Tangible user interface design for learners with different multiple intelligence

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Article Info	ABSTRACT

The creation of learning activities responsive to learners with different basic skills has been limited due to a classroom environment and applied technologies. The goals of this research were to develop Tang-MI, a game with a tangible user interface supporting primary school learners' analytical skills based on the theory of multiple intelligences (MI), and to present design guidelines for a tangible user interface suitable for learners in different MI groups. In this research, the Tangible user interface for multiple intelligence (Tang-MI) was tested with thirty students initially evaluated for their multiple intelligences. The learners' usage behavior was observed and recorded while the students performed the assigned tasks. The behavioral data were analyzed and grouped into behaviors occurring before performing the tasks, during the tasks, and after completing the tasks. Based on the learners' usage behavior, the tangible user interface design guidelines for learners in different MI groups were proposed concerning physical equipment design, question design, interactive program design, audio design, and animated visual feedback design. These guidelines would help educators build learning games that respond to the learners' intelligence styles and enhance students' motivation to learn.

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1. INTRODUCTION

Prior research works have shown that the education sector has focused on a development of learning models responsive to learners' characteristics. Group activities were developed to increase learners' learning achievement [1]. Educational outcomes were studied after improving teaching methods by taking into account learners' educational background [2]. Learning models were designed to match learners'aptitude [3]. Technology was used in teaching and learning activities to help cultivate learning motivation in students. The use of technology also helped strengthen students' knowledge by engaging in hands-on practice.

The theory of multiple intelligences (MI) [4] is a well-known theory supporting the notion that each learner has different learning abilities. MI studies differences in human intellect and classifies them into nine intelligence groups [5]. It helps learners to understand their learning skills by recognizing their competencies. The theory has been applied to various aspects of education, especially primary education, for example, an improvement of learners' deficient skills and a development of learning support for learners

[1, 6, 7], a development of activities for increasing academic achievement [8, 9], and a development of teaching and learning activities according to the MI principle [10, 11].

Based on a review of the research concerning MI, limitations to the development of learning models responsive to different intellectual capabilities were the classroom environment and the use of media and technologies in teaching and learning. Tangible user interface (TUI) [12], a new technology combining the physical and digital worlds together, can potentially facilitate the development of learner-centered learning activities. TUI has contributed to the educational enhancement in terms of hands-on activities. It encourages interactions between humans and computers by physically handling the devices and digitally getting the response.

TUI has been researched and developed to support various educational purposes, particularly for primary school. It was designed as a computer-based teaching system to support low-functioning autism [13]. It was implemented as a game that developed learners' analytical skills regarding the climate change. Learners managed and solved the climate change problem by utilizing devices with sensors attached to them [14]. TUI was used to promote spatial skills by learning about dimensions through photo taking of Lego village [15]. A commercial TUI-based game [16] on a tablet was also developed for languages, jigsaw puzzles, and mathematics. Another TUI-based system [17] combined learning media and equipment such as board games, robots, and computer programming to strengthen learners' skills in writing computer programs. With these developments, TUI has helped in building creative learning patterns in several ways and has made it easy for learners, including those with learning disabilities, to adopt technology for learning. However, the application of TUI to teaching and learning has not taken the theory of MI into account.

This research, therefore, had two objectives. The first objective was to develop a game that took into account the fundamental learning capabilities according to the theory of MI. Hereafter, the game will be referred to as Tangible user interface for multiple intelligence (Tang-MI). Tang-MI was designed not only to strengthen analytical skills of primary school learners (Grade 1-3) whose outstanding intelligence was classified as an analytical group, but also to improve analytical skills of other groups having other types of intelligence. Another objective was to study the usage behavior of learners in order to present tangible user interface design guidelines for learners in different MI groups. We hope this study would help inform how to design TUI that would be appropriate for each MI group.

This paper consists of five sections. The second section explains the theoretical background and related works. The third section describes the research methodology and implementation. The fourth section presents the results of the design and development, the experiment, and design guidelines. The final section concludes this paper along with the implications of this research.

2.   BACKGROUND AND RELATED WORKS

A study of theories and literature review related to the design and development of tangible user interface for learners with different groups in MI is presented. In this section, the first part discusses the theory of multiple intelligence (MI) and related works. The following part provides the details about definitions and the adoption of tangible user interface (TUI) in different domains.

2.1. Multiple intelligence (MI)

In 1983, Howard Gardner introduced multiple intelligence theory (MI) [4]. He studied human aptitude by examining both human neurological system and psychological development. Later in 1999, Gardner divided human characteristics into nine different types of intelligence, namely linguistic intelligence, logical intelligence, spatial intelligence, musical intelligence, kinesthetic intelligence, intrapersonal intelligence, interpersonal intelligence, naturalist intelligence, and existentialist intelligence. Initially, learners used an MI self-assessment scale to evaluate their types of intelligence. The learners selected the answers that best represented themselves. The scores were then summarized and used to classify the learners based on the types of intelligence.

Walter McKenzie [5] later grouped the nine MI types into three groups, which are analytical group, introspective group, and interactive group. Emphasizing on an analytical thinking process, the analytical group consists of logical intelligence, musical intelligence, and naturalist intelligence. Learners who fall into this group are good at classifying things. The introspective group focuses on imagination according to human understanding. The intrapersonal intelligence, existentialist intelligence, and spatial intelligence belong to this group. The interactive group includes linguistic intelligence, kinesthetic intelligence, and interpersonal intelligence. This group emphasizes communication and the ability to use body language for communication.

The MI theory has been well-recognized and applied to several aspects of educational systems. Prior research showed the application of the MI theory in two folds. The first fold was to incorporate the MI theory into the design and development of teaching and learning activities for primary school learners.

Research goals were to develop activities suitable for each MI type, to develop learners' skills, and to examine learners' ability to perform learning activities [10, 11, 18-24]. The second fold was to develop models and procedures for learning activities based on the principle of MI. Several researches focused on learner-centered learning approaches and hands-on activities so that learners could realize their full potential [25-27]. In this research, we focused on applying MI in the design and development of teaching and learning activities. Prior research works can be classified into three approaches of learning activities: scenario and environment, off-class learning, and media-assisted learning as shown in Table 1.

Table 1. Classification of related works in learning activities

Literature	Scenario and environment	Off-class learning	Media-assisted learning
A. Amporndhol [10]	✓		
Z. E. Gunduz and I. D. Unal [18]	✓		
N. Akkuzu and H. Akçay [19]	✓		
A. Mahmudi *et al.* [20]	✓	✓	
N. K. Maccario [21]		✓	
P. Polsombat [11]		✓	
S. T. Selvi [22]	✓		✓
T. Jommanop and S. Mekruksavanich [23]			✓
P. Garmen *et al.* [24]			✓

According to the MI theory and the literature review, the adoption of media and technology in learning has only received little attention. In this study, we employed media-assisted learning activities with the TUI technology to develop learning patterns that are responsive to learners' basic learning skills, as defined by the MI theory.

2.2. Tangible user interface

Tangible user interface (TUI) is an interface that enables a person to interact with digital information by manipulating tangible and movable physical objects. Ishii and Ullmer [12] stated that "*TUIs will augment the real physical world by coupling digital information to everyday physical objects and environments.*"

TUI has been widely used to support diverse areas of education. It was used to create hands-on activities, enabling learners to learn from real experiences. It helped children with or without learning disabilities to use technology more easily. In addition, it made an interaction between humans and computers easier. For primary school students, previous research employed TUI for the development of various skills such as object-oriented programming [28], drawing, science, and language. A TUI-based game called TanPro story [29] taught the concepts of object-oriented programming to children whose age were 6 to 9 years old. The children arranged blocks of programming symbols to control movements of characters in a story. The I/O Brush [30] was a TUI-based tool to enhance children's drawing skills. A paintbrush with a built-in camera could capture objects' patterns and draw the patterns on a screen.

For language skills, children moved physical objects representing English alphabets and arrange them to compose a word, which would be shown on a digital screen [31]. Learners also learned creative storytelling skill by moving square blocks displaying different scenarios, objects, nature elements, and characters to create a story. Afterwards, the student's story would be displayed on a screen [32]. Moreover, TUI could be used to observe children in several scenarios [33-35]. It was also used to support treatment of people with disabilities such as autistic children and people with mental and physical complications [36-38]. Rabia *et al.* [39] designed a TUI to teach visually impaired children about geometry. After the children selected and placed the object on a platform, the system would detect the three-dimensional printed geometric tangible object and described the details to the students.

Literature related to TUI showed that the design and development of TUI has focused on how to apply the technology for promoting learning, developing skills, developing learning activities in the classroom, and even supporting a medical treatment. In terms of designing and developing a TUI-based system that could adapt to student's needs, the application of TUI for educational purposes so far still lacks incorporation of multiple intelligences. By taking the MI theory into account, TUI will be able to respond to students'different intelligence styles. Our study, thus, developed a game-based system that combined both the learning activities supporting the students' multiple intelligences with the TUI technology. This game-based system presented a novel tangible user interface that could respond to learning needs of students with different types of intelligence.

3.   RESEARCH METHOD

The research method could be summed up into two parts as shown in Figure 1. The first part involved the design and development of Tang-MI, a game with a tangible user interface. Tang-MI was designed particularly to build up analytical skills of primary school learners. The second part dealt with a system test with the students in order to examine their usage behavior while they performed the assigned tasks. The learners' usage behavior provided the key information leading to the development of tangible user interface design guidelines for learners in different MI groups. The details of the methodology are explained as follows.
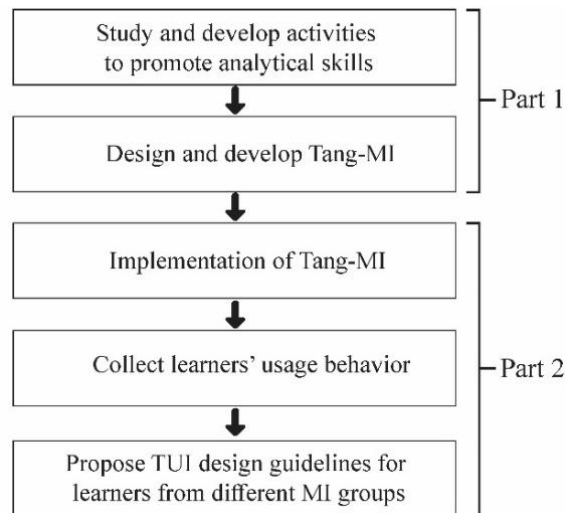

Figure 1. Research method

3.1. Design and development

The researchers first reviewed the teaching and learning activities according to the curriculum of primary education in Grade 1-3 (approximately six to nine years old). The activities were then analyzed in conjunction with the activities promoting multiple intelligences to obtain the learning activities suitable for the analytical skill group (i.e., logical intelligence, musical intelligence, and naturalist intelligence). The obtained activities were used to design a tangible user interface.

The purpose of the development of Tang-MI was to strengthen analytical skills of the learners who were in Grade 1-3 and belonged to the analytical group. Tang-MI was also designed to improve the analytical skills of students who belonged to other groups, i.e., the introspective group and the interactive group. The learning activity implemented in Tang-MI asked the learners to classify musical instruments based on shapes and types. This activity was selected because it required the students to differentiate between objects, thus enhancing their analytical skills. The topics about shapes of objects and types of musical instruments were also suitable for the knowledge of the students in Grade 1-3. The following sections describe three components of Tang-MI, which are a tangible box, musical instrument tags, and an interactive program as shown in Figure 2.

3.1.1. Tangible box

The tangible box had the dimensions of 20 centimeters in length, 20 centimeters in width, and 20 centimeters in height, and had a hole on the top for dropping objects into the box. Tang-MI used three tangible boxes in three colors for accepting different shapes and types of musical instruments. Inside each box, RFID readers were installed beneath a sheet of plastic, which was called a slider, to detect musical instrument tags that were dropped into the box, as illustrated in the Tangible Box of Figure 2. The RFID readers would then transfer data to the interactive program, which would display visual and audio feedback to the students.

3.1.2. Musical instrument tags

Each tag was a model of musical instruments such as drums, guitars, pianos, violins, along with a few pieces of Thai musical instruments as shown in Figure 2. The size of each musical instrument tag was approximately 7.5 to 13 centimeters, allowing the students to hold each piece single-handedly. The

musical instrument tags were produced by a three-dimensional printer using polylactic acid plastic filament. All models were colored with paint that was safe for children. The RFID tags containing specific codes were installed inside each of these models. Once a model was dropped into the box, the RFID tag would be detected by the RFID reader in the tangible box. The RFID reader then transferred the code of each musical instrument model to the interactive program for data processing.
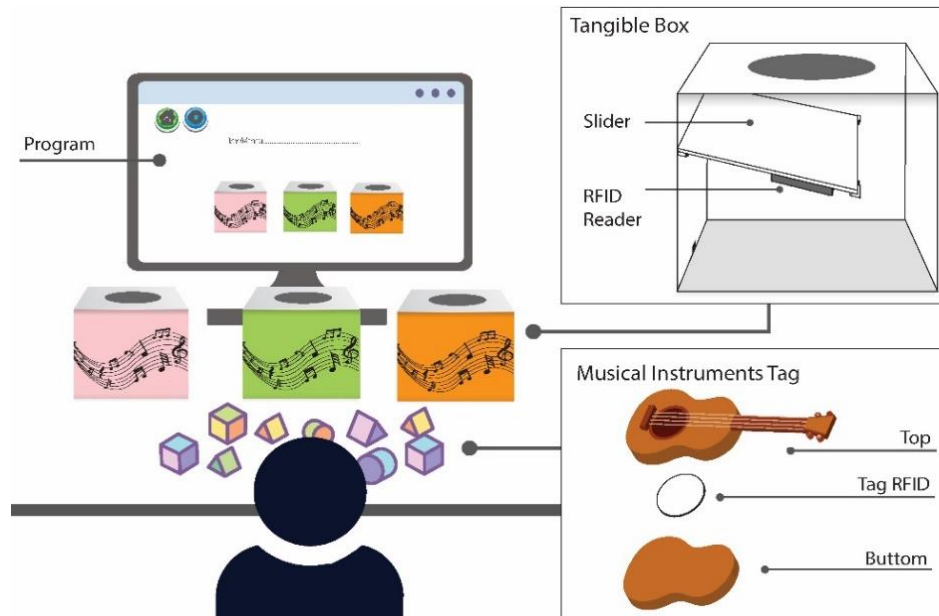

Figure 2. Tang-MI system design

3.1.3. Interactive program

The interactive program mediated an interaction between the students, the tangible box and the musical instrument tags. The functions of the interactive program are described below.

− Level of games: The game was divided into three levels pertaining to Grade 1, 2, and 3. Each level consisted of three tasks with increasing order of difficulty. In general, the tasks required the students to differentiate musical instruments based on shapes of objects and types of musical instruments.
− Registration of players: Each student was required to record his/her name and grade level into the program. Scores and times to complete the game would be recorded and associated with each student's account.
− Interaction: As a student dropped a musical instrument tag into the tangible box, the RFID reader in the box received the code specifically associated with each tag. The program then performed a check whether the student chose correct or incorrect objects and displayed a corresponding visual and audio feedback (which is explained in section 3.4).
− Scores: Scores for each game level were calculated differently. The total scores of Grade 1, Grade 2, and Grade 3 were 15 points, 18 points, and 20 points, respectively. The scores were calculated and presented with star symbols instead of numbers on the digital screen. The score calculation is shown in Table 2.

Table 2. Score calculation and presentation of star symbols

Grade 1 (total of 15 points)	Grade 2 (total of 18 points)	Grade 3 (total of 20 points)	Number of star symbols
1-5 points	1-6 points	1-7 points	★
6-10 points	7-12 points	8-14 points	★★
11-15 points	13-18 points	15-20 points	★★★

− Time: On the digital screen, the program displayed the duration of time the student spent playing the game since the start until the student completed the last task. A pause function was also available to allow the student to resume his/her game play if he/she was interrupted while playing.

−   Data recording: The program recorded the data of each student such as name, grade level, scores, time spent and start time in a text file.

3.1.4. Gameplay of Tang-MI

−   The program displayed a task and boxes on the screen. A task consists of one or more instructions. The student had to analyze and choose the musical instrument tags to drop into the box as specified in the instructions. An example of task and answer are illustrated below.
   a) Task: Pick two musical instruments with the square shape and drop them into the pink box. Pick two musical instruments with the cylindrical shape and drop them into the green box.
   b) Answer: Square shape = a piano and a keyboard
               Cylindical shape = a Thai fiddle and a drum
−   Once the student dropped the musical instrument tags into the boxes, if the answers were correct, the program would present animated fireworks around the correct tangible box in the screen. The tangible box was also programmed to be displayed larger than normal. In addition, the program would display the sound of the musical instrument. In the case that the student responded with an incorrect answer, a different sound would be produced so that the student could learn that their response was inaccurate.
−   The program displayed star symbols to represent scores for each completed task. It also presented a total score the student earned during the game play.

3.2. Implementation of Tang-MI

After the development phase, the Tangible user interface for multiple intelligences (Tang-MI) was tested with the sample groups to study the usage behavior of learners. The evaluation results would be a key input information to derive tangible user interface design guidelines for learners from different MI groups. The details of the implementation phase are explained as follows.

3.2.1. Participants

Thirty primary school students in Grade 1-3 from Watjana Wittayanukul School, Saraburi, Thailand took part in the experiment. Their ages were between 6 to 9 years old. Each participant's intellectual ability was initially evaluated by two-way multiple intelligences ability assessment [40] to determine the MI group the student belonged to. According to the assessment results and the method proposed by Walter McKenzie [5], the participants were then split into three groups consisting of analytical (16 students), introspective (7 students), and interactive (7 students) groups.

3.2.2. Experimental procedure

Before commencing experimental tasks, the participants received a lesson of 10-15 minutes about the content of the learning activities. This introduction provided basic knowledge about types and shapes of musical instruments. Each learner then used Tang-MI to perform the activity on his/her own. The activity was assigned according to the learner's grade level. While playing the game, the learner was free to use the devices without any help. However, the researcher would aid the learner verbally when he/she faced a difficulty or required support. During the experiment, the student's behavioral data was collected through the researcher's observation, video recording, and eye tracking. After finishing the tasks, a semi-structured interview was conducted to find out the participant's opinions towards the Tang-MI.

3.2.3. Data analysis

Based on the data gathered from all channels mentioned earlier, the researchers examined the learner's behavior before performing the tasks, during the tasks, and after completing the tasks. Behavioral issues of interest included first-time interaction with the system, approach to perform the tasks (i.e., reading all the instructions of a task before performing the task or reading and performing one instruction at a time), object-dropping methods (i.e., dropping one object into the box at a time or gathering all objects and drop them all at once), reaction after dropping objects, attention to visual feedback, and reaction to incorrect responses.

4.   RESULTS AND DISCUSSION

In the previous section, the design, the development, and the implementation of Tang-MI were described. The results are explained in the following section. Figure 3 shows the complete setup of Tang-MI whereas Figures 4 and 5 depict a close-up of musical instrument tags and the interactive program, respectively.

Figure 3. Tang-MI equipment set
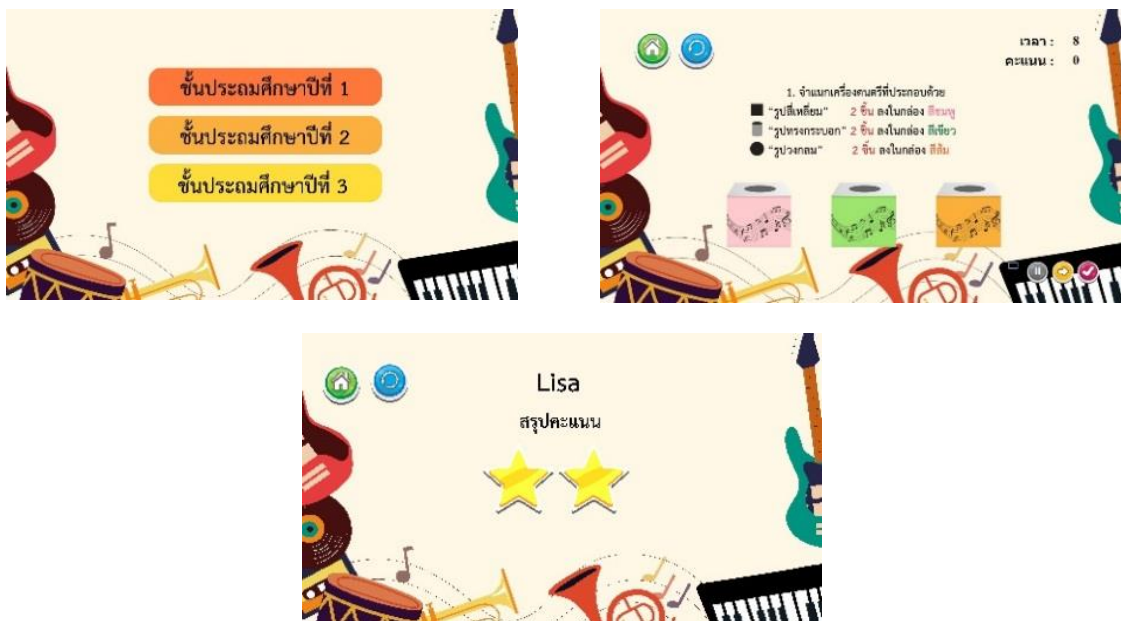

Figure 4. Musical instrument tags

Figure 5. Interactive program

4.1. Learners' usage behavior of Tang-MI

The test results of the Tang-MI showed that all participants from every MI group could use Tang-MI very well and felt engaged with the system. The interviews after the experiment revealed that 98% of all the participants enjoyed using Tang-MI and would like to play the game again. Seventy-two percent of the learners stated that the tasks were not difficult. When the scores of each grade level were converted to a total score of 100 points, the average score achieved by all students was 92 points. The details of the students' behaviors demonstrated while using Tang-MI are summarized in Table 3.

4.1.1. First-time interaction

The study revealed that 87.5% of the learners in the analytical group and 85.71% of the introspective group dropped the musical instrument tags into the boxes without asking for any support. On the other hand, 71.43% of the learners in the interactive group tended to ask for instructions before performing the task. The behavior of the learners in the interactive group corresponded to the outstanding characteristics of this intelligence group. Learners in the interactive group were good at employing languages for communication and using communication to build relationships with others. These characteristics helped them to generate understanding and reflect their thoughts and actions [41]. That is why the interactive group behaved differently from other intelligence groups.

Table 3. Behaviors of learners in each MI group

	Details of Behavior	Analytical group (%)	Introspective group (%)	Interactive group (%)
First-time Interaction	Perform the task (dropping objects) independently	87.5	85.71	28.57
	Ask the researcher before performing the tasks	12.5	14.29	71.43
Approach to perform the tasks	Read all instructions before performing a task	75	28.57	71.43
	Reading and performing one instruction at a time	25	71.43	28.57
Object-dropping methods	Drop one object at a time	75	100	100
	Gather all objects and drop them all at once	25	0	0
Reaction after dropping objects	No interest in musical sound	18.75	28.57	0
	Respond to musical sound	81.25	71.43	100
	• Stop and listen to the sound	68.75	28.58	71.43
	• Turn around to find a source of the sound	12.5	42.85	0
	• Stop and turn around to find a source of the sound	0	0	28.57
Attention to visual feedback	Look at visual feedback	68.75	28.57	71.43
	Do not look at visual feedback	5	71.43	28.57
Reaction to incorrect responses	Continue dropping	23.08	0	14.29
	Stop and look	46.15	80	28.57
	Turn to activity supervisor	7.69	0	57.14
	Stop, look, and turn to activity supervisor	23.08	20	0

4.1.2. Approach to perform the tasks

Seventy-five percent of the learners in the analytical group and 71.43% of the interactive group read all the instructions before they started performing a task. On the contrary, 71.43% of the introspective group read and perform each instruction in a task at a time. These results could be explained by the fundamental capabilities of each MI group. The analytical learners are normally good at analyzing and identifying problems. They can solve complex problems in a systematic manner. Similarly, the interactive learners are competent at contemplating, understanding, and distinguishing things around themselves. With these key competencies, the learners in both groups began the task by first understanding all the instructions, followed by analyzing each instruction, and finally giving answers to each instruction.

4.1.3. Object-dropping methods

Regardless of MI groups, most learners dropped one piece of musical instrument tag into the box at a time. However, some learners in the analytical group (25%) gathered all pieces of musical instrument tags and then dropped them all at once into the box. This kind of behavior corresponded to the logical basis of learning of the analytical learners. They could successfully analyze and solve complicated problems, as well as understand how to sort out the instructions [41].

4.1.4. Reaction after dropping objects

Most learners in every MI group were interested in the musical sound, which was played after the learners dropped objects. The behavior was expressed in three different ways: stop and listen to the sound; turn around to find a source of the sound; and stop and turn around to find a source of the sound. Most of the analytical learners and the interactive learners, 68.75% and 71.43%, respectively, tended to stop and listen to the musical sound before continuing the task. For the introspective group, as they dropped the musical instrument tag and heard the musical sound, 42.85% of them immediately turned around to find where the musical sound came from. The behavior of the introspective learners corresponded to their fundamental behavior, which is sensitivity to the surroundings and ability to distinguish situations around them [41]. Therefore, as they heard the sound, which signified a change in the surroundings, they automatically reacted by turning around to find out the origin of the sound.

4.1.5. Attention to visual feedback

After the learners dropped an object, the interactive program of Tang-MI played the musical sound and displayed the animation at the same time. Most of the analytical learners (68.75%) and the interactive learners (71.43%) paid attention to the animated visual feedback that appeared on the screen. On the contrary, in the introspective group, most of the learners (71.43%) did not look at the animation. They turned their attention to the sound more than to the animation on the screen.

4.1.6. Reaction to incorrect responses

When a sound was played to indicate incorrect answers, 46.15% of the analytical learners and 80% of the introspective learners stopped for a moment before continuing the task. The analytical group is composed of learners who have musical intelligence and logical intelligence. For the musical intelligence, the learners would be sensitive to a change of sound. Therefore, the sound signifying incorrect responses drew their attention. For the logical intelligence, the learners were determined to solve the problem. Once they realized they responded incorrectly, they would show a slight sign of suspicious and concern before resuming the task. For the introspective group, their reaction to the sound was associated with the sensitivity to the environment, which is one of fundamental characteristics of this group.

The interactive learners, however, behaved differently from the other two groups. Most of the interactive learners (57.14%) turned to speak with the activity supervisor when they learned that they gave wrong answers. This observed behavior was due to the basic characteristics of this intelligence group, i.e., language communication. The interactive learners gained more understanding and could reflect their feelings and actions by using language for communication [41]. Interestingly, some analytical learners and interactive learners did not pay attention to the sound and continued to grab a musical instrument tag for the next instruction. It was possible that they did not understand the meaning of the sound indicating the incorrect responses.

4.2. Tangible user interface design guidelines

The experimental results revealed that students from different MI groups behaved differently while interacting with Tang-MI to perform the tasks. The guidelines cover several aspects of design, i.e., physical equipment, question, interactive program, audio, and animated visual feedback.

4.2.1. Guidelines for analytical learners

The learners in the analytical group were competent at identifying and solving problems and enjoyed thinking analytically. They were likely to finish reading all content of a task before giving an answer. Thus, all instructions of each task should be displayed at the same time. The analytical learners are likely to consider a question with complicated conditions as a fun and challenging task. A complex question would also enhance their analytical thinking skill and ability to solve problems according to given conditions. Since the analytical learners already read and understood all instructions within a task, they grabbed multiple objects relevant to the task and dropped them all at once. Based on this behavior, the design of physical equipment should enable learners to take actions, e.g., dropping, with multiple items at the same time.

For the approaches to give feedback, a sound can be used to indicate correct or incorrect actions. It should be designed to give a clear message to the analytical learners, for instance, an audio pronunciation saying the word 'wrong.' In the case of correct actions, an audio could be played in correspondence with the sound of that object, e.g., the sound of a musical instrument. The audio imitating the actual sound of an object might also cultivate learners' motivation. Animation could also be used to provide visual feedback. The design of interactive animation, shown after the learners taking actions, should be noticeable. For example, the animation may display the word 'correct' or 'incorrect' in the middle of the screen or display a graphical animation resembling the object. Moreover, game scores should be displayed in a numerical format rather than a symbol or a sign; presenting numerical scores will not confuse the analytical learners.

4.2.2. Guidelines for introspective learners

In terms of solving a problem, they read each instruction and completed each instruction at a time. According to their behavior, if a task contains several instructions, each of them should be presented individually to the introspective learners. Furthermore, a key competency of the introspective learners is communication skill. They are good at perceiving visuals, colors, and sound. It would be better to present each task and scores by using images, colors, symbols, and sounds rather than texts and numbers. In addition, before commencing, information about the activity, for example, the number of tasks, the goal of the game, and the scoring scheme, should be explained to the introspective learners. The information would help the learners to evaluate themselves and set their own goal to perform this activity.

Regarding the audio and visual feedback, the introspective learners paid more attention to the sound than the animated visual feedback during the experiment. When the learners heard a sound, they turned around immediately to find out its source. A sound equipment, i.e., speakers, should be placed in the same direction with the screen so the learners would be able to figure out the source of the audio while looking at the screen.

For the audio design, like the analytical group, the audio should be designed to imitate the real sound produced by the objects. The sound of different objects would make the learners feel excited. The design of animated visual feedback should also be highly discernible so that the learners could effortlessly notice the movement.

4.2.3. Guidelines for interactive learners

A tendency to communicate is an outstanding characteristic of the interactive learners. At the start of the activity and during the experiment, they were likely to communicate with the activity supervisor and make gestures. It is important that the design of physical devices and interactive programs encourages interactions between the interactive learners and other subjects. The physical equipment can be designed to accommodate more than one player. It can also support a competition between the learners and other players, either human or automated ones.

Like the analytical group, the interactive learners solved each task by reading all the instructions before dropping objects relevant to each instruction. Thus, every instruction within each task can be presented all at once to the learners. The scores earned by the learners should be presented in number instead of symbol. It would be easier for the learners to know the scores they have already achieved.

The interactive learners also paid attention to the sound after they dropped the musical instrument tags. Like other MI groups, the audio imitating the sound of objects could stimulate the learners' interest. An animated character might be employed to help guide the interactive learners during the game play. It can provide information about how to play the game. A communication between the learners and the animated character could be a verbal conversation or vocal narration. In addition, the animated actor can give positive feedback to the learners when they answer correctly, for instance, 'well done' and 'good job'. If the responses are wrong, the animated character can say encouraging words like 'try again.'

5. CONCLUSION

This research presented a novel game with a tangible user interface for primary school learners. The game was built by considering the concept of multiple intelligences. Known as Tang-MI, a goal of the game was to enhance analytical skills of learners in the analytical group, the introspective group, and the interactive group. The learners practiced the analytical skills by classifying shapes and types of musical instruments into boxes. The usage behavior of different learners was also collected and analyzed to propose design guidelines suitable for each learners' group.

The results revealed that learners of different groups could learn to use Tang-MI. The learners also enjoyed using the system and would like to continue playing the game. However, the analytical learners, the introspective learners, and the interactive learners behaved differently to some extent while using the system. At the start of the activity, the analytical group and the introspective group could independently use the system whereas the interactive group tended to ask the activity supervisor. The analytical group and the interactive group completely read all instruction of a task before performing them. The introspective group performed differently. They read and completed each instruction one by one. Most of the learners clearly showed an interest in interactive sound and animation.

Based on the research's findings, the design of tangible user interface should support the learners who have different learning skills. Designers and researchers can apply recommendations of the design guidelines to analyze and develop tangible user interfaces appropriate for the learners' behavior of each MI group. Furthermore, Tang-MI can support the learning process and helps practicing analytical skills of learners with different multiple intelligences skills. Tang-MI provides the opportunity to learn through hands-on activities with physical equipment. With all these aspects, the system responds to the learners' needs and enhances learners' motivation to learn.

Nevertheless, to better improve the learners' experience while playing the game, RFID technology with a high-frequency range should be used rather than the low-frequency ones. The RFID used in this study had a low-frequency range of 125 kHz. It could detect RFID tags at a close range. When an object was dropped on the slider in a position that did not align with the RFID reader, the reader could not detect the RFID tag. In the future work, using high-frequency RFID devices should improve the detection.

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