An Interactive Game Approach for Improving Students’ Learning Performance in Multi-Touch Game-Based Learning

Cheng-Yu Hung, Student Member, IEEE, Fang-O. Kuo, Jerry Chih-Yuan Sun, and Pao-Ta Yu, Member, IEEE

Abstract—This study, based on Taiwanese geographical concepts, develops a multi-touch interactive jigsaw puzzle (MJP) to assist primary school students in solving geographical puzzles. The MJP, which has multi-touch operating characteristics and provides two kinds of scaffolding tools, each with a different level of difficulty, can assist students in solving problems in the games and prevent them from feeling stuck and frustrated. In addition, it explores the influence of the interactive game approach (three levels of difficulty) on learning performance and satisfaction. The results indicated that the learning performance of each group, significantly improved after the experiment. In particular, moderate gaming difficulty led to the best learning performance for learners. A comparison of learners who did not use scaffolding to solve problems and those who did shows the level of the zone of proximal development (ZPD). Moreover, the analysis of satisfaction evaluations by learners with/without scaffolding showed there were statistically significant differences in the measures of learning satisfaction. Finally, this study revealed that the students tended to be over-reliant on the scaffolding tools during the game, which prevented them from internalizing knowledge through the interactive learning process.

Index Terms—Multi-touch technology, scaffolding theory, digital-game based learning, human-computer interaction

1 INTRODUCTION

This research investigated the effect of an interactive game approach (three levels of difficulty) on learning performance and examined how scaffolding tools affect learning satisfaction. Recently, an increasing number of teachers have endeavored to integrate computer games into teaching or training [1], [2] because they see such games as an effective way to construct student knowledge [3]. With the rapid advancement of computer and multimedia technologies, educational computer games have been widely discussed [4]. Researchers have pointed out that educational computer games may contribute to a more interesting learning environment [5], [6], [7]. They have further reported that educational computer games can improve students’ academic performance [4] as well as motivation and satisfaction [2], [8], [9]. Kickmeier-Rust and Albert [10] claim that the one great challenge of developing educational computer games is the provision of support and guidance to learners, while balancing education and gaming and challenging individual abilities. Charsky and Ressler’s [11] study on the use of a computer game in a learning activity confirms this point. Therefore, it is important to provide suitable learning support when employing computer games in education.

According to the Vygotsky’s zone of proximal development (ZPD), Wood et al. [12] developed the concept of scaffolding, a support given to a younger learner by adults or more capable peers for performing an action, in educational contexts. Scaffolds can now be programmed into computer software or digital games [13]. Previous studies on the use of digital scaffolding [13], [14], [15], [16], [17], [18] have revealed that it can provide the necessary support and guidance that students need to prevent frustration [13], and achieve higher learning effectiveness in digital game environments [13], [14]. Scaffolding tools help students solve problems, thereby facilitating the ZPD [19]. Specifically, one purpose of this study is to use of scaffolding tools to facilitate the ZPD.

With advances in technology, students and learning methods are changing [2]. Research has shown that integrating multi-touch technology with computer games facilitates positive intuitive interactions between humans and computers and, in turn, helps students become actively engaged in game-based learning activities [20]. Multi-touch technology allows students to move virtual objects on a screen by tapping and dragging them [1]; this makes the game more engaging [20], [21]. In their study, [2] found that students prefer the multi-touch interface experience of an iPhone game to traditional learning games such as labyrinth games and worksheets. Recent research [20], [22] indicates that multi-touch game-based learning with jigsaw puzzles enables students’ acquisition of historical knowledge. Thus, this multi-touch technology is often used in the teaching of history and other disciplines; however, to the best of our knowledge, it has not yet been applied to instruction in geography.

Geography education forms the basis for understanding physical realities, and learning geography is not easy. A great deal of geography education can be effectively taught through map or geography games [7], [23], [24]. Geography jigsaw puzzles, one type of geography game, can be programmed into digital games. Researchers [7], [24] have pointed out that geography games can improve students’ achievement and motivation in geography learning. More studies are needed in this area to verify that geography jigsaw puzzles with multi-touch technology stimulate student learning in different disciplines. Therefore, another purpose of this study is to investigate whether use of multi-touch technology (three levels of difficulty) in different disciplines improves students’ learning performance in geographical teaching and training.

2 LITERATURE REVIEW

2.1 Multi-Touch Technology

The advent of multi-touch technology has been an important step in improving human-computer interactive environments. Multi-touch interfaces have become widely available for human-computer interaction [25] as platforms for developing interactive digital games for children [24]. Various types of technology can be used to produce multi-touch interfaces. Types of multi-touch interfaces include resistive touchscreens, acoustic wave touchscreens, capacitive touchscreens, and optical imaging touchscreens [26], [27], [28], [29]. Near-infrared (NIR) imaging has recently become an important new addition to multi-touch technology. Infrared radiation is electromagnetic radiation with a wavelength longer than that of visible light (400 to 700 nm). According to [25], NIR cameras can sense target objects more accurately by filtering out environmental noise and interference from projected light. Research [28] has proposed using rear-projected interactive surfaces with total internal reflection to create a low-cost multi-touch sensing system with high capture-rate and resolution. Researchers continue to make progress on designing better sensing systems for interactive environments. The diffused illumination (DI) technique, for instance, recognizes and tracks physical objects using their shapes, fiducial symbols, or tags on the bottoms of the objects [30], [31]. One study [25] proposed, designed, and evaluated the surface computer-supported cooperative work paradigm (CSCW),
which employed the DI technique to detect multi-touch inputs or objects. Their design provided a good prototype for modern DI-based multi-touch systems.

### 2.2 Digital Game-Based Learning

Prensky [32] pointed out the features of game-based learning, including facilitating problem solving, providing feedback, and creating interactions. These conclusions provide a clear direction for the challenging research topic of game-based learning in the following two scopes: cognitive abilities and school achievement. Kinzie and Joseph [33] claimed that “a game is an immersive, voluntary and enjoyable activity in which a challenging goal is pursued according to agreed-upon rules.” Previous studies [3], [4], [7], [8], [34], [35] have indicated the potential for employing digital educational games in improving students’ learning performance. For example, studies have indicated that digital games are an important part of the development of children’s cognition and social processes [36]. Some have reported that educational computer games can improve students’ learning interest [32], [37], [38], and further increase their learning motivation [39], [40], [41].

Wang and Chen [3] found that challenging games encourage learners to be more engaged in the gaming activity, allowing them to better feel the game’s flow. Research has also shown that an iPhone game leads to at least an equivalent learning outcome as a traditional game (without a multi-touch interface), and children prefer the iPhone game (with multi-touch interface) [2]. Ardito et al. [20] conducted an experiment combining multi-touch technology with a historical jigsaw puzzle to promote student learning. Participants of the experiment could use the following multi-touch gestures to operate the historical jigsaw puzzle: moving, rotating, and resizing an object on the screen. These gestures enhanced student interest in participating in the game-based learning activity. Therefore, the use of multi-touch game devices in educational settings [2], [20], [21], [22] may help students actively engage in game-based learning activities [2] and thus enhance learning motivation and learning satisfaction [2], [21]. As such, multi-touch game devices can be used as an effective means by which students acquire and consolidate knowledge [39], [40], [41].

These studies indicate that educational computer games have become a widely discussed research issue. Therefore, how to improve the effectiveness of educational computer games remains an important and challenging topic.

### 3 Research Design

In this study, we adopt the technologies of C# and Microsoft Surface 2.0 SDK to develop the multi-touch interactive jigsaw puzzle (MIJP). Users can run the MIJP in Windows 7 and use a touch monitor to control the jigsaw puzzle. Moreover, Surface 1.0 uses its own custom manipulation processor, requiring programmers to use classes unique to the Microsoft Surface SDK to create inertia and track movements if a person flicks and releases an object on the Surface display. In contrast, Surface 2.0 now uses Windows Presentation Foundation (WPF) 4.0. This not only simplifies development but can also easily create applications to take advantage of the next generation Surface computing device or Windows 7 touch-enabled devices. Detailed description of the Surface 2.0 software architecture is shown in Fig. 1.

#### 3.1 Design of the Multi-Touch Interactive Jigsaw Puzzle

In this study, we developed the MIJP using a DI-based multi-touch interface. The MIJP, as shown in Fig. 2, aims to assist primary school students in the learning of geographical concepts (including location, orientation, and size of each city) of Taiwan. There are 15 cities in Taiwan, and each city is represented as one piece of the jigsaw, whose shape matches the city’s contour. As the digital game needs functions such as rotating objects and zooming, the MIJP extends the application from single-touch to multi-touch technology and provides three operating gestures (moving, rotating, and resizing) for manipulating the jigsaw puzzle pieces. In addition, the MIJP provides two kinds of scaffolding tools, each with a different level of difficulty. Among them, two kinds of scaffolding tools (represented as demonstration and reduction in degree of freedom) indicate three problem-solving functions that match the scaffolding functions defined by Wood et al. [12]. Three levels of difficulty (represented as Level-1, Level-2, and Level-3) indicate the difficulty levels of the operation in the jigsaw puzzle, from easy to difficult. These levels can be adjusted to provide the learners with more challenging and engaging puzzles to enhance their perception of the game flow. Details of these levels are as follows:

1. **Level-1**: The learner only needs to move the jigsaw piece. The MIJP will magnetize the jigsaw piece into the correct position as it reaches the target region.
2. **Level-2**: The learner needs to move and rotate the jigsaw piece. The MIJP will magnetize the jigsaw piece into the correct position as it reaches and matches the orientation of the target region.
3. **Level-3**: The learner needs to move, rotate, and resize the jigsaw piece. The MIJP will magnetize the jigsaw piece into the correct position as it reaches and matches the orientation and size of the target region.

#### 3.2 Situational Design Module

The MIJP clearly provides visual support, such as a “highlight specific jigsaw” feature, “lively color” feature, and the display of problem-solving tools. Detailed description of the problem-solving tools is shown in Fig. 3. The MIJP provides two kinds of scaffolding tools (represented as demonstration and reduction in degree of freedom), as shown in Figs. 3 and 4. First, the...
demonstration tool is meant to demonstrate the solution of the geographical jigsaw puzzles by offering three options: showing the locations of cities in different colors, showing the locations of cities along with the name of the block, and showing the locations of cities without displaying the name of the block, as shown in Figs. 3 and 4. This tool matches the “demonstration” scaffolding function defined by Wood et al. [12] in that it demonstrates or models solutions to a task. Second, the demonstration tool is meant to display the names of neighboring cities of the previous completed jigsaw piece in textual format, as shown in Figs. 3 and 4. The reduction in degree of freedom tool is meant to highlight the neighboring cities of the previous completed jigsaw piece while make the non-candidate pieces invisible, as shown in Figs. 3 and 4. This tool matches the “reduction in degree of freedom” scaffolding function defined by Wood et al. [12] in that it simplifies a task by reducing the number of constituent acts required to reach a solution. Overall, as the jigsaw piece is placed in the correct position, these scaffolding tools will be disabled until learners use them again.

### 3.3 Procedures

This study aims to develop an MIJP to assist primary school students in solving geographical puzzles and to explore the influence of scaffolding on problem-solving ability, learning performance, and satisfaction. Initially, 240 students were recruited, and after they took a pre-test, 17 students with higher prior knowledge were excluded from the study. At the end of the learning, the students took a post-test to measure their learning performance and completed a questionnaire to measure their learning satisfaction. The experiment procedures are shown in Fig. 5, and the details are described as follows.

### 3.4 Participants

We recruited 240 students from 10 third-grade classes at an elementary school located in Changhwa City, Taiwan. The students were randomly assigned to three groups: Level-1, Level-2, and Level-3. Each group consisted of 80 participants and was further divided into four subgroups (without scaffold, demonstration (A1~A3), demonstration (B), and reduction in degree of freedom (C)). Each subgroup consisted of 20 participants and was supported by different scaffolding tools (no scaffolds, demonstration, and reduction in degree of freedom). All the participants took a pre-test about Taiwanese geography. After the pre-test, 17 students with higher prior knowledge were excluded from the study. Afterward, the Level-1 group, which consisted of 74 students, was assigned to operate the MIJP with Level-1 difficulty. The Level-2 group, which also consisted of 74 students, was assigned to operate the MIJP with Level-2 difficulty. Finally, the Level-3 group, which consisted of 75 students, was assigned to operate the MIJP with Level-3 difficulty. Table 1 presents the distribution of participants by group.

### 3.5 Taking the Pre-Test

The pre-test contained 15 single-choice questions, designed by a social study teacher at the elementary school. The maximum score was 15 points. The primary purpose of the test was to assess the students’ prior knowledge about Taiwan’s administrative divisions.

### 3.6 Using the MIJP

Before using the MIJP, the students were taught the jigsaw puzzle rules, including how to operate the system, scaffolding tools use, and multi-touch gesture. They were given five minutes to ask questions, and then they played the jigsaw puzzle game for twenty minutes. During the gaming process, they were allowed to use the scaffold tools assigned to their subgroup for solving problems. The students could use the trial-and-error method or derive their own plan to solve a specific jigsaw puzzle. With respect to the latter, the approach may involve deriving a cognitive strategy for the problem-solving activity through mental

<table>
<thead>
<tr>
<th>Groups</th>
<th>Without scaffold</th>
<th>A1~A3</th>
<th>B</th>
<th>C</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level-1</td>
<td>16</td>
<td>18</td>
<td>20</td>
<td>20</td>
<td>74</td>
</tr>
<tr>
<td>Level-2</td>
<td>16</td>
<td>20</td>
<td>20</td>
<td>18</td>
<td>74</td>
</tr>
<tr>
<td>Level-3</td>
<td>18</td>
<td>18</td>
<td>20</td>
<td>19</td>
<td>75</td>
</tr>
<tr>
<td>Total</td>
<td>50</td>
<td>56</td>
<td>60</td>
<td>57</td>
<td>223</td>
</tr>
</tbody>
</table>
effort [23]. The MIJP recorded the number of times the students used the scaffold tool. Additional screen capture software was used to track the students’ behavior during the entire gaming process. These recorded data were then used to analyze how the students used gaming strategies and the number of problems they solved (i.e., how many pieces of the jigsaw puzzle they completed).

3.7 Data Collection
After using the MIJP, the students took a post-test and a questionnaire to measure their learning performance and learning satisfaction, respectively. The post-test contained 15 multiple-choice questions, designed by the same teacher at the elementary school, and the maximum score was 15 points. The primary purpose of the test was to assess students’ knowledge about the administrative divisions of Taiwan after they had used the MIJP. The differences between the pre-test and post-test scores were evaluated to whether the students’ learning performance had significantly improved.

In the measure of learning satisfaction, the questionnaire, as shown in Table 4, was modified from the questions developed in [42]. These qualitative items have been proven to be a very reliable measurement of satisfaction research based on an analysis of reliability and validity. The questionnaire consists of nine items related to learning satisfaction, which students rate on a 6-point Likert-type scale ranging from 1 (strongly disagree) to 6 (strongly agree). The internal consistency reliabilities assessed by Cronbach’s alpha was 0.91, revealing an acceptable level of reliability [43].

4 RESULT
SPSS for Windows version 17.0 was used for the data analysis. A p-value less than 0.05 was considered statistically significant. ANCOVA was used to analyze the effects of the three difficulty levels on learning performance. Descriptive statistics and ANOVA were used to analyze the effects of playing with/without scaffolding tools on problem solving. The t-test was used to analyze the effects of MIJP on learning satisfaction.

4.1 Effects of the Three Levels of Difficulty on Learning Performance
To test the relationships between the post-test results of the three groups, an ANCOVA was performed on the post-test results of learning performance. In that test, the pre-test scores provided the covariance, the post-test scores were the dependent variable, and the type of game (three levels of difficulty) was the fixed factor. For ANCOVA, the results of Levene’s test were not significant (F(2, 46) = 2.05, p = 0.14 > 0.05), indicating that ANCOVA could be applied.

Table 2 shows the ANCOVA results, which compared the post-test scores of the (1) Level-1, (2) Level-2, and (3) Level-3 groups that did not use scaffolding. The results indicate that the groups at different difficulty levels had significant differences in their test scores (F(2, 46) = 3.68, p < 0.05). Furthermore, a post hoc analysis was performed to examine specific differences in learning performance between the three groups. A least significant difference (LSD) test, by comparing the adjusted mean of 8.03 for the Level-2 group with the Level-3 group score of 6.98 (p < 0.05), revealed that the Level-2 group scores were significantly higher than those of the Level-3 group. Additionally, the Level-3 scores were also significantly higher than those of the Level-1 score of 6.17 (p < 0.05).

4.2 Effects of Scaffolding Tools on Problem-Solving Activity
Table 3 shows the average number of jigsaw-puzzle problems that students in the Level-1, Level-2, and Level-3 groups without/with scaffolding tools solved. The ANOVA result was (F(1, 221) = 8.180, p < 0.01) indicated a significant difference in problem-solving activities between the groups without/with scaffolding tools. Because of the Level-1 difficulty level being comparably easy to implement, the players could complete the whole jigsaw puzzle with or without using scaffolding tools. Furthermore, post hoc analysis was performed to examine specific differences in problem-solving activities between the three groups. An LSD test revealed that the A1–A3 scaffolding tools were significantly higher than the B scaffolding tools, and the C scaffolding tools were also significantly higher than without scaffolding score.

4.3 Evaluation of the Degree of Satisfaction
Table 4 shows the statistical results of the post-questionnaire scales, including the means. The overall mean score was 5.07 (on a six-point scale), which indicated that the students gave positive evaluations of the MIJP. A comparison of the learner groups with/without scaffolding tools shows differences in learning satisfaction. The learner group that received scaffolding tools had a significantly more

### Table 2

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>S.D.</th>
<th>Adjusted mean</th>
<th>F</th>
<th>Post hoc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-test</td>
<td>(1) Level-1</td>
<td>16</td>
<td>6.00</td>
<td>2.88</td>
<td>6.17</td>
<td>3.68*</td>
<td>(2)&gt;(3)&gt; (1)</td>
</tr>
<tr>
<td></td>
<td>(2) Level-2</td>
<td>16</td>
<td>8.56</td>
<td>2.13</td>
<td>8.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3) Level-3</td>
<td>18</td>
<td>6.67</td>
<td>2.76</td>
<td>6.98</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*p < 0.05.

### Table 3

<table>
<thead>
<tr>
<th>Group</th>
<th>(1) Without Scaffold</th>
<th>(2) A1–A3</th>
<th>(3) B</th>
<th>(4) C</th>
<th>ANOVA</th>
<th>Post hoc</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N M(SD)</td>
<td>N M(SD)</td>
<td>N M(SD)</td>
<td>N M(SD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level-1</td>
<td>16 15(0.00)</td>
<td>18 15(0.00)</td>
<td>20 15(0.00)</td>
<td>20 15(0.00)</td>
<td>8.180**</td>
<td>(2)&gt;(3)&gt; (4)&gt; (1)</td>
</tr>
<tr>
<td>Level-2</td>
<td>16 4.38(2.55)</td>
<td>20 12.05(3.03)</td>
<td>20 6.80(2.04)</td>
<td>18 7.00(2.85)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level-3</td>
<td>18 3.89(2.91)</td>
<td>18 7.22(4.11)</td>
<td>20 6.05(2.40)</td>
<td>19 4.32(2.06)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**p < 0.01.
positive perception of the benefit provided by the digital scaffolds for identifying the features of the target objects (Q7) and observing the differences within the target learning objects (Q8).

5 Discussion

Regarding learning performance in the comparison of scores between the pre- and post-tests, players in the grouping methods (i.e., by difficulty levels) showed significant improvement after the experiment. Previous studies [3], [4], [7] have indicated that digital educational games can improve students' learning performance and satisfaction. Particularly, the results of the post-test Table 4 grouping by difficulty levels showed that the degree of game difficulty affected learning performance. Although the learning performance of students in the Level-1 and Level-3 groups significantly improved, those in Level-2 showed the greatest improvement. That is, the Level-2 players exhibited the best learning performance, followed by the Level-3 and Level-1 players. This indicated that providing the students with moderate learning difficulty (such as that of the Level-2 group) may lead to the best learning performance. However, the enhancement of learning performance cannot be attributed entirely to scaffolding or game difficulty; interaction effects may also be a contributing factor. Wood et al. [12] defined "scaffolds" to reflect the ZPD concept proposed in Vygotsky's learning theory [44]. Regarding the effects of scaffolds on problem solving, the study results indicated that scaffolds can significantly increase the number of jigsaw-puzzle problems solved. The scaffolding tools helped students solve the problems, which facilitated the ZPD.

This study represents an important development by performing a similar investigation using a multi-touch technology, which involves a quite different form of interactive learning activity—that is, multi-touch game-based learning. Furthermore, geography game studies [7], [23] have focused on traditional game-based learning environments (without a multi-touch interface). As technology is advancing, students and learning methods are changing [2], and one of the major contributions of this study is that it uses a similar means for geography training but combines it with a multi-touch technology to produce an innovative, effective, and enjoyable learning activity.

5.1 Multi-Touch Interactive Jigsaw Puzzle and the Learning Satisfaction

Based on the results of the learning satisfaction questionnaire, this study found that the learners perceived the games to be fun (e.g., “Learning with the system is more challenging and interesting than learning with the traditional approach”), were satisfied with the game content, and believed that the MIJP design had enabled them to improve their geographical knowledge (e.g., “I had new findings or knowledge about the target learning objects because I used this system to learn in the classroom” and “I have tried new ways or thinking styles to learn owing to the use of this learning system”). In addition, the results of the two items “The guidance provided by this system is helpful to me in learning how to identify the features of the target learning objects” and “The guidance provided by this system is helpful to me in observing the differences within the target learning objects” indicated that the players believed the scaffolding helped them effectively solve the problems presented by the game.

5.2 The Number of Scaffolds Tools Used and the Learning Performance

The results in Table 2 show that learning performance for the Level-2 group was significantly higher than that for the Level-3 group. At Level-2, only two gestures (move and rotate) were needed, while four gestures (move, rotate, zoom-in, and zoom-out) were needed to complete Level-3. It is possible that the third-grade students were not familiar with the touch gestures of the game, so the students in the Level-3 group spent more time on operation (placing a piece of the puzzle in its correct position) and were
unable to complete as many puzzles within the time limits of the game as the Level-2 group. In addition, among the three groups, the results of the Level-1 group were relatively poorer. It is possible that the Level-1 students were able to complete the tasks very quickly (by simply moving the puzzle pieces to the correct position). Compared to the students in Level-2 and Level-3, the students in Level-1 spent less time on the puzzles and therefore it is unlikely that they memorized the positions of the puzzle pieces. As a result, the learning performance of the students in the Level-1 and Level-3 groups was lower than that of the Level-2 group.

The relationship between the number of scaffolds used and the learning performance in this study is shown in Table 5. We found that the players tended to rely excessively on the scaffolding tools, which prevented them from internalizing knowledge through interactive learning. Consistent with prior research that scaffolding in digital gaming environments helps students solve problems and promote the ZPD [13], our findings in Table 3 also show a significant difference between the results of the groups with scaffolding (A, B, and C) and the group without. This indicates that scaffolding within the digital gaming environment can help students solve problems and facilitate the ZPD. However, students may become overly reliant on auxiliary tools, thereby reducing their opportunities to memorize or consider information. The results in Table 5 clearly illustrate such a situation. However, each learner’s knowledge and experience of various gaming domains differs [13], [45]. Additionally, learners may become anxious and give up if a game is too difficult. Scaffolds can increase learner involvement by reducing gaming anxiety, thereby achieving the “flow” described in [13], [45], [46], [47]. In an educational context, complete absorption in activities has been shown to promote optimal learning experiences [47]. Therefore, adapting the tools or providing explicit guidance that promotes deeper absorption in digital gaming can enable players to achieve a flow state.

6 Conclusion
This study examined students’ use of a digital education game with a multi-touch interface. Recently, this method of enhancing student performance has increased in popularity in the field of educational research [2], [20], [21], [22]. In their evaluations of the gaming process, students reported that experiencing an interactive learning approach in a classroom environment made them feel engaged and satisfied. The purpose of this study was to develop a multi-touch interactive jigsaw puzzle (MIJP) with multi-touch operating characteristics, two types of scaffolding tools, and three levels of difficulty to assist primary school students in solving geographic puzzles of Taiwan. The experiment results showed that the interactive game approach (three levels of difficulty) that comprises the three levels of difficulty proposed in this study can improve student learning performance. The post hoc comparison results clearly indicated that the difficulty level of various games had differing effects on the students’ learning performance. In addition, the use of scaffolding tools significantly improved the students’ learning satisfaction. During the learning process, scaffolding facilitated the ZPD.

This study contains several limitations that suggest future research directions. First, this study develops the MIJP based on the administrative divisions of Taiwan. Further research should investigate the potential of its use in other countries. Second, this study evaluates the post-test scores concerning the learning performance of third-grade students. Further research should investigate the potential of its use for students at other elementary grade levels or in higher education to generate empirical evidence with broader generalization.

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References

Table 5: Correlation on the Number of Scaffolds Used and Post-Test Scores

<table>
<thead>
<tr>
<th>Source</th>
<th>Level-1 (post-test)</th>
<th>Level-2 (post-test)</th>
<th>Level-3 (post-test)</th>
</tr>
</thead>
<tbody>
<tr>
<td>With Scaffolding</td>
<td>Person Correlation</td>
<td>Sig. (2-tailed)</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>-0.36*</td>
<td>0.019</td>
<td>58</td>
</tr>
<tr>
<td></td>
<td>-0.25*</td>
<td>0.050</td>
<td>58</td>
</tr>
<tr>
<td></td>
<td>-0.215</td>
<td>0.109</td>
<td>57</td>
</tr>
</tbody>
</table>

*Correlation is significant at the 0.05 level (2-tailed).


