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Design a Robot as a Double with Micro-expression to Participate in a Virtual Situational Learning Environment and its Effect on Students' Learning Performance

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Abstract: One way to encourage students to keep on practicing and studying learning materials is to let them be aware of how they will perform if they are placed in the situational evaluation. Thus, there should be a mechanism to act as a double that can be trained and revised by students so they can watch, monitor, and learn their own performances. Besides, emotional intelligence has gained a lot of attention due to its potential in maintaining situational interactions. Such a skill can detect the micro-expression to grasp the true feelings and hence students can take the appropriate responses. Therefore, this study proposes a learning approach, where students can collaboratively design the robot as their double with micro-expression to participate in situational evaluation tests. To evaluate the effectiveness of the proposed approach, a quasi-experiment was conducted with 90 undergraduate students who enrolled in a Hospitality Japanese course in Taiwan. Three classes were assigned randomly with different learning approaches. The experiment results indicated that the groups with a robot as a double showed significant positive effects in terms of learning motivation and anxiety. Furthermore, a group of students using a double robot with micro-expression exhibited better learning achievement, but their anxiety was also increased. Finally, the limitations of the study and some suggestions for improvement of this proposed approach are provided.

Keywords: Robots for Learning, Virtual Situational Learning Environment, Double, Emotional Intelligence, Micro-expression, Human-Robot Interaction, AI and Robots in Education, Situated Learning, Collaborative Learning, Scaffolding Tool

1. Introduction

One way to encourage students to keep on practicing and studying learning materials is to let them be aware of how they will perform if they are placed in a situational evaluation (Al Hakim, Yang, Liyanawatta, Wang, & Chen, 2022). The situational evaluation here refers to the process of judging actors based on their interaction with other actors, simulated agents, or companions within a specified time during present in a virtual situational learning environment (VSLE). For instance, when students are playing roles as magicians, they have to cast the spell properly during the evaluation so that the scenario can proceed to the next stage of the journey (Al Hakim, Yang, Wang, Yen, Yeh, & Chen, 2021). Therefore, it is necessary to provide a test mechanism to let students watch, know, and learn their own performances that can be designed and revised by themselves. By doing so, students can reflect on their current performance and keep on improving until passing the situational evaluation tests.

In filmmaking, a double is a being who represents the original actor of the film (Piotrowska, 2013). It can create the illusion that makes the spectators or audiences believe that it is their favorite actor who performs the show (Smith, 2004). Thus, the double can be employed as a scaffolding tool that can be trained by students to show their learning outcomes and make the double behave like themselves. On the other hand, emotional intelligence ability has gained a lot of attention due to its potential to guide thinking and behavior, distinguish between different expressions and label them appropriately, and adjust emotions to adapt to environments (Colman, 2015). Such an ability can detect the micro-expression, i.e., involuntary emotional leakage that happens within a fraction of a second and exposes the true emotions of people (Ekman, 2009; Ekman & Friesen, 1969). It is important to grasp micro-expression in particular situations and hence people can take appropriate action to respond to the interlocutors (Soltani, Zarzour, & Babahenini, 2018).

Therefore, this study aims to create a learning environment, where students can collaboratively train or design the double with micro-expression to participate in situational evaluation tests. Moreover, such a learning environment allows students in small groups to immerse themselves with a double to present in a virtual scenario with situational evaluation. Because students show their presentations in front of the audience, they might be driven to revise their own presentation until it is appropriate to the desired design (Chen, Fan, Chang, Chang, & Chen, 2018). The motivation for learning is important because it plays a critical role in the improvement of learning performance (Murphy & Alexander, 2000). Besides, adequate practice in training or designing the double might decrease the anxiety level of students during presentations, which becomes an important issue in a situational learning environment (Liu, Lin, Wu, Chen, & Chen, 2017). To sum up, evaluating the effectiveness of the proposed learning environment to enhance students' learning performance in terms of learning achievement, motivation, and anxiety is worth investigating.

2. Literature Review

2.1 Emotional Intelligence in VSLE

Emotional intelligence is "*the ability to monitor one's own and others' feelings and emotions, to discriminate among them, and to use this information to guide one's thinking and actions*" (Salovey & Mayer, 1990, p. 189). With respect to learning, Perera and DiGiacomo (2013) claimed that emotional intelligence is a good predictor of students' academic performance. Emotional intelligence allows students to have better adaptability to new situations and research has demonstrated a positive relationship between emotional intelligence and achievement of students in a dynamic workplace that requires interactions (Cleary, Visentin, West, Lopez, & Kornhaber, 2018).

When stimulated, human faces will show minor subconscious changes without the control of thoughts within around 0.5 seconds, which are recognized as "micro-expressions" (Zhou, Song, Chen, Chen, Ben, & Cao, 2022). This concept of micro-expression was first discovered by Haggard and Isaacs (1966) and viewed as cues for repressed emotions. Ekman and Friesen (1969) defined micro-expressions as a brief facial movement revealing a true emotion that a person tries to conceal. Micro-expressions are even claimed that as the most promising approach to detect deception, as they usually occur in high-stake situations (Ekman, 2009). With these promising features, a study about micro-expression is worth investigating.

Recent advances in the fields of digital reality have provided new opportunities to let a robot and students become actors and have an authentic experience by immersing themselves in a VSLE with immediate evaluation (Al Hakim et al., 2021; Al Hakim, Yang, Liyanawatta, Wang, Ku, Zhuang, & Chen, 2022). In an authentic environment, students are usually positioned as actors in a particular scenario with learning content and context to interact and solve contextual problems (Barab, Gresalfi, & Ingram-Goble, 2010). They might be role-played as employees in a simulated workplace to emotionally interact with simulated agents and make required decisions that reflect real cases to satisfy the agents (Ke, Moon, & Sokolikj, 2020; Chang, Kao, Hwang, & Lin, 2020). Consequently, emotional intelligence's ability to grasp the real feelings of people through micro-expression is essential to maintaining situational interactions.

2.2 Robots as a Scaffolding Tool to Participate in Situational Evaluation Tests

Currently, a large number of learning activities using robots occur inside the classroom. Robots can play many important roles in learning, including as scaffolding tools to support collaborative learning processes (Okita & Clarke, 2021). Collaborative group strategies can promote individual, group, and community cognitions (Zheng, Yang, Cheng, & Huang, 2014). The robots have characteristics that can be useful for learning, such as flexibility, repeatability, ability to present data, interactivity, appearance, and movement to support instructional goals (Chang, Lee, Chao, Wang, & Chen, 2010).

Atmatzidou and Demetriadis (2012) reported that the students had a positive attitude towards the collaborative learning activities with the LEGO robot, in which they felt that collaborative works become better and interesting, and made high-achievements responsibly to transferring knowledge (as experts) to other groups members, and hence enhanced students' learning motivation. Moreover, Al Hakim et al. (2020) claimed that designing the robot's emotion expressions (sound and facial expression), movements, and speaking features based on the students' preferences can increase their learning interest and concentration. Therefore, a robot can be used as a double that can be designed and revised by the students to represent their learning outcomes (Piotrowska, 2013; Smith, 2004) until the double passes the situational evaluation tests.

Considering the benefits of the robot as a scaffolding tool, this study proposes a learning approach to investigate its impact on the learning performances of students in a VSLE. This study proposes the following hypothesis: learning through design a robot as a double with micro-expression to participate in a virtual situational learning environment can improve students' learning performance. In general, there are two stages in VSLE, one is designing stage and the other is performing stage (Al Hakim, Yang, Liyanawatta, Wang, & Chen, 2022). Initially, before performing in VSLE, all groups with different learning approaches need to construct the scenarios and interactions based on textbook context and content in the designing stage. Three learning approaches are compared, and their effects on students are assessed. The first approach is a micro-expression double robot, wherein a group of students can train or design the robot as their double with micro-expression and practice situational evaluation tests. The second approach involves a double robot as in the first approach but without the micro-expression. The last one uses a conventional instruction approach, wherein a group of students practice situational evaluation tests with their classmates. Moreover, an experiment is conducted in the course of Hospitality Japanese for university students to examine the following questions.

1. Do students learning with the micro-expression double robot approach show better learning achievements than those with a double robot approach or conventional instruction?
2. Do students learning with the micro-expression double robot approach show higher learning motivation than those with a double robot approach or conventional instruction?
3. Do students learning with the micro-expression double robot approach show lower anxiety of learning than those with a double robot approach or conventional instruction?

3. Development of the Micro-expression Double Robot Approach

Fig. 1 illustrates the system architecture. The controller for the whole system, developed on the Android platform, was installed on tablet control. The VSLE program was installed on a personal computer with an NVIDIA graphics card and running on Windows 10. Such a program was used to capture the images of the actors and immerse them into a virtual situational learning scenario, where immediate evaluation and interactive elements were included (e.g., sound effects, the virtual scoring system, and the dynamic scenario). The aforementioned system used WampServer v2.4.9 as the application server and MySQL v5.6.17 as the database server to store all the information.

ZENBO robot from ASUS was employed in this study. The Android-based robot had one screen and two wheels with various LED colors to support emotional actions (i.e., facial expressions, wheel lights, and action). It was 62 cm tall with a round body and had a multimedia deployment feature as well as Wi-Fi connectivity. Furthermore, Microsoft Azure Speech Cognitive Services and DialogFlow services were employed in the robot to manage the speech-to-text and conversation capability, respectively. The robot, tablet control, VSLE program, and database were connected through socket communication.

Figure 1. Architecture of the system.

In this study, a micro-expression double robot approach was developed by referring to the interactive situated learning approach with robots proposed by Al Hakim, Yang, Liyanawatta, Wang, & Chen (2022) and considering ICAP (interactive, constructive, active, passive) framework proposed by Chi and Wylie (2014) (see Fig. 2).

Figure 2. Micro-expression double robot approach.

In the beginning, the schoolteacher gave instruction about the course objectives and taught the content of the textbook (i.e., reserving a seat, ordering meals, and payment in Japanese restaurants), and explained the meaning of each sentence. The schoolteacher also taught students about the emotional interactions in particular situations based on micro-expressions defined in Ekman (1999), helped students in practicing the learning materials, and assisted them to learn pronunciation correctly. Afterward, a description of testing or debugging the situational evaluation tests using a micro-expression double robot was demonstrated, including the tutorial of presenting in VSLE.

Next, students were divided into small groups (5 to 7 members in each group) to construct learning scripts. The format of learning scripts proposed by Chen, et al. (2018) was adopted and modified by researchers and schoolteachers to guide a small group of students while designing the interaction of particular scenarios based on textbook content and contexts. The students designed their presentation with a double and themselves. In this study, the students and a robot were positioned as waitresses and customers in a Japanese restaurant, respectively. The group of students discussed and pondered what action or dialogue that might be performed by the robot as a customer with specific requests in real-life situations. At the same time during scriptwriting process, they also needed to consider the scenario and interaction based on context of robot's emotional responses.

After the learning script was completed, the students can collaboratively work to construct the double robot's micro-expressions and actions using Designing Interface on tablet (Fig. 3 left). Students design or train the robot to perform for them and make the robot behave like themselves, so they can reflect and revise their own presentation. Such an interface also provides a tutorial on how to pronounce a sentence and be able to record voice, replay, and validate whether it can pass the situational evaluation tests (Fig. 3 right). Subsequently, after the learning script was completely digitized into the system, students can debug and practice their designed script with the robot before presenting it in the VSLE.

Figure 3. Designing interface in tablet control.

After finishing the designing stage, all of small groups take turns to rehearsal and present in VSLE with their designed micro-expression double robot, while the other classmates as the audience can watch the actors' performances. In this stage, the teacher situationally controlled the flow of the designed script through the Control Interface on the tablet. Moreover, this interface managed which subtitles were displayed on the screen to be read by the actors. During presentation, the robot is positioned as an interlocutor who is role-playing as a restaurant customer that replays and deploys the emotions, actions, and voices of students based on the designed script (see Fig. 4 left) but in random ways as real-life situations. For instance, the robot requests a beefsteak with a specific cook level, a cup of green tea, and a pudding as a meal, beverage, and dessert, respectively. Fig. 4 (right) shows that when the students correctly performed the interactions, the robot provided positive, happy feedback and praised them. The VSLE then changed the scenario and increased the score. Conversely, when student actors failed in the interaction, the robot provided unhappy feedback and the VSLE decreased the score.

Figure 4. Designed script and illustration of interaction.

4. Experiment

4.1 Participants and Learning Materials

The experiment was conducted in a course of Hospitality Japanese at a university in Taiwan. Three classes were randomly selected as the experimental A, B, and control groups, respectively. All of the students in groups were around 21 years old and taught by the same instructor. Before performing in VSLE, all groups were further randomly divided into smaller groups (five to seven students in a small group) and went to the designing stage with different learning approaches to construct the scripts.

Experimental group A containing 30 students (18 females, 12 males) used the micro-expression double robot. Another class with 30 students (16 females, 14 males) selected as the experimental group B learned with a double robot approach. The control group consisting of 30 students (19 females, 11 males) used the conventional instruction approach. Details of the experimental A, B, and the control groups are shown in Table 1, respectively.

Table 1. *Feature of learning approaches in the study.*

Group	Design the learning scripts	Construct a robot as a double	Construct a double with micro-expression
Experimental group A	✓	✓	✓
Experimental group B	✓	✓	
Control group	✓		

This study compiled the materials taken from the Hospitality Japanese course textbook into a learning script. All three groups used the same learning script. The learning script was developed by the schoolteacher with more than 10 years' experience in teaching the subject. Additionally, the learning script plots was based on the Transformational Play proposed by Barab et al. (2010) to make the developed learning script convey the narrative structures and character development.

4.2 Procedure and Measurement Tools

In this study, experiment was conducted for two months. A pre-test with total scores ranging from 0 to 100 points developed by two schoolteachers was administrated at the beginning of the experiment to evaluate the prior knowledge level of students, along with pre-questionnaires to evaluate their prior perceptions in terms of learning motivation and anxiety. The post-test questions were similar to but different from the pre-test questions to keep the consistency of test. The pre- and post-test questions were designed to measure learning achievement in terms of sentence translation, pitch accent, and situational responses. Regarding the interview, it was conducted in the final stage to obtain the perceptions of students. The experimental procedure was shown in Figure 5.

Figure 5. Experimental procedure.

A single factor covariate analysis (ANCOVA) was employed in this study to evaluate the learning achievements, motivation, and anxiety among the three groups based on the obtained test scores and questionnaire responses. The questionnaires with a five-point Likert scale were used to evaluate the learning motivation and anxiety of students.

The questionnaire adopted to measure the participants' learning motivation was developed based on Wang and Chen (2010). It consists of six items (e.g., "I want to do my best in this class because it is important to show my ability to my classmates, teacher, or the others") and has been reported with a reliability coefficient (Cronbach alpha) of 0.79 (N = 115). With regard to the measurement of the learning anxiety, the foreign language anxiety scale modified by Yang, Chang, Hwang, and Zou (2020) was employed. It consists of eleven questions (e.g., "I feel confident when I speak in a foreign language") with the Cronbach alpha value (0.90) proposed by the original study (N = 51). Moreover, at the end of the experiment, ten students were randomly selected from each group for the interview to have understanding how they perceive the learning approach in detail. The interview questions were based on the study of Al Hakim, Yang, Liyanawatta, Wang, & Chen (2022) and were modified according to the context of this study (e.g., "When using the learning approach, which part did help you study?").

5. Results and Discussion

5.1 Analysis of Learning Achievements

The assumption of the homogeneity regression slopes was met (F = 2.05, p > .05), implying that the ANCOVA was able to be conducted. The adjusted mean of the experimental A, B, and control groups were 72.34, 68.85, and 68.55, respectively, and a significant difference among the three groups was found (F = 15.43, p < .05), indicating that the three groups had significant differences in the post-test scores. By applying pairwise comparisons, it was found that experimental group A outperformed all groups. The results mean that the group of students with the robot as their double with micro-expression (experimental group A) had significantly higher learning achievements than those either with the double robot without micro-expression (experimental group B) or the conventional instruction (control group) in VSLE. Additionally, the effect size of the micro-expression double robot approach reach to a large level with partial eta squared (η^2) = .276 (Cohen, 1988).

Students can learn better when the micro-expression were added to the double robot in VSLE. Because the students in the micro-expression double robot group should trained the robot and need to obey the emotional interactions to pass the evaluation, they outperform those in the other groups in terms of learning achievements. They should be able to perceive the micro-expression of the double robot and then have appropriate reaction related to the situation encountered, as stated by the students in the interviews. Based on the study of Perera and DiGiacomo (2013) and the results of our experiment, we believed that grasping the situation encountered through emotional intelligence revealed in micro-expression plays an important role in the successful performance of students. This finding is in line with the studies by Cleary et al. (2018) and Lam & Kirby (2002); they argued that emotional interaction ability had a positive influence on emotional awareness and management of individual cognitive-based performance. Thus, collaboratively designing or training the robots as an actor's double with micro-expression in a situational learning environment can enhanced students' learning achievements.

5.2 Questionnaires Analysis for Learning Motivation and Anxiety

The responses to the questionnaire were analyzed with ANCOVA to compare the students' learning motivation and anxiety in three different learning approaches. For learning motivation, the homogeneity of regression ratings among the three groups was F = 1.17 (p > .05), revealing the assumption of ANCOVA was fulfilled. The adjusted mean of the post-learning motivation measurement for the experimental group A was 3.83, the experimental group B was 3.68, and the control group was 3.07. The results of ANCOVA demonstrated that there was a significant difference among the three groups' learning motivation (F = 6.324, p < .05, η^2 = .135). The pairwise comparisons showed that experimental groups A and B outperformed the control group, while a significant difference between the experimental group A and B was not exist. The results implies that in the milieu of VSLE, both group of students using a double robot, in spite of with or without micro-expression, had higher learning motivation than the students in the conventional instruction group.

Based on the interviews of the students, it was inferred that the situational evaluation for learning performance provided by the VSLE could drive them to design or train the double robot properly. Because they had to present and complete the learning tasks, they took responsibility for mastering the interaction and revising the double robot until passing the situational evaluation tests. This learning process might increase the frequency of practice and willingness to learn (Atmatzidou & Demetriadis, 2012). Moreover, the curiosity and fantasy brought out by the robot during situational evaluation can enhance students' learning motivation (Chang, Lee, Chao, et al., 2010; Gordon, Breazeal, & Engel, 2015). This could be one of the reasons why experimental groups A and B attained better learning motivation than the control group.

Regarding learning anxiety, several previous studies (Al Hakim, Yang, Liyanawatta, Wang, Ku, et al., 2022; Shiomi, Iio, Kamei, Sharma, & Hagita, 2015), reported that adopting robots in learning activities can decrease students' learning anxiety. The adjusted mean scores of the experimental A, B, and control groups were 3.67, 4.24, and 2.47, respectively. The F-value (F = 46.351, p < .05, η^2 = .534) implies that significant differences exist among three groups in terms of learning anxiety with a large effect size. Based on presented pairwise comparisons, it was found that the experimental group A and B outperformed the control group. The results reveal that the students with a double robot, either with or without micro-expression, had lower learning anxiety than those practicing with their peers before performing in VSLE. We believed that adequate practice in the designing stage can enhance students learning experience in VSLE (Al Hakim, Yang, Liyanawatta, Wang, & Chen, 2022; Al Hakim, Yang, Wang, et al., 2021), and hence they became more prepared and less anxious during the performing.

On the other hand, an interesting result was found that the experimental group B significantly outperformed the experimental group A in terms of decreasing learning anxiety. This finding may happen due to the reason that the students' group with the micro-expression double robot was faced with a situation where the students had to deal with the uncertain emotions of their double robot as an interlocutor in VSLE, as revealed in the interview. Although the unexpected responses from the robots is claimed as non-judgemental during interactions (Alemi, Meghdari, & Ghazisaedy, 2015; Chang, Lee, Chao, et al., 2010), in this study, the micro-expression exposed by the double robot in the group A may increase the anxiety of students. This might be attributed to that the students of group A tried to read the unexpected micro-expression of the robots and manage the situation appropriately in order to pass the situational evaluation during the VSLE performance, therefore, increasing their anxiety.

6. Conclusion, Limitations, and Future Works

This study proposed a micro-expression double robot approach, where students can collaboratively design the robot as their double with micro-expression to participate in the situational evaluation. The major role of the robot in this study is to play as a scaffolding tool to construct the student actor's double that can be revised, and at the same time, as the evaluation tool that enables students to reflect based on their design (i.e., micro-expressions, actions, and students' utterances). After finishing constructing the scenario and interaction as well as training the double robot, both of the double robot and students perform in a VSLE with immediate evaluation.

Based on the experimental results, it is concluded that the students collaboratively designing a robot as their double to complete the situational evaluation showed significant positive effects in terms of learning motivation and anxiety. Furthermore, students' learning achievements were significantly improved when micro-expression was employed in the double robot, but it also increased their learning anxiety. Our study provides a novel area of insight into the use of robots in learning, by integrating pedagogical approaches, reality technology, humanistic design, and practices, to create an immersive intelligent learning environment with a robot as a scaffolding tool that can show learning outcomes and foster emotional intelligence.

However, although the results of this study indicated that the proposed approach is effective, there were several limitations that should be addressed. First, comparing different instructional media with conventional instructional approach, which is categorized as a media comparison study (Surry and Ensminger, 2001), has been claimed as a weakly designed research in the field of educational technology and so could have flaws in the research design itself. Therefore, in the future, authors would discussed how three groups in this study overcame the limitation of the media comparison study using alternative research approach, and thus, our research findings would be more significant for the field. Second, this study conducted an experiment on a Hospitality Japanese course for university students in Taiwan, which might not be proper to apply the findings on different ages, cultures, or learning capabilities of students without further experiments. Future study considering gender and personality is worth investigating since such features can affect students' perception of specific learning environment elements (Denden, Tlili, Essalmi, Jemni, Chen, & Burgos, 2021). Third, the measurement tools were determined by two experienced schoolteachers based on their past experience, which did not measure and analyze the speaking ability, cognitive load, and emotional intelligence level of students. In the future, the authors would cooperate with schoolteachers to construct more appropriate measurement tools. Moreover, since this learning activity involves social recognition by presentation, measuring and analyzing the responsibility, ownership, and autonomy of students in small groups are also interesting topics for further study. Finally, we also plan to improve the robot program that can read and record the micro-expression of students. By doing so, students can more easily design the robot and simultaneously allow themselves to practice emotional interaction.

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