety
[43]	Adaptive CHATbot for WorkFlows	Asynchronous	N/A
[50]	Dialogue Management Model	Asynchronous	Encouragement, Sympathetic, Reassuring
[52]	Learner behaviour and intervention type	Asynchronous	Engagement
[64]	Model of Coaching Pedagogy for Synchronous Collaborative Online Learning	Synchronous Learning	Engagement
[67]	Taxonomy of Pedagogical Conversational Agents Individual	Asynchronous	N/A

B. RQ2: HOW ARE PEDAGOGICAL AGENTS REPRESENTED, WHAT TYPES OF INTERVENTIONS DO THEY USE, AND HOW DO THESE INTERVENTIONS AFFECT LEARNER'S EMOTIONS?

There are 41 source documents used as references to answer RQ2. To address RQ2, we divide the discussion into nine variables: authority, learning domain, role of pedagogical agents, types of interventions, emotional input from learners, external emotions from pedagogical agents, automation techniques, implementation environment, and types of avatars used by pedagogical agents.

1) LEARNING ENVIRONMENT

similar to the discussion in RQ1 about the environments where pedagogical agents are used, asynchronous learning environments, such as e-learning, video lectures, and learning games, feature the highest number of pedagogical agents. Only three sources utilize synchronous environments, such as VLE and video conferencing, while one resource is dedicated to smart classroom environments.

2) ROLE

Regarding the model of authority and the learning domain used as the goal, the pedagogical agent also has a different role. According to the sources examined, various types of pedagogical agent roles were identified, including tutors, motivators, study partners, and teachable agents. As with the domain of learning objectives, the role of an agent may be more than one.

TABLE 3. Learning aspect of pedagogical agent.

Aspect		Paper
Environment	Asynchronous	[18], [25], [26], [28], [29], [30], [31], [33], [34], [35], [39], [40], [41], [43], [44], [45], [46], [47], [49], [50], [51], [52], [53], [54], [55], [56], [57], [58], [59], [60], [61], [63], [66],
	Synchronous	[24], [27], [38], [62]
	Other	[48]
Role	Peer	[18], [47], [55], [58]
	Tutor	[24], [28], [29], [30][26], [31], [34], [35], [37], [38], [39], [40], [41], [43], [44], [45], [46], [47], [49], [50], [51], [52], [53], [54], [55], [56], [59], [60], [63], [66]
	Motivator	[24], [28], [29], [38], [43], [50], [51], [52], [54], [55], [56], [66]
	Other	[25], [44], [47], [48], [49], [57], [61]

In a multi-agent system, pedagogical agents often have multiple roles, including a combination of two roles within one agent or different roles for multiple agents in one system. The most common role for pedagogical agents is that of

tutors, followed by motivators. Study partners, teachable agents, and teaching assistants are less commonly used. The authority of a pedagogical agent is closely tied to its role. There are two types of authority: authoritative and non-authoritative. Based on the sources studied, authoritative pedagogical agents dominate, accounting for 68.3%. The remaining agents fall into the category of non-authoritative, or they exhibit a combination of both types, especially in multi-agent systems.

Based on the reviewed reference sources, pedagogical agents are employed to achieve various learning objectives across domains. Specifically, 26 articles focus on cognitive objectives, five on affective objectives, nine on a combination of cognitive and affective objectives, and one on a combined objective of cognitive and psychomotor domains. In contrast, no articles exclusively address the psychomotor domain. It was found that pedagogical agents are mostly used to improve learner's cognition.

3) INTERVENTIONS

The interventions provided by pedagogical agents across the 41 reviewed articles are highly diverse, yet they can be categorized into several groups for discussion. While the types and forms of interventions offered by pedagogical agents vary, most sources primarily utilize text-based interventions, albeit with different content and objectives. Notably, articles discussing the chatbot model all explore interventions aimed at improving communication between agents and students, enhancing both the duration and flow of academic conversations [43], [50], [52]. In other models, interventions can be in the form of explanations about the material or correct answers that should be, guidelines, and words of encouragement [27]. Texts in interventions provided by pedagogical agents can also contain messages to calm students who experience anxiety [42].

Most pedagogical agents are used to provide material, like teachers, in general, but many pedagogical agents deliver material in stages, especially when explaining examples of solving mathematical problems. Still related to learning materials, pedagogical agents are also widely used to provide guidance or instructional steps. Other interventions related to the cognitive domain are assessment of learning outcomes, providing feedback on learning outcomes, instructions, and questions related to the material. This type of delivery of interventions in the cognitive domain can be through learning videos played by pedagogical agents, display prompts in text form, or in the form of debriefing with the pedagogical agent. Interventions in the form of questions and answers in a communicative dialogue between pedagogical agents and learners in the articles studied also have several characteristics.

In the interaction type where questions originate from the learner to the pedagogical agent, the learner may pose open-ended questions or select from a set of predetermined questions. In contrast, when questions are initiated by pedagogical agents, the scenarios can vary. In the case of pedagogical agents assuming the role of a tutor, they typically present questions to assess the learner's understanding. However, pedagogical agents functioning as teachable agents pose questions as if they lack prior knowledge, prompting the learner to provide insights and explanations within the learning context.

Conversely, interventions in the affective domain can be broadly categorized into two groups based on verbal and non-verbal cues. In the verbal form of intervention, the interventions provided were words of encouragement, motivational or reassuring, either in text or audio. Meanwhile, interventions in non-verbal forms can be in the form of expressions shown by the pedagogical agent's face or body movements.

TABLE 4. Learning intervention by pedagogical agent.

Intervention		Paper
Intervention	Learning Material	[26], [30], [31], [34], [38], [39], [40], [41], [45], [46], [50], [51], [52], [53], [54], [56], [57], [58], [59], [60], [63],
	Guidance	[25], [31], [18], [37], [38], [46][50], [54], [58], [61]
	Motivation/ Encouragement	[24], [50], [51], [52], [54], [55], [56], [61], [62], [63]
	Hint	[18], [47], [55], [62]
	Question/ assessment	[18], [44], [47], [48], [49], [55], [59],
	Other	[48], [62]
Emotional Intervention	Non-verbal	[26], [28], [29], [37], [55], [59], [61],
	Verbal	[24], [28], [30], [41], [47], [50], [51], [52], [54], [55], [56], [59],

4) EMOTIONS OF LEARNERS

Emotional aspects related to pedagogical agents have also been examined in the literature sources obtained. Emotions are the reciprocal outcomes of two-way interactions, particularly between the pedagogical agent and the learner and possibly with the teacher if applicable. Hence, the discussion of emotions is categorized into two aspects: emotional input from learners, which can trigger pedagogical agents to act, and external emotions from pedagogical agents, which form part of the intervention as a response to identified learner needs. However, from all the reviewed documents, there is not a single pedagogical agent that works based on the learner's emotional state. While the pedagogical agent can convey emotional responses, the sources studied suggest that the

pedagogical agent does not operate based on the learner's emotional input. This topic will be discussed further in RQ3.

5) EMOTIONS OF PEDAGOGICAL AGENTS

Sixteen references feature pedagogical agents with intervention outcomes related to emotions. Following what has been discussed in the intervention section in the affective domain, emotions are shown in verbal or non-verbal forms. Emotions that can be shown are neutral expressions, happiness, sadness, enthusiasm, sympathy, and anger. The emotions shown are usually consistent with the goals of the intervention and the authority model.

In terms of appearance, the pedagogical agent can be formed in 2D or 3D with avatar display features showing the head or shoulders up area, half body showing the arms, or a view of the whole body. The most common format for displaying pedagogical agents is in 3D, featuring only facial features, as used by twenty-one sources. In contrast, the 2D display format is employed by thirteen sources; one source utilizes robots as pedagogical agents, and the remaining six sources do not visually represent the pedagogical agent's embodiment.

TABLE 5. Design of pedagogical agent.

Pedagogical Agent Design		Paper
3D Human Avatar	Full body	[27]
	Half-body	[24], [26], [29], [30], [31], [35], [37], [38], [40], [61], [62]
	Head only	[23], [33], [47], [50], [54], [55], [58], [63],
2D Human Avatar	Full body	[56]
	Half-body	[25], [28], [39]
	Head only	[18], [43], [44], [46], [49], [51], [52], [59]
Other Avatar Design	Non-human	[41], [60], [66], [36]
	No appearance	[34], [45], [48], [53], [57],

C. RQ3: WHAT KINDS OF INPUTS ARE USED TO ACTIVATE THE PEDAGOGICAL AGENT'S FUNCTIONS?

Not all the reference articles explicitly explain how pedagogical agents operate or what prompts them to initiate intervention or feedback. Therefore, not all the articles discussed in RQ1 and RQ2 are addressed in RQ3. Furthermore, as mentioned in RQ2, no input is specifically used to analyze learner emotions.

According to the study's findings, the most used input to activate the pedagogical agent is initiated by the learner. Another widely used input type is the student's choice using the available menu. In this type, the learner determines when he needs a pedagogical agent. Available options include requesting instructions, assessments, and scheduling. Learner interactions with pedagogical agents resembling conversations with humans are also found in some of the studies studied. Conversely, biometric input methods like speech recognition and emotion recognition based on facial features remain infrequent for pedagogical agents.

Notably, the study of the 41 selected documents reveals that automation technologies, such as artificial intelligence, have not been extensively employed in pedagogical agents. Only ten sources explicitly mention artificial intelligence technology or other automation algorithms implemented in pedagogical agents. Most AI technologies used are related to Natural Language Processing because the pedagogical agents are conversational agents or chatbots. Apart from these ten sources, other sources do not mention explicitly or only use simple conditional programming. Many sources have the pedagogical agent as the narrator in the video-only format.

TABLE 6. Input for pedagogical agent.

Input Type	Paper
Test answer/ work result	[24], [26], [28], [30], [31], [34], [36], [47], [48], [53], [54], [18], [55], [56], [57], [58], [59], [62], [65], [66]
Menu/ user preference	[27], [29], [37], [38], [43], [44], [45]
Chatbot interaction	[41], [46], [49], [52]
Speech recognition	[25], [50]
Emotion recognition	[42]

IV. GENERAL DISCUSSION

A. MODEL DEVELOPMENT FOR EMOTION-BASED PEDAGOGICAL AGENTS

Related models to pedagogical agents that exist in the study results from documents generally come from other models in the educational domain. The ARCS model (Attention, Relevance, Confidence, Satisfaction) is a model used to stimulate motivation to learn [69]. This model was later developed into Extended ARCS for collaborative 3D gaming environments [27]. In the Extended ARCS model, an ARCS framework is integrated with agent actions, including message delivery, warnings, and communication, all aligned with gaming strategies. The focus of this model is primarily on the emotional impact of the pedagogical agent on the expected emotions of the learner.

The cognitive-affective model in learning using learning videos also focuses on discussing how the teacher (in this context, a pedagogical agent) displays positive emotions during learning so that students are aware and then adopt

the teacher's emotions and provide reactions in the form of higher motivation. [13]. This model initiates discussions about the teacher's emotions and assumes that learners will adopt similar emotional states. There is an architecture and protocol of empathic-pedagogical agent interaction in which there are parameters of the user's emotional status and the user's pedagogical status [42]. Other than that, there are also verbal and non-verbal message parameters. This finding shows that the architecture and protocol have paid attention to the learner's emotions for their interaction with the pedagogical agent. However, the best interaction model for a particular case has not yet been explained.

Several studies have introduced frameworks and models for interventions using chatbots [43], [50], [52]. For instance, [43] focuses on developing a practical framework for organizing the flow and delivery of data in conversations with pedagogical agents. The data architecture in [43] shares similarities with the deep interaction architecture and protocol in [42], but it places greater emphasis on facilitating two-way communication through natural language processing (NLP). Furthermore, there is a model designed for implementing communication strategies and affective backchannels to enhance learner motivation in foreign language learning [50]. These strategies encompass approximation, language adjustments, clarification, confirmation, repetition, and expressing incomprehension. The affective backchannel component involves emotional elements like congratulation, encouragement, sympathy, and reassurance. However, it's important to note that while these models tend to generate outputs with certain emotional tendencies, the methods for collecting emotional data are not explained [50]. Additionally, there is a classification system for learners in foreign language learning with pedagogical agents, based on the form and structure of the sentences they use when interacting with the agents [52].

B. THE ROLE, APPEARANCE, AND IT'S IMPACT OF THE PEDAGOGICAL AGENT

Based on the references, it can be concluded that pedagogical agents can assume roles as tutors, guides, motivators, or friends for learners. A single system can implement multiple agents with various roles, including cases where a single agent assumes multiple roles. In agents with more than one role, agents can act as tutors, motivators, or friends for students [28]. An example of an agent with a multi-agent system and multiple roles is one agent acts as a teacher, and another agent becomes a learner's partner in learning so that a trialogue is created where agents acting as partners may have wrong answers while agents with teacher's role always have the right answers [47]. Additionally, the pedagogical agent has the capability to assume the role of a fellow learner, distinct from that of a tutor or teacher. Pedagogical agents acting as peers are valued as having an affinity with the target model, and pedagogical agents acting as co-learners have also been found to positively influence learner motivation and learning [55]. In the example of synchronous learning, the pedagogical agent can help the teacher function as a 'roaming' facilitator to monitor the learning groups of students in the classroom and analyze which groups need the teacher's assistance [48].

Despite numerous studies examining the visual aspects of pedagogical agents, the outcomes of displaying these agents have yielded mixed results. Gestures and facial expressions have been shown to enhance learner's retention performance when they observe agents employing these expressions, as they contribute to a more human-like appearance of the agent [13], [35]. However, several findings show that the appearance of pedagogical agents does not correlate with or improve learning outcomes and is even dangerous because the design of the pedagogical agent itself is the preference of the designer, not the learner who will use it [51]. The meta-analysis also revealed that most of the agent's social behavior (e.g., gestures, facial expressions, gestures, and sounds) is likely irrelevant to instructional effectiveness [10]. Furthermore, an agent's appearance that closely mimics reality may evoke unease and discomfort among students when viewing it [16], [70]. This result is the effect of the uncanny valley, where when an artificial object is made to resemble a human but still has imperfections, it will produce a scary or disturbing effect [71]. Well-designed instructional designs reduce the cognitive load for learners [28]. Therefore, the design of pedagogical agents must be made with great attention to the needs and context of learning.

The existence of pedagogical agents is related to the cognitive load of learners who use the system. Some studies show that agents increase workload and cause students to lose focus, although some also show increased learning [16]. The appearance of the pedagogical agent may be interesting at first, but over time, the visual character can become distracting [63]. Interactions with pedagogical agents unrelated to the task can also be distracting, even if they are distinct [70]. There is no difference in intrinsic cognitive load when using pedagogical agents during the learning process, but it can help germane cognitive load [28].Emotional intervention alone does not have any impact because students focus more on the learning material conveyed by the video, but when combined with gamification, there is a significant difference [36]. Not showing the character of the pedagogical agent on the screen can reduce cognitive load [33]. Interventions using prompts alone have proven necessary and effective for learners [38].

C. THE LEARNING ENVIRONMENT WHERE THE PEDAGOGICAL AGENT IS APPLIED

Most of the research studied applies pedagogical agents to asynchronous learning environments. Pedagogical agents in asynchronous learning are primarily employed in video-based learning systems spanning various learning domains. Conversely, in synchronous learning, very few instances of pedagogical agents have been identified. The predominant use of pedagogical agents occurs within Virtual Learning Environments (VLEs). This is attributed to the inherent

characteristics of pedagogical agents, which are closely tied to their appearance and the capabilities expected of an ideal pedagogical agent.

In a synchronous learning system, the teacher remains within the learning environment, providing instructions and educational materials. In contrast, in asynchronous learning systems, learners are required to study independently. Consequently, pedagogical agents are introduced to replace the teacher's role, equipped with display features and communication abilities. The pedagogical agent is used as a substitute for the teacher whose natural interactions in the real world are that each individual recognizes one another and remembers the history of past interactions, and based on this history, further interactions are made. [72].

D. INTERVENTION BY PEDAGOGICAL AGENT

In general, all actions taken to intervene in development and learning are learning interventions [73]. However, in the context of computer-based learning, learning interventions in particular can be given through several forms of input, such as feedback, instructions, and prompts based on certain measurement methods so that agents provide intelligent assistive guidance [15]. Interventions can be in the form of leading questions, brief feedback (negative, neutral, and positive), corrections, pumps, instructions, and summaries [47]. These forms of intervention have been adopted by several reference sources studied. However, the interesting thing is that many pedagogical agents are used only as speakers of learning material in videos as characters that replace the teacher's role [40], [59]. The pedagogical agent used as a video speaker in video tutorials does not have any form of interaction or communication with the learner. In addition, many agents do not apply artificial intelligence to provide interventions for learners, so pedagogical agent interactions are made by using conditional programming, which is not very adaptive to the needs of learners. This system of pre-scripted pedagogical agents causes the reaction to be the same for all learners [55]. The agent's response to predetermined choices causes the learner's choices to be limited so that the agent's response cannot be considered as an adaptive response [54]. Specific and adaptive interventions to deal with barriers to learning have not been specifically applied.

1) VERBAL INTERVENTION

Research on the topic of verbal abilities of pedagogical agents (or, more specifically, pedagogical conversational agents), where many interventions are given in the form of communication between learners and pedagogical agents [23], [24], [25], [27], [41], [46], [49], [50], [52]. With this type of conversational pedagogical agent, students usually conduct questions and answers with agents who act as tutors so that the interventions given focus on cognitive aspects. Learning materials are provided through these interactions but can also be in the form of documents that are sent. However, with the conversational pedagogical agent communication model, content with micro-learning and smaller content can increase student motivation and interest in learning so that the learning process is more open and flexible [46]. Conversations need to be rich and fluid to engage users, especially for complex tasks like studying [43]. Even though the communication between the learner and the PCA can be done interactively in two directions, the majority of PCA still do not have empathy or other forms of emotion because their learning targets focus on the affective domain. Some PCAs are used as emotional support for learners, such as for learning and encouraging social skills [27] or motivating learners to communicate.

Interventions provided by pedagogical agents related to learner affective are mostly given in motivation. Not only pedagogical agents in the form of chatbots but also agents used to give quizzes or tests to students. The forms of motivation given are such as motivating students to try, motivating students to add questions to be completed, and congratulating each student on experimenting [28]. Emotional support is not only to motivate or encourage students but also to overcome anxiety, uncertainty, and strength to face challenges [54]. Forms of intervention resembling pedagogical agents can also be through robot media where robots convey expressions in verbal and non-verbal forms to empathize and encourage learners [36]. Interventions related to emotions are not always in the form of motivation. Pedagogical agents can also convey scary emotions when delivering material, especially regarding material that requires more emphasis and attention, such as for health and safety, but interspersed with humor to lighten the mood [29].

The emotions shown by the pedagogical agent are also not only in the form of a certain category of emotions but also in the form of the personality of the pedagogical agent itself. The pedagogical agent can be made to have a dominant or submissive personality that is shown non-verbally [37]. Even the angry emotion shown by the agents was also found to be useful for increasing learning performance compared to pedagogical agents, which showed happiness for female learners, but the opposite results were found for male learners [59].

2) NON-VERBAL INTERVENTION

Interventions in the form of non-verbal are generally given to support the learner's affective. Empirical research on the external properties of pedagogical agents suggests that learner motivation can be positively influenced by the embodied presence (i.e., images and sounds) of the agent [55]. For agents with display features that are not only faces but also arms and legs, the intervention can be in the form of gestures such as pointing to something with the hand [28]. However, in general, verbal forms are given based on facial features such as a smile or other expressions that show empathy for the learner, such as surprise and confusion [28]. Gestures given by pedagogical agents can also show their personality, such as crossing their arms and raising their heads; broad gestures indicate a dominant personality while opening their hands,

lowering their heads, and movements with a narrow range indicate a submissive personality [37]. Positive pedagogical agents show smiling facial expressions, expressive facial movements, and happy eyes with enthusiastic voices, while neutral pedagogical agents display flat, expressionless faces and calm voices [40].

E. TYPES OF INPUT THAT TRIGGER THE WORK OF THE PEDAGOGICAL AGENT

Following the findings of RQ1 and RQ2, numerous pedagogical agents have been designed with interactions that are either predetermined from the outset or lack adaptability. Consequently, the input system used is often confined to straightforward choices made by the learner. One frequently employed input method involves students selecting from available menu options. In this scenario, learners determine when they require assistance from a pedagogical agent, with choices such as requesting instructions, assessments, or scheduling.

Based on the study's results, the most used input method for initiating the pedagogical agent's actions is the learner's work. The learner's work may take various forms, including responses to short questions, test scores, essay answers, and other academic outputs. Typically, these learning outcomes assess the cognitive aspects of the learner's understanding, whether related to the material delivered by the pedagogical agent or external to the pedagogical agent system. Fuzzy is used to determine the level of student learning outcomes based on their test scores into three categories, namely low, medium, and high [28].

Artificial intelligence technology can be employed for this type of input, such as evaluating essay assignments or determining the type of intervention based on learning outcomes. However, in general, pedagogical agents still work based on ordinary conditional programming [55]. Interactions with chatbots also represent a widely used input method. This interaction format is present in pedagogical agents in the form of conversational agents, where agents provide educational content progressively, enabling learners to engage in learning through communication with academic material. Input for communication with conversational pedagogical agents can also use biometric input using speech recognition [25].

Apart from speech recognition, the biometric input discussed in the sources used is facial expressions [27].Visual sensor processing of facial features is commonly employed to analyze students' emotions or affective states during the learning process. Visual sensor processing of facial features is commonly employed to analyze students' emotions or affective states during the learning process. Besides, based on facial expressions, data regarding learner emotions can also be collected using a questionnaire [40]. However, this method does not give real-time results, whereas adaptive interventions that reflect intelligent detection and decision-making are needed for the successful design of pedagogical agents [52].

V. RESEARCH OPPORTUNITIES

From the several existing models and frameworks for these pedagogical agents, in every research result, there are still gaps. These gaps can still be studied further by integrating general and main points that can be used as a model or core framework of pedagogical agents, especially those related to learner emotions. Several models have implemented emotional aspects in them but are more oriented towards the expected results of the learner based on what emotions are given by the pedagogical agent itself, regardless of the learner's initial emotional state. In addition, no model specifically links how interventions need to be given to students with certain emotional conditions in real-time, both in video-based synchronous learning. A study on the pedagogical agent model has also not been found based on the role, type of intervention, and emotional outcomes that need to be achieved.

Most existing pedagogical agents provide instructional interventions that are less adaptive and emotionally personalized. The development of interventions that can be provided by pedagogical agents by prioritizing the learner's emotional condition needs to be studied further. The form of emotional intervention provided can be used to increase student motivation, help students be more focused, or assist students who have other emotional problems in the learning process. In addition, currently, existing pedagogical agents are only used for asynchronous online learning, so there is still an opportunity to examine how they are implemented in synchronous online learning and collaboration with human educators.

There are still very few pedagogical agents that use real-time input technology by utilizing artificial intelligence to recognize students' emotional states, even though there has been a lot of research in the development of emotion recognition systems for learning contexts. The development of pedagogical agents that use the results of the emotion recognition system to provide adaptive and personalized learning interventions also needs to be studied as research opportunities that can be carried out to add value to pedagogical agents.

VI. CONCLUSION

This review focuses on pedagogical agents in various learning environments and their interventions based on students' emotions. Currently, the design of models, frameworks, or architectures has not been widely discussed. The most discussed models are for chatbots, as the trend of developing pedagogical agents in the form of chatbots is less common than for asynchronous video-based learning. The models discussed in this review are mostly applicable to asynchronous learning environments, such as serious games, video-based lectures, and chatbots. Therefore, there is a need for further exploration of the pedagogical agent model with emotion-aware interventions in synchronous learning settings.

However, as explained in the Protocol Limitation subchapter, this literature review only uses Scopus-indexed articles

Q1 - Q4 to maintain the literature quality and validity. Yet, this leads to the possibility of the existence of models related to pedagogical agency and student emotions that are not covered in this article. So, a further extensive literature review may be needed even to create models for pedagogical agents related to student emotions.

Apart from the development model, there has been a lot of research on the pedagogical agent, which is related to learner emotions but is still oriented toward the expected results of learner's emotions rather than considering the initial emotional conditions of the learners. There has been limited research on the type of intervention most suitable for the learner's emotional state in real-time. The practical development of emotion-aware pedagogical agents has also not been widely studied. In alignment with existing models, most developed pedagogical agents primarily focus on asynchronous learning environments. These pedagogical agents mainly support cognitive aspects, as their predominant role is that of a tutor, and they are often used to provide learning materials.

Lastly, using emotion recognition technology has not been frequently mentioned in the references, making it challenging to provide interventions tailored to the learner's emotional condition based on their biometric features. Existing pedagogical agents primarily rely on students' work results or user choices, though the trend toward chatbots suggests the potential for increased sophistication. Therefore, research opportunities in developing pedagogical agents that implement intelligent systems such as chatbot systems and emotion recognition for real-time intervention in synchronous environments are still enormous.

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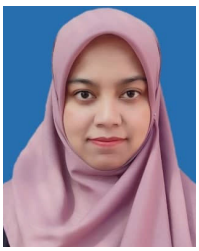

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