Effect Analysis of a Multi-Material Approach to a Problem-Solving Learning System

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***Abstract*—With the rapid development of multimedia, various types of materials used in the design of problem-solving activities have attracted a considerable amount of attention from researchers. The adaptive materials employed in learning activities could enhance learning performance, and motivate learners to seek the solution to a problem. Personalizing a learning environment to optimize individual learning has recently become a popular trend in e-learning. Therefore, this study was carried out to explore how the learning materials of a problem-solving activity influence learning performance; thus we created a multi-material-based learning system (MBLS) consisting of animated game-based material and static text material. The MBLS develops a series of problem-solving tasks to train the learner how to deal with risk. Each task was developed based on the problem-solving model, and the presentation of each task's scenario was classified as either static or dynamic. To achieve the goal of personalized learning, learners could choose the most suitable material for the problem-solving activity. Teachers were included in an expert validation test in this study to examine the performance and reliability of the learning material in the MBLS. The experimental results show that, when the multi-materials are employed, the participants have a 95% probability of obtaining an above-average score using stratification, which suggests that the employed multi-material technique can be a good vehicle for providing adaptive learning that is related to problem solving.**

***Keywords*—Personalize learning, multi-material, e-learning animation, problem solving**

I. INTRODUCTION

In recent decades, rapidly developing web technology and multimedia has been applied widely to teaching and learning methods [1][2]. The main reason is that the learners interact with an online learning platform and portfolios can be dynamically retrieved based on the framework of information and communication technology (ICT) [3]. As a result, deciding which kind of learning material to employ in learning activities has become more interesting than ever, and learners can adjust the learning material to personalize the learning activities. Recently, some studies have indicated that a learning system should provide personalized and adaptive learning programs to improve learning [4]; the multi-materials employed in the learning activities are effective for meeting the requirements of different learners.

The incorporation of web-based learning into dynamic materials such as games has been applied widely to e-learning systems. Notably, the game mechanism can improve the learners' learning performance while maintaining the enjoyable nature of the games [5]. Therefore, problem-solving activities have been aimed toward the use of the e-learning platform rather than conventional paperwork. The dramatically increasing amount of learning materials has also increased the complexity and difficulty of problem-solving activities, making it difficult to enhance the learners' ability to find a solution. This study aims to reduce this difficulty and improve learning performance through undertaking problem-solving activities; the static text or dynamic tool can be integrated as a multi-material system which can assist in adapting the system to learners' preferences or needs.

Accordingly, we developed a multi-material-based learning system (MBLS) for problem-solving activities, in which static textual presentation, animated game techniques, the problem-solving model, and inspiring theory are integrated to facilitate the process of problem-solving activities. Web techniques are used to enable the learning system to interact with and successfully attract learners' interest while efficiently improve their learning performance.

II. RELATED WORK

Determining the correlations between learning performance associated with different materials has engaged the attention of many researchers [6]-[8]. The learning materials affect learning performance in different ways. For example, dynamic materials have a more positive effect on attracting the learner's attention and arousing their interest than static textual material. The exploration of the effects of different multimedia materials plays an important role in problem-solving activities. In particular, game-based learning is defined as one of the learning materials that aims to improve

learners' problem-solving abilities by adopting games in educational settings [9]. Applying game techniques in learning activities aims to enhance learning motivation. The related literature shows that games can be a stimulating motivator for students of all ages [10]. Creating game-based learning systems has been considered as an innovative development in digital learning. Therefore, game techniques are included frequently as a positive component of individual learning.

Various types of materials applied in problem-solving activities have attracted researchers' attention. Mayer et al. proposed that visual material could promote problem-solving transfer and enhance problem-solving comprehension [11][12]. Some studies show that the developed visual style may be congruent to a certain degree [12]. Animation provides explicit external representations, thus the cognitive style is the main difference between animation and static material [12]. For learners, animations are employed to not only provide learners with compensatory illustration with less pronounced visual styles [13], but also to enable a mental representation with a less developed visual style[14]. To summarize, animation is effective for helping learners to imagine processes and conduct a mental representation. Accordingly, it is considered a good tool for problem-solving activities. This study employed animated material in its game-based problem-solving activity to impress the learner with its dynamic display of text and picture.

III. METHODOLOGY

In the MBLS, theories of problem-solving education, learner behavior theory, web technology, and multimedia were employed to develop the adaptive learning system. The architecture of MBLS is illustrated in Fig. 1.

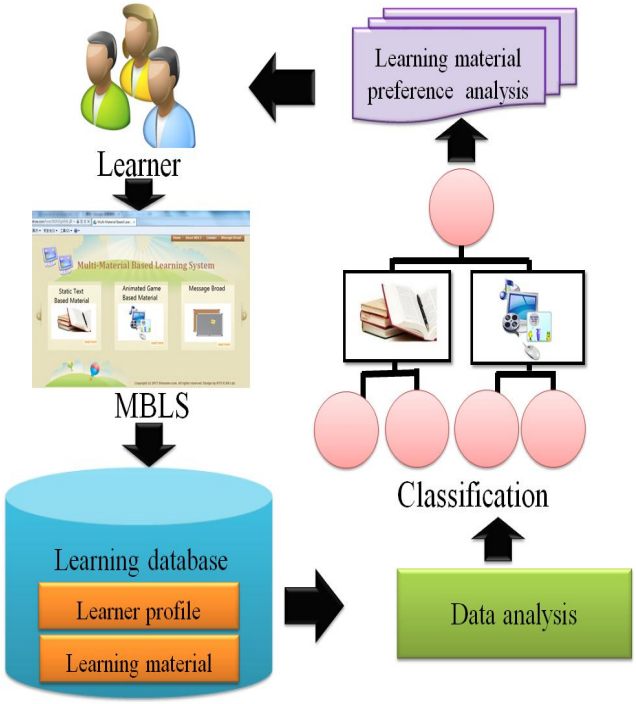

Fig. 1 The architecture of MBLS.

The multi-media materials we designed were classified as static and dynamic types in the MBLS. The textual description was integrated as the static material, and the animated interactive game applied in the MBLS was defined as the dynamic material. The MBLS includes a series of solution-inferring tasks concerned with problem-solving ability training based on the static text-based or animated-based game material. When learners accomplish the problem-solving task, the results of the game are considered the learning profile and are entered into a learning database for data analysis. The purpose of developing education intelligence is to analyze learner preferences of the materials and optimize learning activities. Knowledge management (KM) is employed in the process of data analysis s. More specifically, the web-based architecture acts as a medium between the system and the learner in the MBLS. To enhance the portability of the system, we programed the MBLS to ensure compatibility with mobile device software. Learners can receive immediate feedback even on a mobile device (See Fig. 2), allowing the learner to obtain real-time information. Accordingly, the MBLS can personalize service procedures and provide suggestions based on the inputted information.

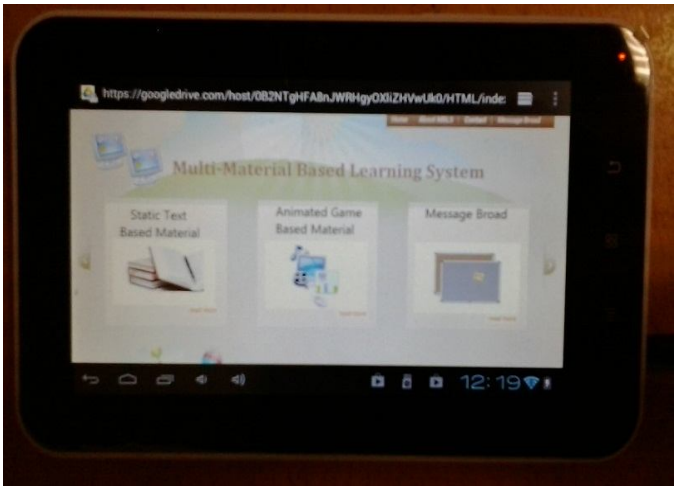

Fig. 2 The result of the MBLS executed on a mobile device.

A. *System design of the MBLS*

Fig. 3 depicts the user interface of the MBLS, which consists of three parts: static text material, animated game-based material, and an interacting mechanism, which consists of a message board and suggestion forum. The MBLS establishes a multi-environmental analysis including static and dynamic characteristics.

Fig. 3 The interface of MBLS

• The scenarios of the game motivate the learner to use skills such as observation, logic analysis, mathematic computation, and associating ability. The problem-solving model collaborates with the goal of personalized learning for development of the learning scenario. In the problem-solving model, the nature of the problem should first be identified. The learner should then start to plan problem-solving strategies and choose optimal resources. The problem-solving process could be monitored by the solver [15]. The MBLS applied the above procedure of the problem-solving model in the scenarios, and displayed them using static text material and animation-based games. Fig. 4 shows the representation of static text material in the MBLS, the subject of each scenario has clear instructions with textual descriptions.

Fig. 4 The representation of static text material.

To compare with static text material, we employed the animated-based game in the MBLS for the same scenarios. Fig. 5 demonstrates the interface of the animation-based game, which incorporates the problem-solving model into the game scenario design. The learner in the gaming process was asked to observe the conversation in the animation and find the solution to the problem by observing the gameplay. Learners can monitor the problem via the board which records the procedure of the game. Each game was developed based on four main training subjects: observation, logic analysis, mathematic computation, and associating ability (See Fig. 6).

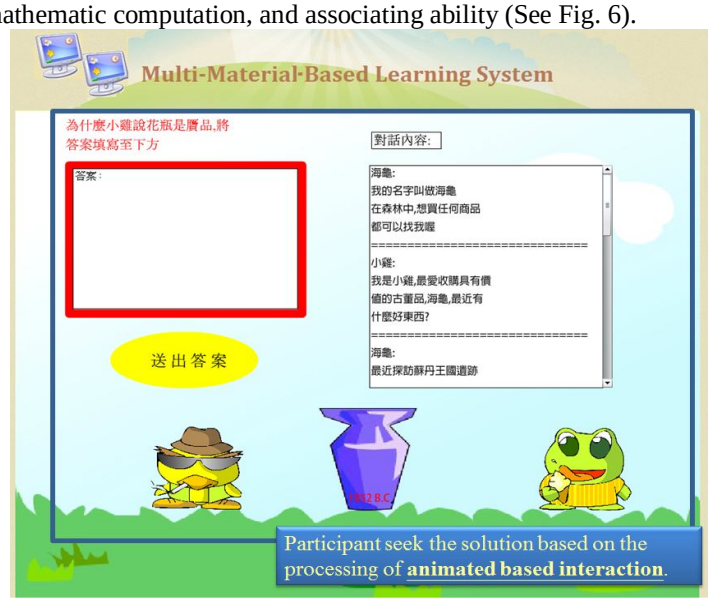

Fig. 5 The interface of an animation-based game

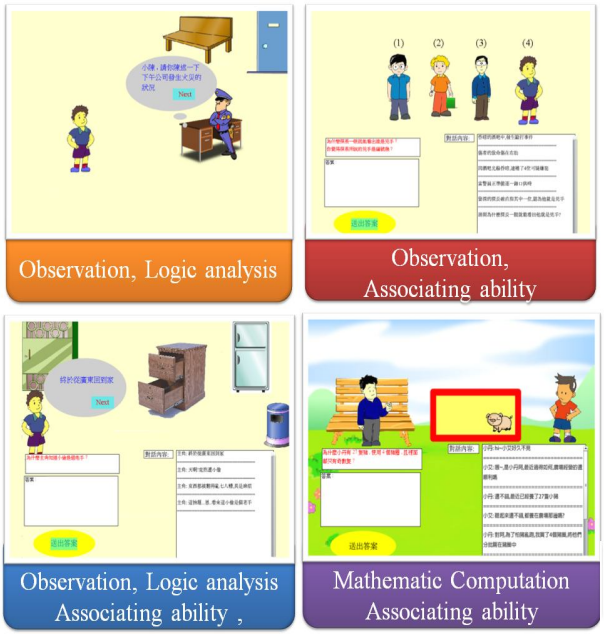

Fig. 6 The game scenarios and training items

B. *Information interaction mechanism in the MBLS*

Iterative learning can enhance learners' motivation; knowledge sharing and appropriate feedback is helpful to make the learning activity adapt to train the learner's problem-solving skills. Therefore, the message board and contact function are included in the MBLS. Users such as learners or teachers can share their experiences, suggestions, even the suggestions concerned with learning materials, knowledge and information by interacting on the message board (See Fig. 7). To increase the efficiency of the learning system, users can give feedback, make suggestions, or share ideas about the system by sending an email (See Fig. 8). After the message has been received by the system, we'll immediately respond to the user based on their needs or suggestions for the purpose of increasing the user stratification and learning intention.

Fig. 7 The interface of the message board in the MBLS

Fig. 8 The function of the contact system in the MBLS

IV. EXPERIMENT

A. *Experimental design*

This study aims to develop a multi-material learning system that includes a series of problem-solving tasks. Accordingly, the data source of an expert validation test is essential for examining the performance and reliability of the MBLS. We collected data from eight teachers whose teaching experience averaged 4.7 years. The data were saved in the learning database as preference analysis guidelines. The collected information is displayed in Table 1. For the purpose of adapting the analysis results in real cases, the performance evaluation based on the successful information system model [15] was included in the research questions. All participants completed the experiment in approximately half an hour, and they were paid US$5 dollars to participate.

TABLE I
THE VARIABLES OF THE LEARNER PREFERENCE SURVEY.

Variables	Description	Type
ID	Identify sample	Numerical
Teaching experience	1 to 8 years (Mean=4.75 years)	Numerical
Learning performance	Each scenario is scored with 0~1point, and the total scores for each scenario are 4 points	Numerical
Gender	Male (51%); Female (49%)	Categorical
Learning material	Static text-based/ Animation-based game	Categorical
Game scenario	The subjects of Scenarios1~4 are "observation and logic analysis", "associating ability, logic inference, observation", "logical inference on the geometric space", "mathematic computation, associating ability and observation".	Categorical
10 evaluation items (see result session for the items)	5-point Likert-type scale questionnaires with response options ranging from strongly disagree to strongly agree (type=1~5)	Categorical

B. Analysis of system performance validation by expert test

The integral evaluation included the following six factors: information, system quality, service quality, intention to use, user satisfaction, and net benefits, which ranged from "strongly agree" (1 point) to "strongly disagree" (5 points). Table 2 shows the results of the MBLS performance evaluation based on the successful information system model, each dimension obtained a good evaluation. Teachers felt the proposed approach could assist teachers in teaching problem-solving activities and improve both the students' learning performance and learning motivation.

TABLE II
The integral performance evaluation

	The degree of agreement
Information quality	2.0
System quality	2.1
Service quality	2.0
Intention to use	1.8
User satisfaction	1.8
Net benefits	2.3

In order to explore whether animation-based interaction game material influences teaching performance or not, we carried out an in-depth investigation to determine the correlation between animation-based games and teaching performance. Fig. 9 demonstrates that animation-based games improved students' problem-solving ability and had a positive effect on teaching efficiency.

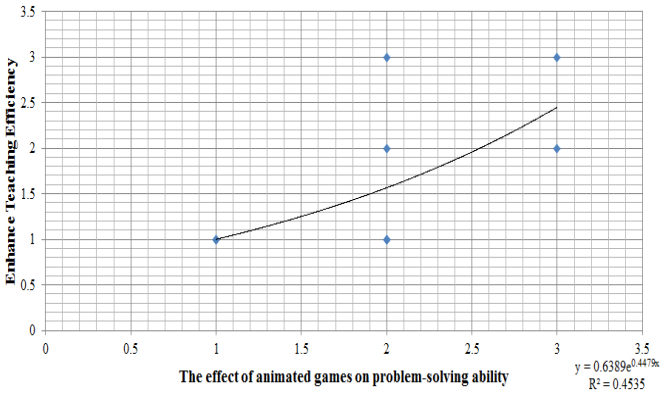

Fig. 9 THE REALATIONSHIP BETWEEN ANIMATION MATERIALS AND TEACHING EFFICIENCY

The following ten items were included in the performance evaluation of the MBLS and user cognition: "The animation-based game of the MBLS could stimulate the ability of problem solving" (Q1); "The animation-based material could enhance learning efficiency in the current task" (Q2); "The user interface provides a "user-friendly" experience" (Q3); "The function of the system is well defined"(Q4); "Have intentions to use the MBLS for problem-solving activities" (Q5); "Animation-based material could enhance the ability of problem solving"(Q6); "The MBLS enhances learning motivation" (Q7); "The MBLS is useful for problem-solving activities"(Q8); "In the MBLS, information acquisition and sharing could assist the performance of teaching" (Q9); "The incorporation of IT technology into animated games is effective for attracting learners' attention to the problem solving activities" (Q10). Moreover, we examined the significance of these items. The response options were scored with a Likert's five point scale to examine whether the mean of each item was significantly different from the median. The results show that each item obtained above-average scores not only for satisfaction of the system and material designs, but also to support our view concerned with problem-solving activities (See Fig. 10). Strong evidence suggests that the MBLS received high levels of appreciation as a problem-solving activity from the teachers.

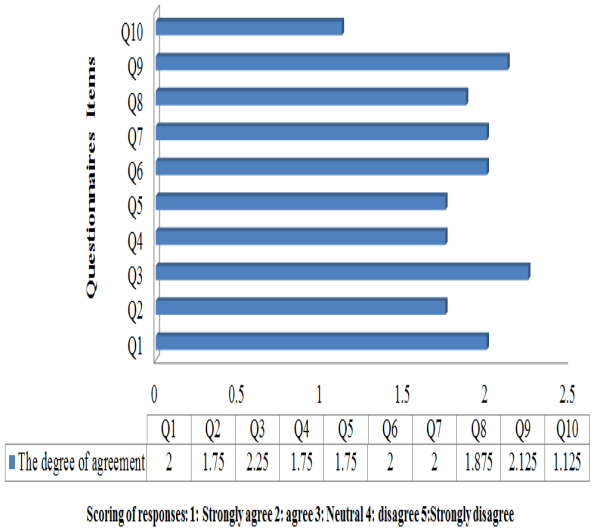

Fig. 10 RESULTS OF AVERAGE SCORES FOR EVALUATION ITEMS

C. *Analysis of system performance effects on the different seniority of teachers*

In this study, we used a t-test to examine the questionnaire items separately, based on the different seniority of the teachers. The seniority was classified into three levels: senior (8 years), middle (5 years), and junior (1 year). In addition, the degree of agreement ranked from strongly agree (1 point) to strongly disagree (5 points), the lower score means the participants strongly agree with the view we proposed. The senior teachers gave 2.3 points of satisfaction on the integral performance. The teachers in the junior (1.8 points) or middle (1.7 points) level of seniority have higher user satisfaction than senior. Table 3 illustrates the score of each questionnaire item from the senior group. The senior teachers significantly agree (t=3.0 p-value = 0.001 < 0.05) that the incorporation of IT technology into animated games is effective for focusing the learners' attention on the problem-solving activity.

TABLE III
THE RESULTS OF THE SENIOR GROUP

The senior level of seniority										
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Max	3	3	3	2	3	3	2	3	3	2
Mean	2.5	2.5	2.5	2	2.5	2.5	2	2.5	2.5	1.5
Min	2	2	2	2	2	2	2	2	2	1
S.D	0.71	0.71	0.71	0.00	0.71	0.71	0.00	0.71	0.71	0.71

Table 4 shows the score of each questionnaire item for the middle group, which imply that the teachers in the middle level of seniority have a significantly high level of satisfaction with the efficiency of the animated game to provoke a problem-solving ability (t=3.69 p-value = 0.005 < 0.05) and enhance learning efficiency (t=3.69 p-value = 0.005 < 0.05). Moreover, they significantly agree that animation-based material could enhance the ability of problem solving (t=7.07 p-value = 0.000 < 0.05), and feel that the MBLS is helpful (t=2.45 p-value = 0.042 < 0.05) and useful (t=4.24 p-value = 0.001 < 0.05). The MBLS received good evaluations as a user interface (t=3.46 p-value = 0.007 < 0.05), service (t=7.07 p-value = 0.000 < 0.05), and for intention of use (t=7.07 p-value = 0.000 < 0.05).

TABLE IV
THE RESULTS OF THE MIDDLE GROUP

The middle level of seniority										
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Max	3	3	3	2	2	2	3	3	3	1
Mean	1.75	1.75	2	1.75	1.75	1.75	2	1.5	1.75	1
Min	1	1	1	1	1	1	1	1	1	1
S.D	0.96	0.96	0.82	0.50	0.50	0.50	1.15	1.00	0.96	0.00

The experimental result indicated significant levels of user interface satisfaction for the junior teachers (See Table 5). Notably, they strongly agree (t=3.0 p-value = 0.001 < 0.05) that the MBLS has well-defined functions and provides a precise service for the user.

TABLE V
THE RESULTS OF THE JUNIOR GROUP

The junior level of seniority										
	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Max	2	1	4	2	1	3	2	3	3	1
Mean	2	1	2.5	1.5	1	2	2	2	2.5	1
Min	2	1	1	1	1	1	2	1	2	1
S.D	0	0.00	2.12	0.71	0.00	1.41	0.00	1.41	0.71	0.00

This supports the claims of the integral performance analysis and separate evaluation; the MBLS can enhance both learning and teaching efficiency by providing a multi-material learning system. Successful personalized learning should be adaptive to the learner's need, and the result of the expert validation test implied that the MBLS could achieve this goal of adaptive learning.

V. CONCLUSION

In this study, we developed the MBLS and examined the system with an expert validation test. The MBLS implements an animation-based game as dynamic material. The teachers involved in the process assured the reliability and correctness of the material content. Our experiment showed that the MBLS can successfully employ multi-materials in a problem-solving learning system and the learning activity can be adapted for personalized learning. The main contributions of the MBLS are: (1) the evaluation of the teaching experience related to user satisfaction and collection of related suggestions on the MBLS from experts. (2) This study also determined that the animated material is useful for assisting with teaching.(3) The materials and scenarios have been integrated based on the problem solving theory. (4) The

contact function of the MBLS uses applied knowledge to interact with the user (learner/teacher). The system personalizes the learning activity to improve the efficiency of learning, and enhances the convenience of human interaction with the computer. Moreover, based on web techniques, the MBLS includes the integration of cross-domain knowledge and the use of real-time information sharing. The findings of this study are that the personalized material and interaction mechanism of the system could help learners concentrate on the problem-solving learning system online. The MBLS provides immediate feedback to the user, which could assist in optimizing the learning effect. Future studies should increase the sample size to investigate more the learning character, and design the algorithm to adapt the system to the individual's traits and further personalize the problem-solving activities.

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