Emotion Recognition of Pedagogical Agents in Education

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November 2024

Abstract

The influence of an agent's emotional state on students' learning from educational videos has been a topic of growing interest. Drawing inspiration from the studies conducted by Lawson et al. (2021) and Beege and Schneider (2023), this paper examines participants' ability to accurately perceive various emotions exhibited by a virtual instructor (i.e., an animated pedagogical agent) during a video lecture introducing ChatGPT. Furthermore, it explores whether participants' performance varied depending on the emotional expressions of the agent. In this study, we recruited 300 participants to test their learning outcomes and evaluation on agents with four different emotions (two positive and two negative emotions), conveyed through voices and facial expressions. These emotions are: happy, content, frustrated, and sad. The results revealed that participants could recognize the emotions expressed by AI instructors: Happy agents were rated highest for happiness, content agents for contentment, frustrated agents for frustration, and sad agents for sadness. However, when it came to learning performance, participants who interacted with agents displaying negative emotions (frustration and sadness) performed better on tests than those exposed to positive emotions (happiness and contentment). In terms of subjective experience, participants rated positive emotion agents as more engaging, expressive, and enjoyable, with happy agents receiving the highest ratings. While positive emotions enhanced participants' perceptions of the agents, these did not translate into better learning outcomes, highlighting the complexity of emotional influence in educational settings.

Keywords. *Emotion Recognition, Pedagogical Agents, Education, Artificial Intelligent*

1 Introduction

Artificial Intelligence (AI) have revolutionised modern education. In the post-COVID19 pandemic era, the implementation of pedagogical agent (PA) as virtual instructor have gained significant attention. A PA refers to a computer-generated or designed character which serve instructional purposes in educational settings (Martha & Santoso, 2019; Veletsianos & Russell, 2013). Recent meta-analyses outlined that the implementation of PAs fosters learning outcomes (Castro-Alonso et al., 2021; Schroeder et al., 2013). But the outcomes could be greatly influenced by the characteristics of the agents, and the emotional state is one of them. With modern AI technologies, the agents' mimic of human emotions has reached an incredible level. These emotionally capable

agents are not just conveyors of information but actors capable of evoking emotional responses in learners that may impact their motivation and cognitive engagement. This paper investigates the extent to which participants can accurately discern a virtual instructor's emotional state during educational video presentations and how these perceived emotions affect learning outcomes.

Emotions play a critical role in educational settings, influencing learning through verbal and non-verbal cues such as tone, facial expressions, and body language (Guo et al., 2012; Buttussi & Chittaro, 2019). Positive emotional activation can enhance motivation and cognitive effort and thus improving learning outcomes as suggested by the emotional design hypothesis (Stark et al., 2018; Plass & Kalyuga, 2019). Teacher enthusiasm, for instance, has been linked to higher academic performance (Keller et al., 2014). Conversely, Cognitive Load Theory (CLT) posits that emotional processing can introduce extraneous cognitive load, potentially distracting learners and impairing comprehension (Sweller et al., 2019). Empirical research on emotional pedagogical agents highlights both opportunities and challenges. Lawson et al. (2021) found that agents' emotional expressions, particularly facial cues, foster social presence and engagement, which aligns with emotional response theory (Mottet et al., 2006). When agents appear human-like, stronger learner connections form and enhance learning outcomes (Mayer, 2014a). However, overly intense or inappropriate emotions can act as distractors (Norman, 2004), underscoring the need for balanced emotional presentation that supports cognitive processes without imposing excessive cognitive load.

This study builds upon these insights by examining whether the current generation of AI-generated pedagogical agents can deliver emotions more effectively, enhancing or challenging previous findings. Particularly, by incorporating advancements in AI and graphics, we address the limitations highlighted by Lawson et al. (2021) who noted the constraints of their agents' visual quality. Through an analysis of participants' recognition of five distinct emotional states (happy, content, neutral, frustrated, and sad) portrayed by an high-fidelity AI-generated instructor during a video lecture on ChatGPT, this paper aims to contribute a further understanding of how emotional expressions influence learning outcomes and perception. The study's findings will provide valuable implications for the design and deployment of pedagogical agents in educational settings, particularly in the context of using advanced technologies to optimise emotional representation.

2 Literature Review

Pedagogical agents have become integral components of technology-enhanced learning across diverse disciplines, spanning from humanities to STEM education, and from higher education to military training (Taglieri et al., 2017). These agents, characterised as computer-generated or designed entities serving instructional functions within educational contexts (Martha and Santoso, 2019), have evolved to include emotional capable entities defined as affective pedagogical agents. These abilities enable them to manifest human-like emotional states and interactions, which potentially exert a distinct influence on learners' educational experiences and performances (Kim et al., 2003; Johnson and Lester, 2018).

The intertwining of cognitive processing and emotional experiences underscores the crucial role of emotions in learning (Pekrun and Stephens, 2010; LeDoux and Brown, 2017). These emotional impacts encompass verbal cues, such as humour expression, and non-verbal cues, including facial

expressions, tones, and voices, which wield significant sway over learning motivations and outcomes (Buttussi and Chittaro, 2019; Guo et al., 2012). Nonetheless, the theoretical foundations concerning the emotional impact on learning outcomes remain multifaceted (Beege and Schneider, 2003). The emotional design hypothesis posits that emotional experiences can either facilitate or impede learning, with positive activation fostering motivation and enhancing mental efforts, thus yielding superior learning outcomes (Park et al., 2015; Stark et al., 2018; Plass and Kalyuga, 2019; Schneider, 2021). Emotional design focuses on the use of design features in learning environments that aim to elicit specific emotions, enhancing the emotional and cognitive experience of learners. These features, such as colors, shapes, facial expressions, or sounds, do not add extra content but modify the affective qualities of the environment to influence learners' emotional states. Research has shown that positive emotions induced through these features can improve learning by reducing cognitive load and increasing engagement (Plass et al., 2014; Mayer and Estrella, 2014). Empirical evidence supports this contention, exemplified by instances such as teacher enthusiasm correlating with enhanced mathematics achievement (Keller et al., 2014) or higher academic performance (Brighham et al., 1992). Conversely, emotions can act as suppressors, as posited by the Cognitive Load Theory (CLT), wherein emotional processing may impose extraneous cognitive load, detracting from learning goals (Sweller et al., 2019). Studies by Oaksford et al. (1996) and Norman (2004) underscore the inhibitory effects of emotions on attentional focus and deductive reasoning.

Similar to human agents, the emotional process of pedagogical agents can significantly influence learning outcomes (Lawson et al., 2021). When pedagogical agents exhibit human-like features such as gesturing, conversational language, and facial expressions, they build up a sense of social connection between themselves and learners, thereby enhancing learning outcomes (Mayer, 2014a). This proposition aligns with the emotional response theory, which demonstrates how emotional responses mediate interactions between instructors' communications and students' behaviours (Mottet et al., 2006). Consequently, the emotional cues emitted by pedagogical agents, whether verbal or non-verbal, can evoke positive emotions in learners, thereby augmenting affective perceptions, intrinsic motivations, and ultimately, learning outcomes (Liew et al., 2017; Beege and Schneider, 2021).

The inspiring Lawson et al. (2021) demonstrated this process and delved into the influence of pedagogical agents' emotions on learning outcomes, utilising Mayer's cognitive-affective model of e-learning (2020b) as a theoretical framework (Figure. 1 and 2). According to this model, an e-learning environment involving a pedagogical agent displaying positive emotion leads the learner to recognize the agent's emotional stance, which set up an affective response towards the agent, influencing cognitive processing and ultimately enhancing learning outcomes. This model reflects the interaction between emotion and cognition, suggesting that positive emotional cues from pedagogical agents can enhance motivation and engagement, leading to better learning results (Plass and Kaplan, 2016). Among all the emotional cues, their investigation primarily focused on non-verbal facial expressions, adopting Russell's model of core affect (Russell, 2003) to classify emotions into quadrants based on valence and arousal (Figure. 1). Russell's core affect model proposes two key dimensions: valence (from displeasure to pleasure) and arousal (from passive to active), which can be applied to understand the emotional responses of both learners and instructors in e-learning environments. This model has been useful for categorising achievement emotions and understanding how they influence learning outcomes (Harley et al., 2020; Pekrun, 2016). While previous studies concentrated on understanding how pedagogical stimuli emotions in learners, Lawson et al. (2021) sought to deepen comprehension regarding how learners perceive

and interpret emotions conveyed by pedagogical stimuli. However, their study could be enhanced, as their visual representation of agents was relatively poor despite advances in graphics and AI technology. This persistent issue as discussed by Johnson and Lester (2018), leads to consideration of whether a more advanced technology - the AI-generated avatars in our case, could yield more distinct emotional expressions, potentially bolstering or refuting their findings.

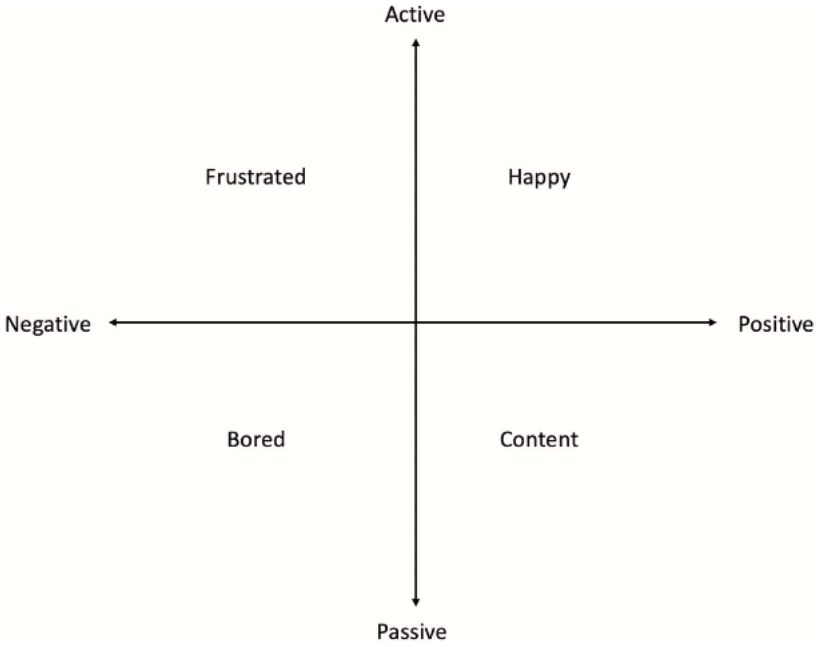

Figure 1: An Example of the Cognitive-affective Model of e-Learning, When the Instructor Displays Positive Emotion, such as Being Happy (Lawson et al., 2021)

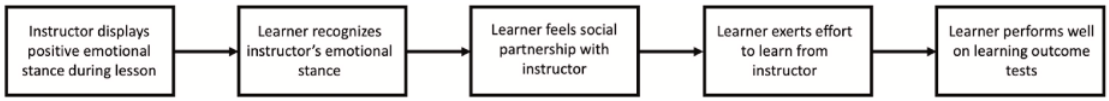

Figure 2: Model of Core Affect Adapted from Russell (2003) and Lawson et al. (2021)

3 Hypotheses

As described in the literature review, this study is a follow-up investigation building on the work of Lawson et al (2021) with the low-fidelity virtual agents being replaced with high-fidelity human-like pedagogical agents. Therefore, our hypotheses would be similar.

Based on the cognitive-affective theory of e-learning, learners recognise the emotional tone of instructors in video lectures. This leads to Hypothesis 1: Participants will give higher ratings to the emotion displayed by the instructor than each of the other three emotions. More specially, for

the happy agents, participants will give higher ratings of happiness than each of the other emotions (content, frustrated, bored, sad). For the content agents, participants will give higher ratings of content than each of the other emotions. For the frustrated agents, participants will give higher ratings of frustration than each of the other emotions. For the sad agents, participants will give higher ratings of sadness than each of the other emotions.

Based on the emotional design hypothesis, learners who watched instructional videos with agents with positive emotions (happiness and contentment) should have better post-video performance on test (Hypothesis 2). In particular, for the happy and content agents, participants should have better improvements after the videos than those of negative emotions (frustrated, bored, sad).

4 Method

4.1 Experiment Design

Our instructional video presented by AI avatars offers a concise introduction to a technological tool called ChatGPT, which is a generative artificial intelligence chatbot developed by OpenAI and released in 2022. The AI avatars are configured to exhibit the following emotions: happy, content, neutral, frustrated, and sad.

Prior to viewing the videos, participants are asked to complete a quiz to assess their baseline knowledge of ChatGPT. Following this initial assessment, each participant is randomly assigned to watch a single video featuring an avatar displaying one of the specified emotional expressions. Each participant views only one randomly selected video, establishing the independent variable of the experiment as the emotion expressed by the AI avatar.

Following the video presentation, participants are asked to rate the instructional effectiveness of the AI avatar and identify the emotions it conveyed. They then complete a post-test identical to the pre-test, enabling measurement of any knowledge gains related to the subject matter. This pretest-posttest design helps to identify improvements in their understanding.

To account for potential participant-related biases or limitations, a demographic questionnaire is included, collecting information such as age, gender, and educational background. This data helps contextualise the results and provides insights into how these demographic variables may influence the outcomes of the study.

4.2 Videos

(a) Happy (b) Content (c) Neutral (d) Frustrated (e) Sad

Figure 3: Emotion categories with corresponding images of the AI agents.

The images of the agents used for video generation were created using *Midjourney* (`https://www.midjourney.com/`). The five emotions being portrayed are: happy, content, neutral, frustrated, and sad (see the static pictures below). The videos are then generated using an AI-generated video creation platform called *D-ID* (`https://www.d-id.com`). It transforms still photos into personalised streaming AI videos, enabling users to generate photorealistic digital humans and dramatically reducing the cost and hassle of video production at scale. The advantages of this platform are the easy creation of high-fidelity agents whose appearances are extremely close to humans and no complicated coding or motion capture technology is required (see the example interface below). The five video clips involve the same script and agent in same gender with different faces.

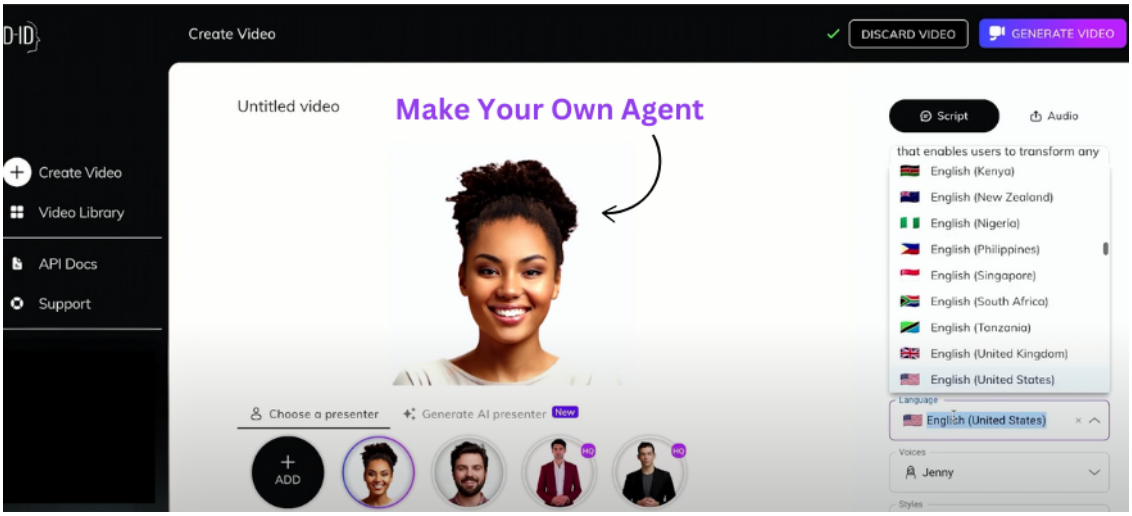

Figure 4: The D-ID agent generation interface

4.3 Participant

300 participants were recruited via the online research platform *Prolific* (`https://www.prolific.co`). Eligible participants are at least 18 years old and their consent on their willingness of partici-

pation are confirmed. The participation is voluntary and participants have the ability to withdraw at any point without any cost. Each participant will be paid £1.5 for their participation. The participation is anonymous and no personally identifiable information is asked, but demographic data will be collected. These data include: age, gender, profession, mother tongue, field of ethnicity, field of study, familiarity with pedagogical agents, country of residence.

4.4 Questionnaire

The questionnaire consists of five main sections. The first section gathers socio-demographic data. The second section includes a pre-test on the topic of ChatGPT, covering aspects such as its full name, the company behind it, its characteristics and functions, and its applications. The third section assesses the participants' perceptions of the instructor's emotional state. Participants are asked to rate how happy, content, frustrated, or sad the instructor appeared, using a Likert scale ranging from 1 (*Not at all*) to 5 (*Very much*), with an additional option of "*Can't estimate*." The fourth section is a post-video evaluation of the instructor's performance, focusing on four aspects: facilitating learning, credibility, human-likeness, and engagement. Each aspect is rated on a 5-point scale, ranging from "*Strongly disagree*" to "*Strongly agree*." The final section is a post-video test on the educational content, which mirrors the pre-test, consisting of true/false questions identical to those in the pre-test.

4.5 Data Collection

The experiment is conducted online and the questionnaire is constructed using the survey platform *SoSci Survey* (`https://www.soscisurvey.de`). After distribution, some of the responses were invalid, we then redistributed until there are 300 valid responses. The validation is tested by some obvious questions - The questionnaire asked "Please choose 'Agree' for this question", if we receive answers other than the required option, then the whole response is treated as invalid.

5 Results

5.1 Demographic features of participants

We conducted an analysis of the demographic features of our participants and found that the majority (62.7%) are under the age of 30, indicating that the participants are relatively young. Furthermore, most participants are female (70.7%), have an academic background in technology-related fields (70.5%), and possess prior experience using pedagogical agents (83.4%). However, a majority of the participants do not work in technology-related professions (74.8%). Additionally, their mother tongue is most likely to be English (44.5%).

5.2 Can people recognise the emotion being portrayed by the instructor?

The data on emotion ratings provided by participants were not normally distributed, as indicated by the Shapiro-Wilk test ($p > 0.05$). Therefore, the post hoc testing of Wilcoxon was applied to examine Hypothesis 1 regarding emotion recognition. The results are presented in Table 1. According to the table, participants who viewed agents expressing happy emotions rated the emotion as significantly higher for happiness than for boredom and sadness, but not for contentment. For agents expressing contentment, participants rated the targeted emotion significantly higher than the other three emotions. For agents expressing frustration, participants gave a significantly higher rating to frustration than to all three other emotions. For agents expressing sadness, participants rated sadness significantly higher than happiness and contentment, but not higher than boredom. Although the results were not flawless, they suggest that in most cases participants were able to recognize the emotions conveyed by the agents, especially more positive emotions from more negative emotions. And the effect sizes were high (mostly above 1 standard deviation), which is important because it shows that emotions can be recognised easily. This conclusion aligns with Lawson et al (2021). Thus, Hypothesis 1 is supported.

	Mean	**Standard Deviation**
Happy Instructor		
Happy	3.43	1.16
Content	2.30	1.31
Frustrated	1.57*	0.84
Sad	1.34*	0.72
Content Instructor		
Happy	3.75*	0.86
Content	3.69	1.26
Frustrated	2.33*	1.41
Sad	2.17*	1.29
Frustrated Instructor		
Happy	1.35*	0.71
Content	1.25*	0.71
Frustrated	2.93	1.43
Sad	2.63*	1.61
Sad Instructor		
Happy	1.29*	0.71
Content	1.40*	0.78
Frustrated	2.55*	1.35
Sad	3.69	1.38

Note: Items marked with * indicate a statistically significant difference at $p < 0.05$.

Table 1: Means and SDs of ratings for the AI agents

5.3 Do positive emotions improve learning performance better than negative emotions?

The pretest-posttest results suggest a rejection of Hypothesis 2. Specifically, after viewing the educational videos, participants who interacted with agents exhibiting negative emotions (frustration and sadness) achieved higher test scores compared to those who interacted with agents displaying positive emotions (happiness and contentment). Participants exposed to agents expressing neutral emotions scored between these two groups.

Given that the data are not normally distributed, the non-parametric Wilcoxon test was used as an alternative to the t-test to evaluate whether the differences in scores among the three groups were statistically significant. The results indicate that the differences between them are indeed significant. Consequently, we conclude that Hypothesis 2 is rejected.

Emotions	**PRE-test avg. score**	**POST-test avg. score**	**Score Difference**	**p-value**
Negative	8.39	8.89	0.50	<0.01
Neutral	8.49	8.88	0.39	<0.01
Positive	8.47	8.75	0.28	<0.01

Table 2: Comparison of test scores across different emotions.

We further investigated potential reasons for this rejection by analysing participants' perceptions of the agents' performance. A Kruskal-Wallis H test, followed by a Dunn post hoc test, was conducted to examine group differences. The results (Table 3) indicate that, although the objective measure of test grades did not demonstrate a significant impact of the AI agent's emotional cues, subjective perceptions revealed notable contrary trends. Participants who interacted with videos featuring "happy" and "content" agents assigned significantly higher scores to statements such as "made them focus on the relevant information" and "made the instruction interesting." These participants also rated the agents as more "interesting" and "enjoyable" than those interacting with agents displaying other emotions. Importantly, these differences were statistically significant ($p < 0.05$).

Additionally, the findings suggest that participants perceived the agents as engaging overall. Specifically, agents with positive emotions (happy and content) emotions were rated as significantly more "expressive," "enthusiastic," "entertaining," and "motivating" compared to agents with negative emotional states. And within the positive emotions, happy agents receive the highest scores. These results highlight the potential of emotionally expressive AI agents to enhance subjective learning experiences, even in the absence of corresponding improvements in objective outcomes.

Question	**Happy**	**Neutral**	**Content**	**Frustrated**	**Sad**
Facilitating Learning					
The agent led me to think more deeply about the presentation.	3.48	3.59	3.40	3.19	3.31
The agent made the instruction interesting.*	3.69	3.74	3.32	3.06	3.07

Question	Happy	Neutral	Content	Frustrated	Sad
The agent encouraged me to reflect what I was learning.	3.56	3.54	3.40	3.31	3.16
The agent kept my attention.	3.74	3.80	3.81	3.48	3.41
The agent presented the material effectively.	4.16	4.05	4.02	3.83	3.77
The agent helped me to concentrate on the presentation.	3.42	3.47	3.49	3.15	2.90
The agent made me focus on the relevant information*	3.74	3.92	3.68	3.35	3.34
The agent improved my knowledge of the content.	4.11	4.25	4.19	4.05	4.08
The agent was interesting.*	3.66	3.61	3.30	3.08	2.82
The agent was enjoyable.*	3.56	3.56	3.19	2.82	2.54
Credibility					
The agent was knowledgeable.	4.32	4.37	4.39	4.21	4.15
The agent was intelligent.	3.92	4.00	3.85	3.71	3.85
The agent was useful.	4.18	4.31	4.26	4.11	4.00
The agent was helpful.	4.16	4.23	4.20	4.08	4.08
The agent was instructor-like.	3.60	3.69	3.84	3.48	3.28
Human-like					
The agent has a personality.	2.64	2.39	2.32	2.27	1.95
The agent's emotion was natural.	2.61	2.86	2.75	2.32	1.66
The agent was human-like.	3.29	3.37	3.11	2.9	2.56
The agent's movement was natural.	2.53	2.63	2.53	1.90	1.80
The agent showed emotion.	2.58	2.02	1.98	2.22	2.21
Engaging					
The agent was expressive.*	2.95	2.56	2.44	2.42	2.33
The agent was enthusiastic.*	3.45	2.51	2.63	2.34	1.78
The agent was entertaining.*	3.18	2.38	2.78	2.32	1.97
The agent was motivating.*	3.11	2.98	2.91	2.44	2.07
The agent was friendly.	3.89	3.32	3.49	2.50	2.38

Note: Items marked with * indicate a statistically significant difference at $p < 0.05$.

Table 3: The group differences on ratings for instructor's performance

6 Discussion

This study aligns with Lawson et al. (2021), finding that learners were generally able to recognise the emotional tone of an AI instructor and distinguish between the four targeted emotions: happiness, contentment, frustration, and sadness. However, when comparing the active versus passive dimensions of emotion (e.g., happiness versus contentment), no clear recognition was observed.

These findings highlight that learners are conscious of the emotional tone conveyed by instructors during information delivery. Furthermore, learners can discern the emotional tone of an instructor, even when the instructor is an AI agent, underscoring the importance of emotion portrayal in creating effective instructional videos with both human and virtual instructors.

This research provides support for Russell's (2003) model of core effect in the context of online lessons. Participants were able to differentiate between emotions associated with each of the four quadrants in Russell's model: positive/active, positive/passive, negative/active, and negative/passive. The findings suggest that these emotions are not only distinct but also recognisable by learners when presented by a virtual AI instructor, particularly along the valence dimension (i.e., positive versus negative).

The results of the study, particularly the improvements in test scores, do not support the emotional design hypothesis. While the hypothesis predicts that AI instructors exhibiting positive emotions would enhance learner performance to a greater extent, the findings reveal an inverse trend. This discrepancy may be attributed to several factors. One plausible explanation is that the video materials and associated test items used in the study were overly simplistic. This issue is particularly pronounced given that a significant proportion of participants possessed prior educational backgrounds in technology. As a result, many participants likely already knew the correct answers before engaging with the instructional videos. Alternatively, the low complexity of content may have rendered the materials insufficiently challenging to discern any meaningful impact of emotional design on learning outcomes. These factors suggest that the simplicity of the experimental design could have limited the ability to test the hypothesis effectively.

On the other hand, while the test scores did not improve as much as initially anticipated, the responses indicate that the AI instructors were perceived as engaging and supportive in facilitating learners' learning process. This finding highlights the significant potential of leveraging emotions in educational contexts and underscores the importance of incorporating emotional design elements when developing AI-based educational tools. Even though the measurable improvements in learning outcomes may not always be immediate or overtly evident, the emotional engagement fostered by the AI have the potential to play a critical role in enhancing the overall educational experience.

7 Reference

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