Effects of Facial Recognition and Text Semantic Recognition on Affective Tutoring System

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Abstract

Facial recognition is the fastest method to detect emotions, and it can be combined with text semantic recognition to increase the accuracy of emotion detection. Emotions and creativity have often been discussed in recent years. A student will be interested in learning as long as he or she enjoys learning. Mind mapping is an active and simultaneous use of the left and right brains to stimulate the creativity and imagination of the learner, which is complementary to positive emotion. This study constructed an affective adaptive learning system that combines text emotions and facial clues in chatbot conversations to understand the emotional responses of learners during the learning process. The system is tailored to accommodate diverse learners through modules of varying difficulty scales, the incorporation of mind maps to support teaching and learning, and the implementation of asynchronous online discussion forums for discourse and feedback on course-related topics. The results revealed significant differences in critical thinking, reflective thinking, and problem-solving skills between the experimental and control groups, and students in the experimental group outperformed those in the control group on the creation of mind maps.

Keywords: Mind map, Facial emotion, Text semantic recognition, Affective tutoring system

1 Introduction

In recent years, the increasing maturity of multimedia [1-2] and artificial intelligence technologies [3] has led to the gradual growth of biometric applications [4-5] in everyday life. Facial recognition is the fastest method to detect emotions, and it can be combined with text semantic recognition to increase the accuracy of emotion detection. Emotions and creativity have often been discussed in recent years. The definition of a person's skills and preparedness for society has evolved in response to scientific innovation, technological advancements, growing globalization, and rapid changes in social competition [6].

Learning now requires selective, thoughtful organization of knowledge for flexible problem-solving, with creativity, critical thinking, and reflection being essential skills. Yet, there's limited research and practical application in education on assessing and developing critical thinking skills, accordingto Facione [7], involves purposeful, reasoned thinking that includes problem-solving, reasoning, and the ability to be creative.

There has been considerable discussion lately about emotions and creativity. [8] Students must find their learning experiences enjoyable to remain engaged. Uninteresting and stressful learning diminishes their interest significantly. Evaluating the outcomes of learning experiences is increasingly necessary, as lackluster content heightens stress and further reduces learning interest.

In the Technology and Art courses, learners can be aided in recognizing the ebb and flow of their emotions. Art has the power to soothe one's feelings. Through the process of artistic activities, we can understand the inner world and needs of the learners.

Conversely, the more joy there is in learning, the more positive emotions are fostered [8]. It also promotes positive thinking and improves the performance of imagination, creativity, and association. Mind mapping is a dynamic that engages both the left and right brains. It not only stimulates creativity and imagination but also complements positive emotions. Some studies have evidenced that joyful emotions can stimulate students' minds, leading to better performance, imagination, and creativity [9]. Thus, the presented system not only provides learners with more engaging learning through adaptive learning adjustments but also stimulates learners' creativity, imagination, and association by incorporating mind mapping to assist teaching and learning.

This study established an emotional recognition learning system using affective computing techniques (ACT) to understand learners' facial emotional responses during the learning process. The system first recognized students' emotions as they engaged in chatbot dialogues, leveraging emotional recognition to provide adaptive learning adjustments for the course content during the learning process. Mind mapping uses the entire brain to foster meaning creation and problem solving skills. It is also an effective way to aid the brain in memory retention, organization and structuring.Therefore, in the learning process of students, how to make good use of appropriate learning strategies to assist students in obtaining effective learning should not be underestimated. Thus, aligned with the above discussion, the study has incorporated mind mapping

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instruction and asynchronous online discussion forums into the curriculum, which aim to enhance students' creativity, critical thinking, reflection, and problem-solving skills. The research questions are as follows:

1. Is there a significant improvement in critical thinking when using the affective adaptive learning system?
2. Is there a significant increase in reflective thinking skills when using the affective adaptive learning system?
3. Is there a significant improvement in problem-solving ability when using the affective adaptive learning system?

2 Literature Review

2.1 Mapping Creative Thinking and Problem Solving

Creativity is an inventive and productive ability encompassing broad thinking and imagination. It represents a thinking process where creative thinking serves as a problem-solving mechanism, assuming multiple roles and meanings in generating creative outcomes. [10]. Creativity is a personality trait emphasizing divergent thinking, risk-taking, curiosity, and imagination, showcasing the ability to form new relationships between things and ideas using traditional creative processes. Studies show that mind mapping aids in systematic knowledge organization, enhancing memory retention and comprehension. It also helps students improve problem-solving skills, identify hidden issues through brainstorming, and apply logical thinking. [11] They establish cognitive connections among knowledge, expand their imaginations during the learning process, and make it an enjoyable experience. Students not only continued to use mind mapping one month after completing the program, but also applied their learning to other disciplines [12]. With the rapid evolution of information technology, mind maps are no longer confined to pen and paper drawings. They can be created on mobile devices, such as tablet PCs using apps [13]. Thus, in this study, mind mapping supported by digital devices was used as a teaching tool to help students construct creative thinking processes and improve their problem-solving skills.

2.2 The Relationship between Critical Thinking, Reflection, and Knowledge

Critical thinking involves applying prior knowledge, common sense, and experience, rather than inventing solutions spontaneously. [14] Numerous studies have established a close relationship between critical thinking and knowledge, claiming that while prior knowledge may not always have a direct impact on critical thinking, it is absolutely necessary for critical thinking. Suter [15], These competencies are sequential: students first interpret ideas, then evaluate solutions, explore and clarify inconsistencies or missing information, and finally explain their thinking process outcomes.

Reflection has the potential to boost learning. Schön [16] described the process of reflection as a dialogue between the practitioner and a problematic situation, where solutions to the problem are proposed. Boyd and Fales [17] recognized reflection as the integration of thought and action. When a student encounters a problem, the optimal time for education is when the problem is immediately discussed. Reflective thinking skills in experiential education are a promising educational strategy. As Howe, Hennessy [18] suggested, the teacher's questions prompt student reflection and discussion, enhancing teacher-student interaction and peer learning. Encouraging introspection and dialogical reflection helps students maintain positive learning emotions and motivation, clarify concepts, and collaboratively solve problems through empathy and support [19].

In this study, learning sheets with questions and peer discussions in forums were integrated into the curriculum to help students think critically, reflect on what they are learning in the system, and develop the assigned problem-solving skills.

3 Research Method

3.1 System Structure

In this study, Figure 1 depict the system architecture and system interface of this study, which is divided into four sections. The zone of emotion recognition captures facial emotions and semantic emotions, and then the results are sent back to the emotional record and stored in the database. With this emotional feedback, the system provides the learner with an Emotional adaptability course and the emotional agent offers the learner a corresponding emotional response.

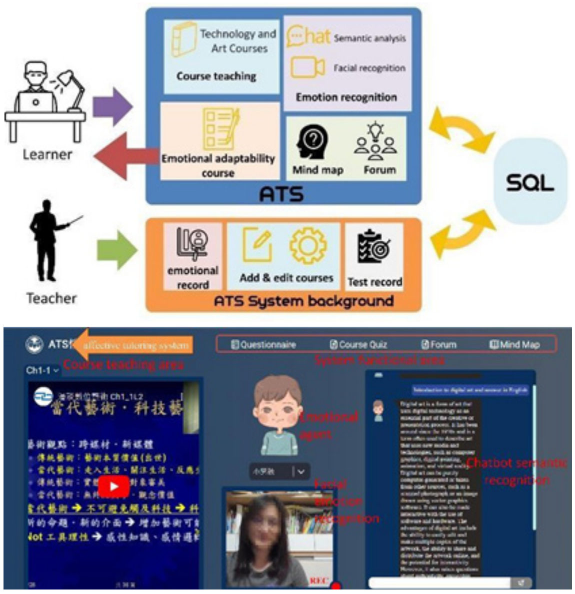

Figure 1. The structure of learning system and interface design

The teaching section provides videos and materials, allowing teachers to add and edit course information. Evaluation results are uploaded for record keeping. Students can edit and upload their mind maps for instructor review. A discussion forum facilitates peer collaboration and course-related discussions. This study introduced an affective adaptive learning system incorporating mind mapping, using HTML, CSS, and JavaScript for the client interface, PHP and SQL for the server database, and Python for text semantic recognition. Development occurred on a Windows 10 PC equipped with a Webcam for facial detection and internet access.

3.2 Facial Recognition

Clmtrackr is a JavaScript library for facial emotion analysis, utilizing the Viola-Jones algorithm for initial face detection in images, marking it with a rectangle. It then examines this rectangle closely to identify facial boundaries like the nose and mouth, analyzing features with CLM (constrained local models). [20]. The CLM algorithm for facial feature recognition was introduced by researchers Saragih, Lucey [21]. The face model unergoes trained using image data from the MUCT database, which includes some image data created by the developers. As shown on Figure 2, the MUCT database has been trained using 3, 755 face photos and 70 facial traits. It is based on Ekman and Friesen [22] facial and sensory features to define six facial expressions: happiness, anger, sadness, surprise, disgust, and fear.

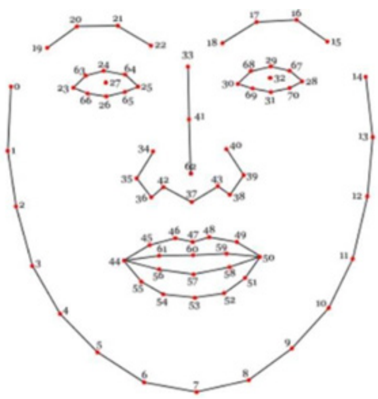

Figure 2. The face features from Clmtrackr's analysis

CLM (constrained local models) accurately positions facial feature points by initializing their location and matching average features within neighboring domains. It utilizes two statistical models: the Shape Model, modeling face shape through feature point distribution for shape changes, and the Patch Model, offering a matching criterion for feature points by modeling their surrounding domain for optimal matches., as depicted in Figure 3 below.

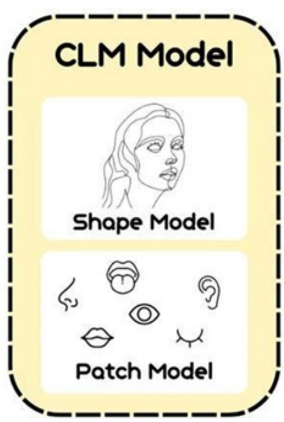

Figure 3. CLM model

A shape model is constructed by first removing rotational, training dataset for model training [23]. The text highlights scaling, and translational variations through graphical analysis. the importance of sequence and time-series context in Variation bases and their magnitudes are determined with PCA. For the patch model, SVM is trained with samples to classify data and identify the correctness of image blocks.

The CLM search procedure is as follows: Starting with the initial image, the classification method of a support vector machine (SVM) (Figure 4) is employed to classify the area around its features and generate the response image. The response image is obtained by filtering the feature points using filter techniques. Then, using the optimization function and the shape function, new feature positions are determined. These steps are repeated until all feature points reach a stable position (Figure 5).

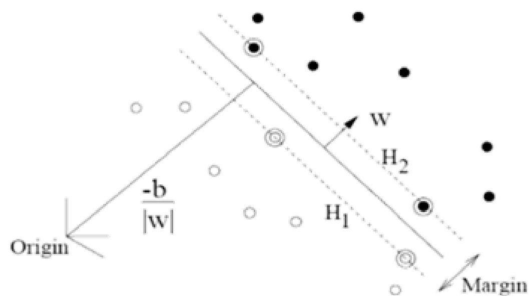

Figure 4. SVM classifier

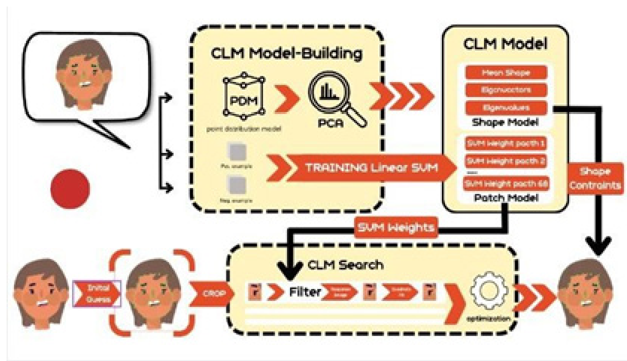

Figure 5. The framework of CLM model

3.3 Text Semantic Emotional Recognition

Python is used to develop text semantic recognition as a server access and data processing interface.

Keywords are extracted and matched into sentences using the NLTK and Jieba packages. The keywords are then saved as retrieval objects. Levenshtein distance and long short-term memory (LSTM) are used to classify the data in order to generate a categorized conversation system.

The proposed Chatbot system analyzed text sentiment partially using Keras (Tensflower's API) and categorized the sentiment of text semantics into positive and negative using Word2Vector. Meanwhile, drawing from the literature on short text categorization on Twitter, the study utilized over 40,000 Twitter short text posts labeled with positive and negative sentiments as the initial training methods. For natural language processing (NLP) tasks, recurrent neural networks (RNN), especially LSTM, are preferred for their learning capabilities. Conversely, convolutional neural networks (CNN) dominate feature recognition. Recent studies have moved towards integrating both methods into a single model, rather than relying on one approach. Among them, the LSTM-CNN model exhibits superior accuracy when compared to CNN-LSTM, pure CNN, orpure LSTM, as indicated by Baccouche, Ahmed [24].

Thus, the system adopted LSTM-CNN as the classification method, achieving an accuracy of 92%, as illustrated in Figure 6.

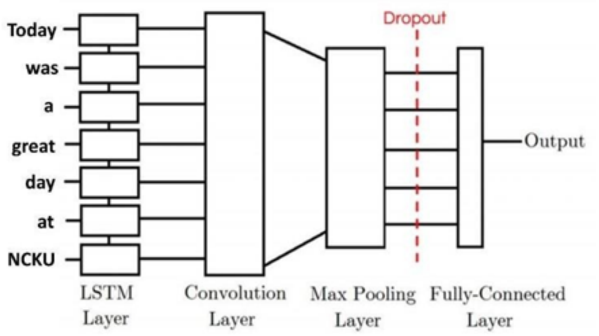

Figure 6. The model of LSTM- CNN

3.4 Dialogue System

To minimize the syntactic error rates, the dialogue system was built based on the retrieval model of the Chatterbot module, Q&A mode dialogue system. By matching the rules of the shortest edit distance in Chinese syntax, the most similar sentences was found for responding to the learners. The textual questions originated from 1572 common dialogues with students in class, co-written by experts. The accuracy of this dialogue system is 82%, as shown in Figure 7. For example, let a and b be two strings, with lengths $|a|$ and $|b|$, whereas lev (i, j) is the shortest editing distance between the lengths of the two strings. The algorithm used between two strings is the Levenshtein Distance Function.

$$\mathrm{lev}_{a,b}(i,j) = \begin{cases} \max(i,j) \\ \min \begin{cases} \mathrm{lev}_{a,b}(i-1,j)+1 \\ \mathrm{lev}_{a,b}(i,j-1)+1 \\ \mathrm{lev}_{a,b}(i-1,j-1)+1_{(a_i \neq b_j)} \end{cases} \end{cases}$$

Figure 7. Levenshtein distance function

3.5 Mind Mapping

The GoJs's mind map makes use of the interactive chart provided by the JavaScript library. It also converts the compiled mind maps into JSON format using PHP and jQuery and stores them of the server of learning system. As shown in Figure 8, learners can directly edit the mind map within the learning system and upload it to the proposed learning system.

Figure 8. Mind map editing screen and uploading to server

4 Method

The participants were 43 students from a university in southern Taiwan, randomly divided into the experimental group (N = 22) and the control group (N = 21). Each group was further subdivided into 10 groups of students (4-5 students) at random. Then, the odd-numbered groups were assigned to the control group and the even-numbered groups were assigned to the experimental group. In the experimental group, the ATS learning system is equipped with facial and text semantic recognition capabilities, enhancing interactive teaching. The control group uses a standard digital learning system paired with a chatbot for instructional support, lacking emotional recognition features. This setup contrasts advanced technology in the experimental group with a more conventional digital approach in the control group.

A total of six weeks of experimental procedures were tailored for this study. A pre-test questionnaire, including critical thinking, reflective thinking, and problem solving, was administered before the first and second weeks of the course. It aimed to examine whether there were any potential learning differences between the experimental group and the control group before the use of the learning system. Additionally, a presentation was used to explain the system and provide a course description. While learners actually operated the learning system, they were given the opportunity to create a mind map with the help of the course scaffolding after using the learning system. In the third and fourth weeks, learners can freely access the learning system without any strict time limits. In the fifth and sixth weeks, group work with cooperative learning in a discussion forum was conducted, focusing on the questions given on the learning sheet, gathering the answers from the Internet, and involving peer discussion within the discussion forum. After collaborative learning with their peers and accessing the learning system again to construct their mind maps, students were asked to finish a post-test questionnaire, as shown in Figure 9.

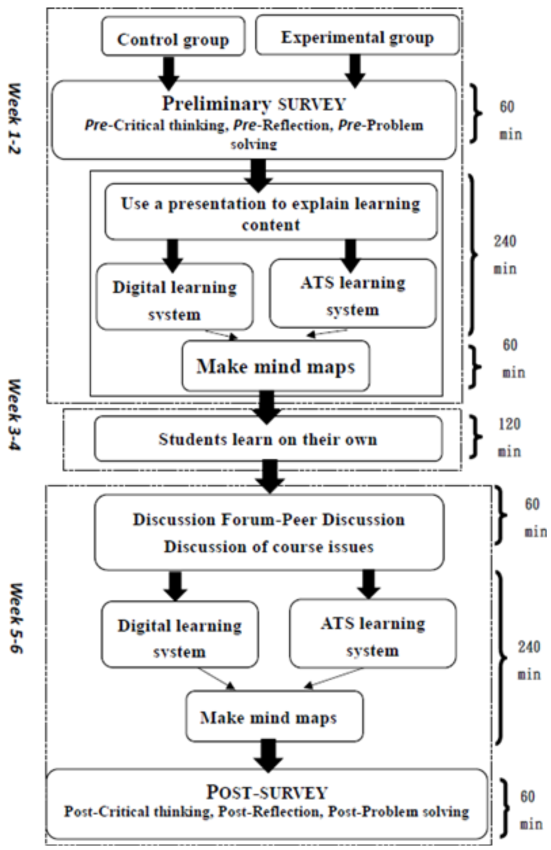

Figure 9. Experiment flow chart

5 Results

5.1 Analysis of Mind Mapping

In this study, the digital mind map assessment rubric was developed based on the scoring criteria for mind maps as proposed by Buzen and Buzen [25]. Modifications were made to align with the specific characteristics of digital mind maps used in this study and following discussions with educators. As outlined in Table 1, the assessment criteria are divided into three main categories: breadth, depth, and rules. The category of rules is further divided into five subcategories. Breadth assesses the number of main branches and sub-branches extended from the central idea. Depth evaluates the number and accuracy of details in the sub-branches. Rules assess compliance with the five sub-criteria. Each criterion is scored on a scale of up to five points, with a total possible score of 35. Higher scores indicate better performance in digital mind mapping.

Table 1. Mind map scoring criteria

	Criteria	Score
	Breadth (Concepts)	5
	Depth (Details)	5
Rules:	1. Central theme	5
	2. Uniform color for same branch	5
	3. Smooth lines	5
	4. Keywords of approximately 1-5 characters	5
	5. Words above the lines	5

For the reliability test of the evaluators, two educators independently assessed the digital mind maps based on the criteria specified in the digital mind map assessment rubric. This approach was adopted to maintain fairness and impartiality. Since the scores represent continuous variables, the reliability between the two evaluators was determined using the Pearson product-moment correlation coefficient. A coefficient of 0.86 was obtained, indicating a high degree of reliability between the evaluators' scores.

In order to assess the difference in mind maps produced by the experimental group (N = 22) and the control group (N = 21), the results of the post-scoring analysis will be conducted later. From the digital mind mapping works, it can be observed that, guided by the scaffolding of the curriculum, most of the mind maps in the pre-testing were mostly about the contents of the curriculum as depicted in Figure 10. Conversely, guided by the collaborative learning with peers in the discussion forum, the mind maps in the post-testing showed greater innovation and expansions with additional notes, as shown in Figure 11.

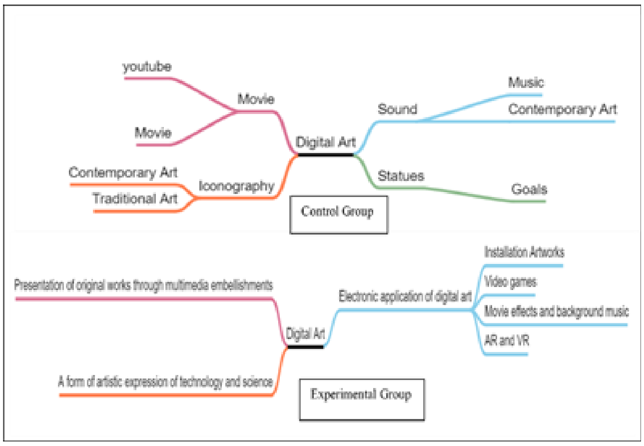

Figure 10. Mind mapping works in the pre-testing

Figure 11. Mind mapping works in the post-testing

5.2 Result and Discussion Forum

The assessment method for the discussion questions in this study is based on the framework proposed by Anderson, Krathwohl [26], which is a revision of Bloom's taxonomy Bloom, Engelhart. The educational objectives are categorized into three domains: cognitive, affective, and psychomotor. Within the cognitive domain, there are six levels of cognition: knowledge, comprehension, application, analysis, evaluation, and creation. Each level is scored out of 5 points, making the total score 30. To ensure the reliability of the evaluators, two educators independently assessed the students' discussion contents based on a discussion question analysis rubric. Since the scoring involves continuous variables, this study utilized the Pearson product-moment correlation coefficient to determine the reliability between the two evaluators. A coefficient of 0.82 was obtained, indicating a high degree of reliability between the evaluators' scores.

The study compared question discussion scores in a forum between experimental and control groups, revealing results after integrating mind mapping into the affective adaptive learning system. Table 2 presents the results of the independent sample t test, indicating a significant difference in the mean value of the question discussion scores (p = 0.000, p < 0.001) between the experimental group (M = 24.77, SD = 4.75) and the control group (M =19.05, SD = 5.15) in the forum (t(41) = 3.79, p = 0.000). Compared with the control group, participants in the experimental group provided more comprehensive answers to the questions in the discussion forums and engaged in more frequent peer-to-peer discussions and learning behaviors.

Table 2. Results of the learning sheet in the discussion forum using independent t-test

	M (*SD*)		df	*t*	*p*
	EG (*N* = 22)	CG (*N* = 21)			
Learning sheet	24.77 (4.75)	19.05 (5.15)	41	3.79	0.000

Note. Experimental group, EG; Control group, CG

5.3 Analysis of Critical Thinking

This study was then conducted to find out the consistency of prior knowledge about digital art between the control group (N = 21) and the experimental group (N = 22). This study adapted the critical thinking skills proposed by Schraw and Dennison [27]. The Cronbach's alpha coefficients stated by the original study was 0.95, implying acceptable and highly acceptable reliability of the students' critical thinking. A pre- and post-test of critical thinking questionnaires was developed with a five-point Likert's scale, and the results were analyzed using one-way ANCOVA.

After eliminating the potential effects, the effect of the independent variable on the dependent variable was examined (F = 8.87*, p = 0.005 < 0.01), indicating that the difference between the groups reached a significant level (Table 3). The students in the experimental group scored significantly higher in critical thinking skills compared to the students in the control group.

Table 3. Results of critical thinking skills using ANCOVA

Source of variation	*SS*	*df*	*MS*	*F*	*p*
Group	3.073	1	3.073	8.874	.005
Error (between groups)	13.850	40	.346		

5.4 Analysis of Reflective Thinking Skills

In addition, to find out whether there is consistency of prior knowledge about digital art between the control group (N = 21) and the experimental group (N = 22), the study adapted the reflective thinking skills proposed by Kember, Leung [28]. The Cronbach's alpha coefficients stated by the original study was 0.83, implying acceptable and highly acceptable reliability of the students' reflective thinking skills. A pre- and post-test of reflective thinking questionnaires was developed with a five-point Likert's scale, and the one-way ANCOVA was employed to examine the results.

After eliminating the potential effects, the impact of the independent variable on the dependent variable was determined by F = 4.59*, p = 0.038 < 0.05, indicating a significant difference between the groups (Table 4). The students in the experimental group scored significantly higher in reflective thinking skills than the students in the control group.

Table 4. Results of reflective thinking skills using ANCOVA

Source of variation	*SS*	*df*	*MS*	*F*	*p*
Group	.443	1	.443	4.59	.038
Error (between groups)	3.85	40	.096		

5.5 Analysis of Problem-solving Thinking Skills

To assess if the experimental group (N = 22) and the control group (N = 21) had consistent prior knowledge about digital art, the study adapted the problem-solving skills proposed by Hwang and Chen [29]. The Cronbach's alpha coefficients stated by the original study was 0.9, implying acceptable and highly acceptable reliability of the students' problem solving. A pre- and post-test of the problem-solving questionnaire was developed with a five-point Likert's scale, and the one-way ANCOVA was used to examine the results. After eliminating the potential effects, the impact of the independent variable on the dependent variable was determined by F = 7.42*, p = 0.01 < 0.05, indicating that the difference between the groups reached a significant level (Table 5). The students in the experimental group scored significantly higher in problem-solving skills than the students in the control group.

Table 5. Results of problem-solving skills using ANCOVA

Source of variation	*SS*	*df*	*MS*	*F*	*p*
Group	3.20	1	3.20	7.426	.010
Error (between groups)	16.80	40	.431		

6 Discussion and Conclusions

Currently, many teaching systems emphasize motivation enhancement in the learning process through game-based learning, emotional exploration, and real-time feedback to improve students' learning effectiveness.

However, there is often less consideration given to improving learners' problem-solving skills, critical thinking, and reflective thinking skills. This study aimed to address this gap by developing an affective adaptive learning system with the integration of mind mapping into the curriculum knowledge learning process to enhance students' learning effectiveness. Meanwhile, the study also assisted the students in constructing forum discussions on problems within the asynchronous curriculum environment of the learning system, thereby assisting the students in thinking critically, reflecting on the knowledge they have acquired in the system, and achieving the problem-solving-related abilities.

The divergent thinking of mind maps allows us to generate many different perspectives on a topic [30]. It involves an associative process where a central concept is projected outward, and each string of words and concepts can become a center of its own and extend outward into infinite diffusion. Each diffusion also leads back to the main concepts, and is then associated with the brain's innate mental abilities through the use of words, numbers, rows and columns, sequences, images, colors, symbols, and associations. As a result, mind maps not only enhance creativity and memory retention but also add an element of interest and personalization.

The discussion forums in the study's system allow learners to develop problem-solving skills through course-related questions, boosting creativity, critical thinking, and reflection. Emotions significantly influence learning, with the chatbot in the online forum acting as both a motivator for supportive relationships and a potential barrier to communication and growth due to conflicting goals and personalities. The proposed affective-adaptive learning system enhances students' creativity by integrating mind maps into education. It supports the problem-solving process, in line with scholars like Tang and Vezzani [31], by emphasizing continuous review and reflection for innovative solutions and optimal problem-solving decisions.

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