THE DESIGN AND IMPACT OF THE PEDAGOGICAL AGENT: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

A pedagogical agent is an anthropomorphic virtual character used in an online learning environment to serve instructional purposes. The design of pedagogical agents changes over time depending on the desired objectives for them. This article is a systematic review of the research from 2007 to 2017 related to the design factors of pedagogical agents and their impact on learning environments. The objective of this review is to identify and analyze pedagogical agents through the context in which they are constructed, the independent variables used in pedagogical agent research, and the impact of the pedagogical agent implementation. The review found that research on the design of pedagogical agents has different forms, namely text, voice, 2-D character, 3-D character, and human. The independent variables used in the studies are categorized into the appearance of agents and the role of agents. Moreover, the combination of pedagogical agent designs and role designs of pedagogical agents has significant positive impacts on student learning and student behavior. Recommendations are also provided at the end of this review.

Keywords: systematic literature review, pedagogical agent, teachable agent, learning motivation, agent role, learning outcome, e-learning.

INTRODUCTION

The pedagogical agent is a field of research that has emerged over the past two decades (Schroeder & Adesope, 2014) and has been shown to provide support for the needs of learners by reacting to the learning pathway students undertake (Clarebout, Elen, Johnson, & Shaw, 2002). Literally, pedagogical agents are intelligence agents with a pedagogical agenda (Haake, 2009) and refer to computer-generated characters used in educational settings to fulfill pedagogical goals (Gulz, Haake, Silvervag, Sjödén, & Veletsianos, 2011a). A pedagogical agent is an anthropomorphic virtual character used in an online learning environment to serve instructional purposes (Veletsianos & Russel, 2013) and to serve as a learning tool by providing help and guidance, demonstrating principles and procedures, and demonstrating examples to help learners process and store information so they can learn anytime and anywhere. The learning environment of pedagogical agents was made from scratch using complex computer programs, but now cheap and easy-to-operate software is available to educators who want to include agents in their instruction (Schroeder & Adesope, 2012). Previous research has shown that students who interact with agents produce more solutions in tests than students who do not interact with them (Moreno, Mayer, Spires, & Lester, 2001). Notwithstanding the fact that pedagogical agents cannot completely replace human-human interactions, pedagogical agents may provide motivational benefits, such as reduced anxiety and increased involvement, to learners in some situations (Schroeder & Adesope, 2014)

and improve learning and student performance (Veletsianos & Russell, 2013).

Research on pedagogical agents was originally done from a technological perspective, and research on pedagogical agents from an educational perspective began in the late 1990s (Clarebout et al., 2002). The development of pedagogical agents varies from year to year. Between 2007 and 2017, researchers claimed that pedagogical agents provided support in education as mentors, motivators, facilitators, navigators, and collaboration assistants. Until now research on pedagogical agents was based on the agents' appearance, how they communicate with learners (verbally or nonverbally), and how they provide feedback to improve learners' performance, increase learning activities, motivate learners, and increase engagement. With the advancement of human-computer interaction technology, it is possible to create more human-like and realistic pedagogical agents. This article provides an analysis of the opportunities and challenges of implementing pedagogical agents based on the independent and dependent variables required in pedagogical agent design. The results of this review enable researchers from various fields of studies to develop pedagogical agents using the best design to achieve their desired impacts.

This systematic literature review (SLR), which is based on Kitchenham and Charters (2007), investigates several research papers published between 2007 and 2017. It aims to identify and analyze pedagogical agents through the context in which they are constructed, the independent variables used in pedagogical agent research, and their impacts in the context of learning.

This article is divided into six sections:

1. the introduction
2. information on related works about pedagogical agent reviews
3. a discussion of pedagogical agent theories
4. the results of the systematic review
5. a discussion of pedagogical agent design and recommendations
6. the conclusion

A REVIEW OF PEDAGOGICAL AGENT RESEARCH

To understand the current development of pedagogical agent research, this study reviews papers published in IEEEXplore, Science Direct, ACM Digital Library, Springer, and Web of Science in a ten-year period from 2007 to 2017. The criteria used in this study are (1) that the article is an empirical study; (2) that the article is published in English; and (3) that learning outcome is the main output (a dependent variable). To collect the relevant studies, online database searches were conducted with the keywords: "pedagogical agent*" OR "teachable agent*."

Kim and Baylor (2016) reviewed the research progress in pedagogical agent roles and capabilities based on their original work in 2005. They found that what students want from an agent are good teaching ability (the agent should be knowledgeable) and the ability to give motivation (the agent should be friendly and kind). They also found that students significantly learn better and have greater motivation when working with two agents (split-persona effect) than with one mentor agent.

This review is different from Kim and Baylor (2016) and the other previous reviews that were done in the 2007–2017 period in two ways (e.g., Ergül & Koç, 2013; Guo & Goh, 2015; Heidig & Clarebout, 2011; Schroeder & Adesope, 2013; Schroeder & Adesope, 2014; Schroeder, Adesope, & Gilbert, 2013; Schroeder & Gotch, 2015; Soliman & Guetl, 2010; and Veletsianos & Russell, 2013). First, this study follows the guidelines of Kitchenham and Charters (2007) to identify pedagogical agent research papers. The guidelines summarize three stages in a systematic review: (1) planning a review, (2) conducting a review, and (3) reporting a review. Second, this study focuses on how pedagogical agents are designed and their impacts on student learning. The research questions guiding the review of pedagogical agents are as follows:

1. How are pedagogical agents constructed?
2. Which independent variables should be included in pedagogical agent designs?
3. What are the significant results in respect to empirical evidence of the impact of the implementation of pedagogical agents?

PEDAGOGICAL AGENT THEORIES

The evolution of technology is an integral part of the improvement of pedagogical agents. Human Computer Interaction (HCI) technology plays an important role in the design of pedagogical agents. He et al. (2017), in a study of HCI, found that voice interaction technology is one of the fastest

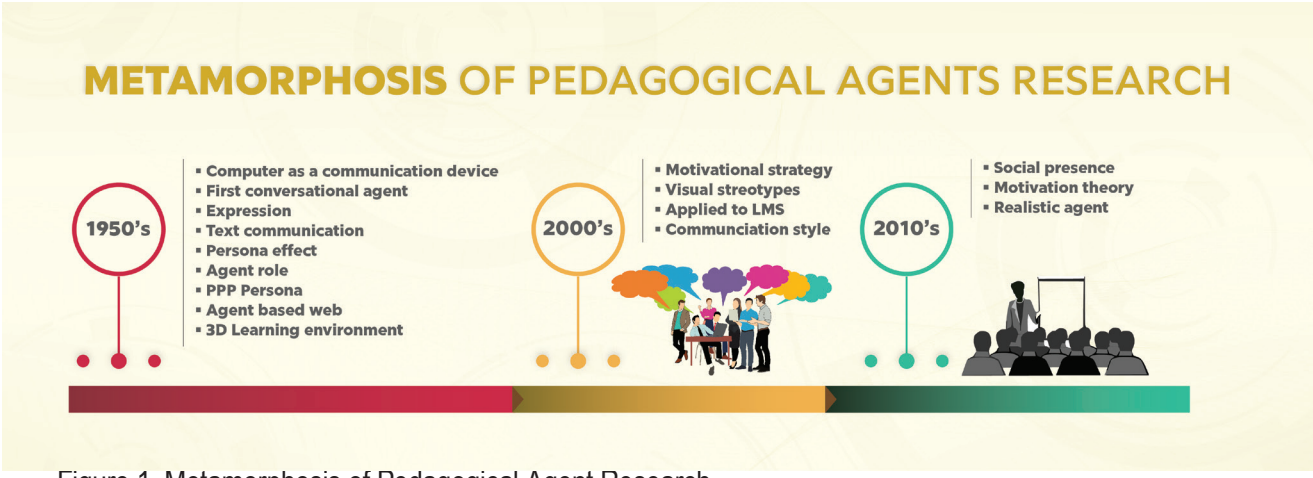

Figure 1. Metamorphosis of Pedagogical Agent Research

growing HCI technologies, which includes voice recognition, speech synthesis, and natural language understanding. Gesture interaction technology has also been studied extensively in recent years. Human head movement recognition technology based on two-dimensional graphics, three-dimensional images, or deeper image recognition algorithms is increasingly being noticed by researchers. Augmented reality technology is also a new field of study for the design of pedagogical agents. Zhen-Yu (2012) in He et al. (2017) states that augmented reality, using interactive technology, sensors, and computer graphics generated in virtual environments, provides a harmonious environmental reality in which virtual elements appear to be part of the real environment.

Social agency theory is the theoretical framework most frequently used in pedagogical agent research. It assumes that sounds and images in pedagogical agents build social cues and trigger social responses that can improve student activities to learn the material deeply (Atkinson, Mayer, & Merrill, 2005). The development of pedagogical agents varies from year to year. Figure 1 illustrates the metamorphosis of pedagogical agent research. The definition of pedagogical agents also evolved in accordance with the research undertaken. The different definitions of pedagogical agents can be seen as follows:

1. Pedagogical agents are animated characters (Carlotto & Jaques, 2016; Kim, 2016; Liew, Zin, & Sahari, 2017; and Rančić, Kuk, Pronić-Rančić, & Ranelović, 2015); digital characters (Kim, Thayne, & Wei, 2017); virtual characters (Da Costa Pinho, Epstein, Reategui, Corrêa, & Polonia, 2013; and Schroeder, Romine, & Craig, 2017); autonomous characters (Johnson & Lester, 2016); chatbots (Savin-Baden, Tombs, & Bhakta, 2015); and lifelike characters (Schroeder & Gotch, 2015) that are embedded in a computer-based or virtual learning environment.

2. Pedagogical agents are agents used to enhance student learning (Schroeder et al., 2017); to create a high face-to-face learning interaction (Johnson & Lester, 2016); to simulate conversations (text or speech) and nonverbal behavior (Liew & Tan, 2016); to assist students in the learning process (Carlotto & Jaques, 2016); to facilitate learning (Schroeder & Gotch, 2015); to guide users (van der Meij, van der Meij, & Harmsen, 2015); and to support the roles of students and teachers (Terzidou & Tsiatsos, 2014).

3. Pedagogical agents are agents who act as a tutor (Kim, 2016); as agents for educational purposes (Mohtadi, Hajami, & Allali, 2014; and Savin-Baden et al., 2015); as intelligent agents developed based on pedagogical learning theory (Lim, Ailiya, Miao, & Shen, 2014); and as agents that can operate continuously and autonomously to support student activities (Da Costa Pinho et al., 2013).

Based on the above notions, it can be concluded that a pedagogical agent is an agent (single or multi) in the form of a virtual character equipped with artificial intelligence that can support the students' learning process and use various instructional strategies in an interactive learning environment. A teachable agent is a special kind of pedagogical agent that uses the benefits of learning by teaching (Blair, Schwartz, Biswas, & Leelawong, 2007).

Teachable agents work by letting students teach them and then assessing their knowledge by providing a series of questions to solve problems.

RESULTS

This section presents findings based on our analysis of the published research. We used nonstatistical methods to evaluate and interpret the findings of the study. Based on the aforementioned search strategy, a total of 347 papers were found and 121 papers fulfilled the inclusion criteria. However, only 50 papers were accepted to be reviewed (21 papers were rejected because their full version could not be accessed, 27 papers were rejected because there was no control group, 20 papers were rejected because there was no significant evidence, and three papers were rejected because they were are not relevant to the research questions).

This section describes the relationship between the design of pedagogical agents and the independent variables used in the appropriate results. The current review only focuses on the 50 papers with significant results, which are described in Table 1. Table 1 illustrates how pedagogical agents are designed, the variables used to influence the performance of pedagogical agents, and the significant variables that result from the implementation of pedagogical agents. The findings are presented in the next paragraph to answer the research questions.

Addressing Research Question 1: How are Pedagogical Agents Constructed?

Research on the design of pedagogical agents has five forms: text, voice, 2-D character, 3-D character, and human. However, some researchers combine 2 or 3 forms. This is in accordance with one of the principles of pedagogical agent designs of Moreno, namely, the principle of modalities (Clarebout & Heidig, 2012; Moreno, 2005), which suggests that pedagogical agents communicate better via spoken text than voice or text only. This study has found that the most widely used form is text (72%), 31 papers use the combination of text and other forms, and five papers use text only. The second most widely used form is 3-D character (52%). According to Schroeder and Adesope's review (2013), a more realistic 3-D agent form can be more precise and effective than a 2-D agent form. There are 24 papers that use 3-D characters with other forms as a pedagogical agent and two papers that use 3-D characters only. The least used form is human (4%) and the use of this form is found in Schroeder and Traxler (2017) with significant results. There were only two papers that use human with voice or human with text. According to Schroeder and Traxler (2017), the addition of human physical representation into the learning environment provides a higher and more compelling human-like value that can increase involvement in learning. This is consistent with Wang and Antonenko (2017), who state that the presence of instructors produces a significant positive effect on learning, satisfaction, and mental effort, which is an important factor that contributes to learner motivation and engagement in self-regulated online learning environments. Finally, voice form is never used alone. Selection of voice form is always combined with other forms. Likewise, there are only three papers that use 2-D characters without being merged with other forms. The distribution of pedagogical agent designs can be seen in Table 1.

Addressing Research Question 2: Which Independent Variables Should be Included in Pedagogical Agent Designs?

In this review, we have found a study using various independent variables. However, in general all these variables lead to two things: the appearance of agents and/or the role of agents. The study of these two general variables is aimed at helping agents to guide the learning process and provide motivation in learning through their visual presence and behavior. Our study has found that 40% of the research papers focus on the role of agents, 38% focus on agent appearance, and 22% focus on the role and appearance of agents. In the research focusing on the appearance of agents, independent variables used are visual variables that can be seen directly by students: presence, performance, age, gesture, appeal, gender, cueing, enthusiasm, ethnicity, intervention, affection, emotion, empathy, facial expression, first impression, and noninteractive talking of agents. Meanwhile, in the research focusing on the role of agents, independent variables used are the variables that guide the learning process associated with the theory of motivation in education: instructor/navigation/guidance, collaboration assistant, motivator, expert/mentor, facilitator, metacognitive suggestion, reminder, self-report, and hint/feedback/prompt. The dissemination of

Table 1. The Distribution of Studies on Design, Independent Variable, and Dependent Variable

Author(s)	Design of Pedagogical Agent					Independent Variable		Dependent Variable (Significant Result)		
	T	V	2-D	3-D	H	Agent Appearance	Agent Role	Student Learning Outcome	Student Behavior	Agent Value
Kizilkaya and Askar (2008)	✓		✓				ING Motivator	SA		
Baylor and Kim (2009)			✓			Gesture Facial expr.	ING	LG	PERC	IE
Chase et al. (2009)	✓		✓			Presence	ING HFP	LT LA		
Jaques et al. (2009)	✓		✓			Presence Affective Emotional	HFP	SP		
Cheng et al. (2009)	✓	✓	✓				HFP	SP LA		
Chin et al. (2010)	✓		✓				HFP	SP		
Murray and Tenenbaum (2010)		✓		✓			ING Motivator EM	LG	SE PERC	
Veletsianos (2010)		✓		✓		Presence Facial expr. First impr.		LG		
Woolf et al. (2010)	✓		✓			Affective Intervention	HFP		SC AFF EX PERC	
Gulz et al. (2011b)	✓						ING HFP	SX LG		
Arroyo et al. (2011)			✓			Presence Emotional	Motivator HFP		AFF	
Kim and Wei (2011)	✓			✓		Gender Ethnicity			ATT	
Matsuda et al. (2011)	✓			✓		Presence	HFP	SS		
Ozogul et al. (2011)	✓		✓			Age		LA		
Pareto et al. (2011)	✓						ING	SP LG	SE	
Azevedo et al. (2012)	✓			✓			MS HFP	LT LE		
Matsuda et al. (2012)	✓			✓			HFP	LG		
Pareto et al. (2012)	✓						ING	SS		
Johnson et al. (2013)		✓		✓		Gesture Cueing Facial expr.		LG		

Author(s)	Design of Pedagogical Agent					Independent Variable		Dependent Variable (Significant Result)		
	T	V	2-D	3-D	H	Agent Appearance	Agent Role	Student Learning Outcome	Student Behavior	Agent Value
Wang and Yeh (2013)				✓		Appeal Gender		LA	PERC	Recall
Chin et al. (2013)			✓			Performance	HFP	LG		
Lin et al. (2013)	✓			✓		Presence	HFP	SS		
Matsuda et al. (2014)	✓		✓				MS	LA		
Osman and Lee (2014)		✓	✓			Gesture Facial expr.	ING CA Motivator EM	SP SS		
Pareto (2014)	✓						HFP	LG	SAT ENG	
Tzeng and Wang (2014)			✓				HFP	SP	PE	
Terzidou and Tsiatsos (2014)	✓						Motivator Facilitator Reminder		PU	
Duffy and Azevedo (2015)	✓			✓		Presence	Motivator HFP	LA	SRL	
Shiban et al. (2015)	✓			✓		Presence Age Gesture Gender	HFP	SP	INT	
Sjödén and Gulz (2015)	✓		✓				ING HFP	SP		
van der Meij et al. (2015)		✓		✓		Gender	Motivator		SE	
Yung and Pass (2015)	✓		✓			Cueing	HFP	SP		IE
Adamo-Villani and Dib (2016)	✓	✓		✓		Gesture Appeal		LG		
Azevedo et al. (2016)	✓			✓		Emotional	ING Motivator SRM HFP	LG	MMR	
Bouchet et al. (2016)	✓			✓			HFP		SRL	
Guo and Goh (2016)	✓		✓			Gesture Affective Facial expr.	HFP		EN BI LM PU	
Hayashi (2016)	✓			✓		Gesture	Facilitator MS	SP		

Author(s)	Design of Pedagogical Agent					Independent Variable		Dependent Variable (Significant Result)		
	T	V	2-D	3-D	H	Agent Appearance	Agent Role	Student Learning Outcome	Student Behavior	Agent Value
Krämer et al. (2016)				✓		Gesture Gender		SP		
Lalle et al. (2016)	✓			✓		Emotional	HFP		EEM	
Martin et al. (2016)	✓			✓			HFP	LG		
Mondragon et al. (2016)	✓			✓		Emotional	ING Motivator HFP	SP		
Terzidou et al. (2016)	✓			✓			ING CA Motivator Facilitator		ATT COH	
Beege et al. (2017)	✓	✓		✓		Age		SP		
Wang and Antonenko (2017)		✓			✓	Presence Gesture Facial expr.		LG	S VA	Recall
Kim et al. (2017)	✓		✓				ING HFP	LT	AX	
Liew, Tan et al. (2017)	✓	✓	✓			NIT			PERC	
Liew, Zin et al. (2017)		✓		✓		Gesture Cueing Enthusiasm Emotional Facial expr.	HFP		AFF EEM CO LM	
Schroeder and Traxler (2017)	✓				✓	Presence Performance		TE	ENG ME	
Thompson and McGill (2017)		✓		✓		Gender Ethnicity Emphatic	HFP		SE ATT	EVA
Xie and Luo (2017)	✓			✓			HFP	STC LA	S	

Design of Pedagogical Agent. T: text; V: voice; 2-D: 2-D character; 3-D: 3-D character; H: human.

Agent Appearance. Facial expr: facial expression; First impr: first impression; NIT: noninteractive talking.

Agent Role. ING: instructor/navigator/guidance; CA: collaboration assistant; EM: expert/mentor; MS: Metacognitive suggestion; SRM: self-report measures; HFP: hint/feedback/prompt.

Student Learning Outcome. SP: student performance; SX: student experience; STC: student task-completion; SS: student score; SA: student achievement; LT: learning time; LE: learning efficiency; LA: learning activities; TE: training efficiency; LG: learning gain.

Student Behavior. SC: self-concept; SRL: self-regulated learning strategies; SE: self-efficacy; SAT: student act as a tutor; AFF: affective outcome; ATT: attitude; EN: enjoyment; BI: behavioral intention; EEM: enhanced emotions; CO: cognitive outcome; ENG: engagement; S: Satisfaction; AX: anxiety; EX: excitement; PERC: student perceptions; INT: student interest; LM: learning motivation; COH: cohesiveness; PE: perceived effort; PU: perceived usefulness; VA: visual attention; ME: moderate effect; MMR: metacognitive monitoring and regulation.

Agent Value. EVA: evaluation; IE: instructional efficiency.

research on the use of independent variables can be seen in Table 1.

Addressing Research Question 3: What are the Significant Results in respect to Empirical Evidence of the Impact of the Implementation of Pedagogical Agents?

Only 12 papers show significant impacts of the implementation of pedagogical agents. The fact that the rest do not show any significant impacts provides an opportunity for future research. Our review will only present papers with significant results to know the current research development on pedagogical agents. The significant variables in our study are divided into three groups: student learning outcome, student behavior, and agent value. Some research on pedagogical agents shows that the pedagogical agent implementation has significant impacts on the process and learning outcomes. In our review, 76% of the research papers show significant impacts of the implementation of pedagogical agents on student learning outcomes. In the student behavior group, the study shows that there are significant impacts of the implementation on the changes in student behavior or the changes perceived by students during the learning process and/or after learning with pedagogical agents. A total of 50% of the studies show significant results in student behavior. In the agent value group, the researcher focuses on the student's assessment of the agent, and the reuse of the agent by the student. This becomes important in the studies that focus on visual appearance of agents. The dissemination of research with significant results can be seen in Table 1.

These are the variables included in student learning outcomes: student performance, student experience, student task-completion, student score, student achievement, learning time, learning efficiency, learning activities, learning gain, and training efficiency. Meanwhile, these variables are included in the student behavior group: students acting as tutors, affective outcomes, attitudes, enjoyment, behavioral intention, enhanced emotions, cognitive outcomes, engagement, satisfaction, anxiety, excitement, student perceptions, student interest, learning motivation, cohesiveness, perceived effort, perceived usefulness, visual attention, self-concept, self-regulated learning strategy, self-efficacy, metacognitive monitoring and regulation, and moderate effects. The last group is the agent values, and the variables belonging to this group are recall pedagogical agent, evaluation, and instructional efficiency.

DISCUSSION AND RECOMMENDATIONS

Following advances in computer technology, the design of pedagogical agents has become more human-like and these agents are expected to promote learning and knowledge transfer (Lewis, 2003). Good design elements in constructing pedagogical agents can make students more involved in learning (Heidig & Clarebout, 2011), but the design needs to be integrated with the latest technologies on character art, animation, natural speech, movement, and nonverbal communication.

The character design of pedagogical agents will have a significant positive impact on student learning (e.g., Adamo-Villani & Dib, 2016; Beege, Schneider, Nebel, Mittangk, & Rey, 2017; Johnson, Ozogul, Moreno, & Reisslein, 2013; Krämer, Karacora, Lucas, Dehghani, Rüther, & Gratch, 2016; Ozogul, Reisslein, & Johnson, 2011; and Veletsianos, 2010) and may influence student behavior (e.g., Kim & Wei, 2011; Liew, Tan, Ismail, 2017). Research done by Wang and Yeh (2013), Schroeder and Traxler (2017), and Wang and Antonenko (2017) shows significant results on student learning outcomes and student behavior. The design of pedagogical agents also has a major impact on the learning environment and the role of pedagogical agents can significantly improve student learning outcomes (e.g., Azevedo et al., 2012; Cheng et al., 2009; Chin et al., 2010; Gulz, Haake, & Silvervarg,2011b; Kizilkaya & Askar, 2008; Martin et al., 2016; Matsuda et al., 2012; Matsuda et al., 2014; Pareto, Haake, Lindström, Sjödén, & Gulz, 2012; and Sjödén & Gulz, 2015), alter student behavior (e.g., Bouchet, Harley, & Azevedo, 2016; Terzidou & Tsiatsos, 2014; and Terzidou, Tsiatsos, Miliou, & Sourvinou, 2016) and both (e.g., Kim et al., 2017; Murray & Tenenbaum, 2010; Pareto, Arvemo, Dahl, Haake, & Gulz, 2011; Pareto, 2014; Tzeng & Wang, 2014; and Xie & Luo, 2017). The combination of the character design and the role design of pedagogical agents has a significantly positive impact on student learning and student behavior (e.g., Arroyo, Woolf, Cooper, Burleson, & Muldner, 2011; Azevedo et al., 2016; Baylor & Kim, 2009; Chase, Chin, Oppezzo, & Schwartz,

2009; Chin, Dohmen, & Schwartz, 2013; Duffy & Azevedo, 2015; Jaques, Lehmann, & Pesty, 2009; Laile et al., 2016; Liew et al., 2017; Lin, Atkinson, Christopherson, Joseph, & Harrison, 2013; Matsuda et al., 2011; Mondragon, Nkambou, & Poirier, 2016; Osman & Lee, 2014; Shiban et al., 2015; Thompson & McGill, 2017; van der Meij et al., 2015; Woolf et al., 2010; and Yung & Pass, 2015).

Pedagogical agent design is always associated with motivation in learning. As a dependent variable, pedagogical agents have an impact on learning motivation levels (such as self-efficacy, cognitive outcome, anxiety, engagement), and as an independent variable they can be manipulated to improve learning motivation (such as expression, emotion, feedback, suggestion). A major challenge for designing pedagogical agents is to make them capable of diagnosing emotional states and motivating students in learning processes to adjust to agent instructional behaviors (Krämer & Bente, 2010).

The most common motivational framework used in pedagogical agent research is social-cognitive. Kim and Baylor (2007) argue that pedagogical agents can enhance conventional computer-based learning and can effectively serve as a social-cognitive tool that serves to build social relationships, model new beliefs and attitudes, and share empathy, which allows learners to show better performances and more positive attitudes. In social-cognitive theory, self-efficacy is emphasized as a key driver of motivated actions, and cues that affect future self-efficacy and support self-regulated learning are identified (Cook & Artino, 2016). The concept of self-regulation is important in pedagogical agent research as it regulates how students manage their motivation and learning in distance learning environments. This study found that only four papers use self-efficacy (e.g., Murray & Tenenbaum, 2010; Pareto et al., 2011; Thompson & McGill, 2017; and van der Meij, et al., 2015) and two papers use self-regulated learning as impact variables (e.g., Bouchet et al., 2016; and Duffy & Azevedo, 2015).

This study does not find information on how pedagogical agents are applied in the instructional design using pedagogy or andragogy, which would impact learning techniques and goal achievement. Self-regulated learning is often used in the pedagogical method, while the andragogy method is self-directed learning. Self-regulated learning is commonly used in school environments, but it also applies in personal learning environments. Self-regulated learning is considered a microlevel concept (Saks & Leijen, 2014). According to Jossberger et al. (as cited in Saks & Leijen 2014), self-directed learning is considered a wider construction that includes more specific self-regulated learning but not vice versa. Self-directed learning goes into the macrolevel concept. In self-directed learning, students can independently start learning tasks, whereas in self-regulated learning, tasks can be governed by the teacher (Robertson, 2011). Thus, self-directed learning is suitable for adults or undergraduate students.

We suggest that pedagogical agent research continues to build and broaden the scope of motivational theory beyond the socio-cognitive to incorporate some motivational theories tailored to the levels of student education and use pedagogy/andragogy methods, or a combination of both, to have an impact on motivation and learning. With respect to the development of Human Computer Interaction (HCI) and augmented reality technologies, we also recommend that the future visual design research of pedagogical agents using HCI technology be combined with augmented reality technology.

CONCLUSION

The current paper presents a systematic literature review of the empirical evidence of pedagogical agent research. The review has found that the mixed design factors of pedagogical agent research significantly improve learning performance and student behavior. Some of the motivation theories are used in pedagogical agent research as part of the pedagogical agent design. This study provides recommendations to address those opportunities and challenges. The results of this study can be used as a reference by any institution to do an initial analysis on pedagogical agents.

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REFERENCES

Adamo-Villani, N., & Dib, H. N. (2016). A study of the effects of teaching avatars on students' learning of surveying mathematics. International Journal of Information and Communication Technology Education, 12(2), 1–13. doi:10.4018/IJICTE.2016040101

Arroyo, I., Woolf, B. P., Cooper, D. G., Burleson, W., & Muldner, K. (2011). The impact of animated pedagogical agents on girls' and boys' emotions, attitudes, behaviors and learning. In Proceedings of the 2011 11th IEEE International Conference on Advanced Learning Technologies, ICALT 2011 (pp. 506–510). doi:10.1109/ICALT.2011.157

Atkinson, R. K., Mayer, R. E., & Merrill, M. M. (2005). Fostering social agency in multimedia learning: Examining the impact of an animated agent's voice. Contemporary Educational Psychology, 30(1), 117–139. doi:10.1016/j.cedpsych.2004.07.001

Azevedo, R., Landis, R. S., Feyzi-Behnagh, R., Duffy, M., Trevors, G., Harley, J. M., Bouchet, F., Burlison, J., Taub, M., Pacampara, N., Yeasin, M., Rahman, A. K. M. M., Tanveer, M. I., & Hossain, G. (2012). The effectiveness of pedagogical agents' prompting and feedback in facilitating co-adapted learning with metatutor. In S. A. Cerri, W. J. Clancey, G. Papadourakis, & K. Panourgia (Eds.), Intelligent Tutoring Systems: 11th International Conference, ITS 2012, Chania, Crete, Greece, June 14–18, 2012. Proceedings (pp. 212–221). Berlin, Heidelberg: Springer Berlin Heidelberg. doi:10.1007/978-3-642-30950-2_27

Azevedo, R., Martin, S. A., Taub, M., Mudrick, N. V, Millar, G. C., & Grafsgaard, J. F. (2016). Are pedagogical agents' external regulation effective in fostering learning with intelligent tutoring systems? In A. Micarelli, J. Stamper, & K. Panourgia (Eds.), Intelligent Tutoring Systems, ITS 2016 (Vol. 9684; pp. 197–207). doi:10.1007/978-3-319-39583-8_19

Baylor, A. L., & Kim, S. (2009). Designing nonverbal communication for pedagogical agents: When less is more. Computers in Human Behavior, 25(2), 450–457. doi:10.1016/j.chb.2008.10.008

Beege, M., Schneider, S., Nebel, S., Mittangk, J., & Rey, G. D. (2017). Ageism—age coherence within learning material fosters learning. Computers in Human Behavior, 75, 510–519. doi:10.1016/j.chb.2017.05.042

Blair, K., Schwartz, D. L., Biswas, G., & Leelawong, K. (2007). Pedagogical agents for learning by teaching: Teachable agents. Education Technology, 47, 56–61.

Bouchet, F., Harley, J. M., & Azevedo, R. (2016). Can adaptive pedagogical agents' prompting strategies improve students' learning and self-regulation? In A. Micarelli, J. Stamper, & K. Panourgia (Eds.), Intelligent Tutoring Systems, ITS 2016 (vol. 9684; pp. 368–374). doi:10.1007/978-3-319-39583-8_43

Carlotto, T., & Jaques, P. A. (2016). The effects of animated pedagogical agents in an English-as-a-foreign-language learning environment. International Journal of Human Computer Studies, 95, 15–26. doi:10.1016/j.ijhcs.2016.06.001

Chase, C. C., Chin, D. B., Oppezzo, M. A., & Schwartz, D. L. (2009). Teachable agents and the protégé effect: Increasing the effort towards learning. Journal of Science Education and Technology, 18(4), 334–352. doi:10.1007/s10956-009-9180-4

Cheng, Y., Chen, L., Huang, H., Weng, S., Chen, Y., & Lin, C. (2009). Building a general purpose pedagogical agent in a web-based multimedia clinical simulation system for medical education. IEEE Transactions on Learning Technologies, 2(3), 216–225. doi:10.1109/TLT.2009.18

Chin, D. B., Dohmen, I. M., Cheng, B. H., Oppezzo, M. A., Chase, C. C., & Schwartz, D. L. (2010). Preparing students for future learning with teachable agents. Educational Technology Research and Development, 58(6), 649–669. doi:10.1007/s11423-010-9154-5

Chin, D. B., Dohmen, I. M., & Schwartz, D. L. (2013). Young children can learn scientific reasoning with teachable agents. IEEE Transactions on Learning Technologies, 6(3), 248–257. doi:10.1109/TLT.2013.24

Clarebout, G., Elen, J., Johnson, W. L., & Shaw, E. (2002). Animated pedagogical agents: An opportunity to be grasped? Journal of Educational Multimedia and Hypermedia, 11(3), 267–286.

Clarebout, G., & Heidig, S. (2012). Pedagogical agents. In Seel, N. M. (Eds.) Encyclopedia of the Sciences of Learning, vol. 6 (pp. 2567-2571). New York: Springer.

Cook, D., & Artino, A. R. (2016). Motivation to learn: An overview of contemporary theories. Medical Education, 50(10), 997–1014. doi:10.1111/medu.13074

Da Costa Pinho, I., Epstein, D., Reategui, E. B., Corrêa, Y., & Polonia, E. (2013). The use of text mining to build a pedagogical agent capable of mediating synchronous online discussions in the context of foreign language learning. In Proceedings—Frontiers in Education Conference, FIE (pp. 393–399). IEEE. doi:10.1109/FIE.2013.6684853

Duffy, M. C., & Azevedo, R. (2015). Motivation matters: Interactions between achievement goals and agent scaffolding for self-regulated learning within an intelligent tutoring system. Computers in Human Behavior, 52, 338–348. doi:10.1016/j.chb.2015.05.041

Ergül, E., & Koç, M. (2013). The role of animated agents in web-based distance education. Procedia—Social and Behavioral Sciences, 83,1016–1022. doi:10.1016/j.sbspro.2013.06.189

Gulz, A., Haake, M., Silvervarg, A., Sjödén, B., & Veletsianos, G. (2011a). Building a social conversational pedagogical agent: Design challenges and methodological approaches. In D. Perez-Marin & I. Pascual-Nieto (Eds.), Conversational Agents and Natural Language Interaction: Techniques and Effective Practices (pp. 128–155). doi:10.4018/978-1-60960-617-6.ch006

Gulz, A., Haake, M., & Silvervarg, A. (2011b). Extending a teachable agent with a social conversation module—effects on student experiences and learning. In G. Biswas, S. Bull, J. Kay, & A. Mitrovic (Eds.), Artificial Intelligence in Education: 15th International Conference, AIED 2011, Auckland, New Zealand, June 28–July 2011 (pp. 106–114). Berlin, Heidelberg: Springer Berlin Heidelberg. doi:10.1007/978-3-642-21869-9_16

Guo, Y. R., & Goh, D. H.-L. (2015). Affect in embodied pedagogical agents: Meta-analytic review. Journal of Educational Computing Research, 53(1), 124–149. doi:10.1177/0735633115588774

Guo, Y. R., & Goh, D. H.-L. (2016). Evaluation of affective embodied agents in an information literacy game. Computers & Education, 103(C), 59–75. doi:10.1016/j.compedu.2016.09.013

Haake, M. (2009). Embodied pedagogical agents from visual impact to pedagogical implications (Doctoral thesis, Lund University). Retrieved from http://lup.lub.lu.se/record/1389720

Hayashi, Y. (2016). Coordinating knowledge integration with pedagogical agents effects of agent gaze gestures and dyad synchronization. In A. Micarelli, J. Stamper, & K. Panourgia (Eds.), Intelligent Tutoring Systems, ITS 2016 (Vol. 9684; pp. 254–259). doi:10.1007/978-3-319-39583-8_26

He, Z., Chang, T., Lu, S., Ai, H., Wang, D., and Zhou, Q. (2017). Research on human-computer interaction technology of wearable devices such as augmented reality supporting grid work. International Congress of Information and Communication Technology (ICICT 2017), Procedia Computer Science, 107, 170–175. doi:10.1016/j.procs.2017.03.074

Heidig, S., & Clarebout, G. (2011). Do pedagogical agents make a difference to student motivation and learning? Educational Research Review 6(1):27–54. doi:10.1016/j.edurev.2010.07.004

Jaques, P. A., Lehmann, M., & Pesty, S. (2009). Evaluating the affective tactics of an emotional pedagogical agent. In Proceedings of the 2009 ACM Symposium on Applied Computing (pp. 104–109). New York, NY: ACM. doi:10.1145/1529282.1529304

Johnson, A. M., Ozogul, G., Moreno, R., & Reisslein, M. (2013). Pedagogical agent signaling of multiple visual engineering representations: The case of the young female agent. Journal of Engineering Education, 102(2), 319–337. doi:10.1002/jee.20009

Johnson, W. L., & Lester, J. C. (2016). Face-to-face interaction with pedagogical agents, twenty years later. International Journal of Artificial Intelligence in Education, 26(1), 25–36. doi:10.1007/s40593-015-0065-9

Kim, Y. (2016). The role of agent age and gender for middle-grade girls. Computers in the Schools, 33(2), 59–70. doi:10.1080/07380569.2016.1143753

Kim, Y., & Baylor, A. L. (2007). Pedagogical agents as social models to influence learner attitudes. Educational Technology, 47(1), 23–28.

Kim, Y., & Baylor, A. L. (2016). Research-based design of pedagogical agent roles: A review, progress, and recommendations. International Journal of Artificial Intelligence in Education, 26(1), 160–169. doi:10.1007/s40593-015-0055-y

Kim, Y., Thayne, J., & Wei, Q. (2017). An embodied agent helps anxious students in mathematics learning. Educational Technology Research and Development, 65(1), 219–235. doi:10.1007/s11423-016-9476-z

Kim, Y., & Wei, Q. (2011). The impact of learner attributes and learner choice in an agent-based environment. Computers & Education, 56(2), 505–514. doi:10.1016/j.compedu.2010.09.016

Kitchenham, B., & Charters, S. (2007). Guidelines for performing systematic literature reviews in software engineering version 2.3. (EBSE Technical Report EBSE-2007-01). Retrieved from https://www.elsevier.com/__data/promis_misc/525444systematicreviewsguide.pdf

Kizilkaya, G., & Askar, P. (2008). The effect of an embedded pedagogical agent on the students' science achievement. Interactive Technology and Smart Education, 5(4), 208–216. doi:10.1108/17415650810930893

Krämer, N. C., & Bente, G. (2010). Personalizing e-learning. The social effects of pedagogical agents. Educational Psychology Review, 22(1), 71–87. doi:10.1007/s10648-010-9123-x

Krämer, N. C., Karacora, B., Lucas, G., Dehghani, M., Rüther, G., & Gratch, J. (2016). Closing the gender gap in STEM with friendly male instructors? On the effects of rapport behavior and gender of a virtual agent in an instructional interaction. Computers & Education, 99(Supplement C), 1–13. doi:10.1016/j.compedu.2016.04.002

Lalle, S., Mudrick, N. V, Taub, M., Grafsgaard, J. F., Conati, C., & Azevedo, R. (2016). Impact of individual differences on affective reactions to pedagogical agents scaffolding. In D. Traum, W. Swartout, P. Khooshabeh, S. Kopp, S. Scherer, & A. Leuski (Eds.), Intelligent Virtual Agents, IVA 2016 (vol.

10011; pp. 269–282). doi:10.1007/978-3-319-47665-0_24

Liew, T. W., Zin, N. A. M., & Sahari, N. (2017). Exploring the affective, motivational and cognitive effects of pedagogical agent enthusiasm in a multimedia learning environment. Human-Centric Computing and Information Sciences, 7(9). doi:10.1186/s13673-017-0089-2

Liew, T. W., Tan, S. M., & Ismail, H. (2017). Exploring the effects of a non-interactive talking avatar on social presence, credibility, trust, and patronage intention in an e-commerce website. Human-Centric Computing and Information Sciences, 7(42). doi:10.1186/s13673-017-0123-4

Liew, T. W., & Tan, S. M. (2016). Virtual agents with personality: Adaptation of learner-agent personality in a virtual learning environment. In 2016 11th International Conference on Digital Information Management, ICDIM 2016 (pp. 157–162). doi:10.1109/ICDIM.2016.7829758

Lim, S. F., Ailiya, Miao, C., & Shen, Z. (2014). Persuasive teachable agent with goal net. In Proceedings—IEEE 14th International Conference on Advanced Learning Technologies, ICALT 2014, (pp. 461–463). doi:10.1109/ICALT.2014.235

Lin, L., Atkinson, R. K., Christopherson, R. M., Joseph, S. S., & Harrison, C. J. (2013). Animated agents and learning: Does the type of verbal feedback they provide matter? Computers & Education, 67, 239–249. doi:10.1016/j.compedu.2013.04.017

Martin, S. A., Azevedo, R., Taub, M., Mudrick, N. V, Millar, G. C., & Grafsgaard, J. F. (2016). Are there benefits of using multiple pedagogical agents to support and foster self-regulated learning in an intelligent tutoring system? In A. Micarelli, J. Stamper, & K. Panourgia (Eds.), Intelligent Tutoring Systems, ITS 2016 (vol. 9684; pp. 273–279). doi:10.1007/978-3-319-39583-8_29

Matsuda, N., Cohen, W. W., Koedinger, K. R., Keiser, V., Raizada, R., Yarzebinski, E., . . . Stylianides, G. (2012). Studying the effect of tutor learning using a teachable agent that asks the student tutor for explanations. In 2012 IEEE Fourth International Conference on Digital Game and Intelligent Toy Enhanced Learning (pp. 25–32). doi:10.1109/DIGITEL.2012.12

Matsuda, N., Griger, C. L., Barbalios, N., Stylianides, G. J., Cohen, W. W., & Koedinger, K. R. (2014). Investigating the effect of meta-cognitive scaffolding for learning by teaching. In S. Trausan-Matu, K. E. Boyer, M. Crosby, & K. Panourgia (Eds.), Intelligent Tutoring Systems: 12th International Conference, ITS 2014, Honolulu, HI, USA, June 5–9, 2014. Proceedings (pp. 104–113). Cham: Springer International Publishing. doi:10.1007/978-3-319-07221-0_13

Matsuda, N., Yarzebinski, E., Keiser, V., Raizada, R., Stylianides, G. J., Cohen, W. W., & Koedinger, K. R. (2011). Learning by teaching simstudent—An initial classroom baseline study comparing with cognitive tutor. In G. Biswas, S. Bull, J. Kay, & A. Mitrovic (Eds.), Artificial Intelligence in Education: 15th International Conference, AIED 2011, Auckland, New Zealand, June 28–July 2011 (pp. 213–221). Berlin, Heidelberg: Springer Berlin Heidelberg. doi:10.1007/978-3-642-21869-9_29

Mohtadi, M. T., Hajami, A., & Allali, H. (2014). Pedagogical agent for metacognitive scaffolding in interactive learning environments. In 2014 International Conference on Multimedia Computing and Systems—(ICMCS) Proceedings, (pp. 652–656). doi:10.1109/ICMCS.2014.6911216

Mondragon, A. L., Nkambou, R., & Poirier, P. (2016). Evaluating the effectiveness of an affective tutoring agent in specialized education. In K. Verbert, M. Sharples, & T. Klobucar (Eds.), Adaptive and Adaptable Learning, EC-TEL 2016 (vol. 9891; pp. 446–452). doi:10.1007/978-3-319-45153-4_41

Moreno, R. (2005). Multimedia learning with animated pedagogical agents. In R. E. Mayer (Ed.), The Cambridge handbook of multimedia learning (pp. 507–524). Cambridge, UK: Cambridge University Press.

Moreno, R., Mayer, R., Spires, H., & Lester, J. (2001). The case for social agency in computer-based teaching: Do students learn more deeply when they interact with animated pedagogical agents? Cognition and Instruction, 19(2),177–213. doi:10.1207/S1532690XCI1902_02

Murray, M., & Tenenbaum, G. (2010). Computerized pedagogical agents as an educational means for developing physical self-efficacy and encouraging activity in youth. Journal of Educational Computing Research, 42(3), 267–283. doi:10.2190/EC.42.3.b

Osman, K., & Lee, T. T. (2014). Impact of interactive multimedia module with pedagogical agents on students' understanding and motivation in the learning of electrochemistry. International Journal of Science and Mathematics Education, 12(2), 395–421. doi:10.1007/s10763-013-9407-y

Ozogul, G., Reisslein, M., & Johnson, A. M. (2011, June). AC 2011–344: Effects of visual signaling on pre-college students' engineering learning performance and attitudes: Peer versus adult pedagogical agents versus arrow signaling. Paper presented at the 2011 ASEE Annual Conference & Exposition, Vancouver, CA. Retrieved from https://pdfs.semanticscholar.org/1335/4922ec31f880ae53694cc8b298d4d0ffd89d.pdf

Pareto, L. (2014). A teachable agent game engaging primary school children to learn arithmetic concepts and reasoning. International Journal of Artificial Intelligence in Education, 24(3), 251–283. doi:10.1007/s40593-014-0018-8

Pareto, L., Arvemo, T., Dahl, Y., Haake, M., & Gulz, A. (2011). A teachable-agent arithmetic game's effects on mathematics understanding, attitude and self-efficacy. In G. Biswas, S. Bull, J. Kay, & A. Mitrovic (Eds.), Artificial Intelligence

in Education: 15th International Conference, AIED 2011, Auckland, New Zealand, June 28—July 2011 (pp. 247–255). Berlin, Heidelberg: Springer Berlin Heidelberg. doi:10.1007/978-3-642-21869-9_33

Pareto, L., Haake, M., Lindström, P., Sjödén, B., & Gulz, A. (2012). A teachable-agent-based game affording collaboration and competition: Evaluating math comprehension and motivation. Educational Technology Research and Development, 60(5), 723–751. doi:10.1007/s11423-012-9246-5

Rančić, D., Kuk, K., Pronić-Rančić, O., & Ranelović, D. (2015). Agent-based approach for game-based learning applications: Case study in agent-personalized trend in engineering education. In G. Jezic, R. J. Howlett, & L. C. Jain (Eds.), Agent and Multi-Agent Systems: Technologies and Applications: 9th KES International Conference, KES-AMSTA 2015 Sorrento, Italy, June 2015, Proceedings (pp. 453–466). Cham: Springer International Publishing. doi:10.1007/978-3-319-19728-9_38

Robertson, J. (2011). The educational affordances of blogs for self-directed learning. Computers and Education, 57(2), 1628–1644. doi:10.1016/j.compedu.2011.03.003

Saks, K., & Leijen, A. (2014). Distinguishing self-directed and self-regulated learning and measuring them in the e-learning context. Procedia—Social and Behavioral Sciences. 112, 190–198. doi:10.1016/j.sbspro.2014.01.1155

Savin-Baden, M., Tombs, G., & Bhakta, R. (2015). Beyond robotic wastelands of time: Abandoned pedagogical agents and new pedalled pedagogies. E-Learning and Digital Media, 12(3-4), 295–314. doi:10.1177/2042753015571835

Schroeder, N. L., & Adesope, O. O. (2012). A case for the use of pedagogical agents in online learning environments. Journal of Teaching and Learning with Technology,1(2),43–47.

Schroeder, N. L., & Adesope, O. O. (2013). Do 3D pedagogical agents help students learn science? In K. Nettleton & L. Lennex (Eds.), Cases on 3D Technology Application and Integration in Education (pp. 49–71). Hershey, PA: IGI Global Publishing. doi:10.4018/978-1-4666-2815-1.ch003

Schroeder, N. L., & Adesope, O. O. (2014). A systematic review of pedagogical agents' persona, motivation, and cognitive load implications for learners. Journal of Research on Technology in Education, 46(3), 229–251. doi:10.1080/15391523.2014.888265

Schroeder, N. L., Adesope, O. O., & Gilbert, R. B. (2013). How effective are pedagogical agents for learning? A meta-analytic review. Journal of Educational Computing Research, 49(1), 1–39. doi:10.2190/EC.49.1.a

Schroeder, N. L., & Gotch, C. M. (2015). Persisting issues in pedagogical agent research. Journal of Educational Computing Research, 53(2), 183–204. doi:10.1177/0735633115597625

Schroeder, N. L., Romine, W. L., & Craig, S. D. (2017). Measuring pedagogical agent persona and the influence of agent persona on learning. Computers and Education, 109, 176–186. doi:10.1016/j.compedu.2017.02.015

Schroeder, N. L., & Traxler, A. L. (2017). Humanizing instructional videos in physics: When less is more. Journal of Science Education and Technology, 26(3), 269–278. doi:10.1007/s10956-016-9677-6

Shiban, Y., Schelhorn, I., Jobst, V., Hörnlein, A., Puppe, F., Pauli, P., & Mühlberger, A. (2015). The appearance effect: Influences of virtual agent features on performance and motivation. Computers in Human Behavior, 49, 5–11. doi:10.1016/j.chb.2015.01.077

Sjödén, B., & Gulz, A. (2015). From learning companions to testing companions. In C. Conati, N. Heffernan, A. Mitrovic, & M. F. Verdejo (Eds.), Artificial Intelligence in Education: 17th International Conference, AIED 2015, Madrid, Spain, June 22–26, 2015. Proceedings (pp. 459–469). Cham: Springer International Publishing. doi:10.1007/978-3-319-19773-9_46

Soliman, M., & Guetl, C. (2010). Intelligent pedagogical agents in immersive virtual learning environments: A review. In MIPRO 2010 Proceedings of the 33rd International Convention (pp. 827–832). Opatija, Croatia: IEEE.

Terzidou, T., & Tsiatsos, T. (2014). The impact of pedagogical agents in 3D collaborative serious games. In 2014 IEEE Global Engineering Education Conference (EDUCON), April 1–8. (pp. 1175–1182). doi:10.1109/EDUCON.2014.7096838

Terzidou, T., Tsiatsos, T., Miliou, C., & Sourvinou, A. (2016). Agent supported serious game environment. IEEE Transactions on Learning Technologies, 9(3), 217–230. doi:10.1109/TLT.2016.2521649

Thompson, N., & McGill, T. J. (2017). Genetics with Jean: The design, development and evaluation of an affective tutoring system. Educational Technology Research and Development, 65(2), 279–299. doi:10.1007/s11423-016-9470-5

Tzeng, S. C., & Wang, P. T. (2014). Identification features and pedagogical agents in a mathematical game. In 2014 Computer Games: AI, Animation, Mobile, Multimedia, Educational and Serious Games (CGAMES) (pp. 1–5). doi:10.1109/CGames.2014.6934153

van der Meij, H., van der Meij, J., & Harmsen, R. (2015). Animated pedagogical agents effects on enhancing student motivation and learning in a science inquiry learning environment. Educational Technology Research and Development, 63(3), 381–403. doi:10.1007/s11423-015-9378-5

Veletsianos, G. (2010). Contextually relevant pedagogical agents: Visual appearance, stereotypes, and first impressions and their impact on learning. Computers & Education, 55(2), 576–585. doi:10.1016/j.compedu.2010.02.019

Veletsianos, G., & Russell, G. S. (2013). Pedagogical agents. In J. M. Spector, M. D. Merrill, J. Elen, & M. J. Bishop (Eds.), Handbook of Research on Educational Communication and Technology (pp. 759–769). New York, NY: Springer Science + Business. doi:10.1007/978-1-4614-3185-5_61

Wang, C.-C., & Yeh, W.-J. (2013). Avatars with sex appeal as pedagogical agents: Attractiveness, trustworthiness, expertise, and gender differences. Journal of Educational Computing Research, 48(4), 403–429. doi:10.2190/EC.48.4.a

Wang, J., & Antonenko, P. D. (2017). Instructor presence in instructional video: Effects on visual attention, recall, and perceived learning. Computers in Human Behavior, 71, 79–89. doi:10.1016/j.chb.2017.01.049

Woolf, B. P., Arroyo, I., Muldner, K., Burleson, W., Cooper, D. G., Dolan, R., & Christopherson, R. M. (2010). The effect of motivational learning companions on low achieving students and students with disabilities. In V. Aleven, J. Kay, & J. Mostow (Eds.), Intelligent Tutoring Systems: 10th International Conference, ITS 2010, Pittsburgh, PA, USA, June 14–18, 2010, Proceedings, Part I (pp. 327–337). Berlin, Heidelberg: Springer Berlin Heidelberg. doi:10.1007/978-3-642-13388-6_37

Xie, T., & Luo, L. (2017). Impact of prompting agents on task completion in the virtual world. International Journal of Online Engineering, 13(6), 35–48. doi:10.3991/ijoe.v13i06.6850

Yung, H. I., & Paas, F. (2015). Effects of cueing by a pedagogical agent in an instructional animation: A cognitive load approach. Educational Technology & Society, 18(3), 153–160.