Developing Multimedia Instructional Material for Robotics Education

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Abstract: - To develop the multimedia instructional material for robotics education, this study tried to develop a multimedia instructional material for robotics education and applied to a course to figure out the usability and utility. In this multimedia instructional material, there are four main sessions: adventure of the robot, assembly, programming, and demonstration video. The multimedia instructional material was designed to motivate students by an interesting adventure story, to introduce the assembly of a robot to complete the mission introduced in the adventure story, to introduce the programming of the operations of a robot to command the robot to complete the mission introduced in the adventure story, and to demonstrate the process of completing a mission. Finally, triangulation method was applied in this study to assess the user perception of the multimedia instructional material for robotics education. The triangulation data was obtained by observation, qualitative analysis of feedback generated by a class blog, and quantitative analysis of student perception of the multimedia instructional material for robotics education. Accordingly, the analysis results indicated that the multimedia instructional material for robotics education was effective and achieved high student satisfaction.

Key-Words: - LEGO, MINDSTORMS NXT, Robot, Robotics education, Programming, Assembly

1 Introduction

Robots are now widely used throughout the world for many applications. Accordingly, the field of robotics education has received increased attention from educators and prospective students in Taiwan. For instance, the number of Taiwan students participating in the World Robot Olympiad has increased, and they have achieved notable success.

In 2005, Taiwan team won 1st of the judges' award of the open competition. In 2006, a Taiwan won 1st and 2nd place in an open competition of primary school students. The senior high school age group also won an award.

In 2007, Taiwan team won 1st, 2nd, 3rd and 4th place in the primary school age group. Junior high school students won 1st, 2nd and 3rd place, and the senior high school students won 2nd place. Additionally, Taiwan team placed 3rd in the open competition of combined primary, junior high and senior high school students [1].

Although the Taiwan team achieved excellent results in the WRO, the formal education system in Taiwan lacks adequate learning material and training courses. Almost all material and courses are provided by specialized training orgnizations. In addition, these training courses are usually expensive and often available only in large cities such as Taipei and Kaohsiung. Therefore, many primary and junior high school students must enroll in private courses to learn robotics. However, these courses may not be accessible to students who are financially disadvantaged or students who live in rural areas. Therefore, this study designed and developed a multimedia learning material which provides low-cost robotics instruction. The designed material is suitable for students at all levels, including those with no background in robotics. Therefore, the aims of this study were to develop multimedia instructional material and evaluate its effectiveness.

In Taiwan, the LEGO MINDSTORMS NXT system is widely used for robotics instruction because it enables easy assembly and programming. Accordingly, we used LEGO MINDSTORMS NXT to design and develop the multimedia instructional material. Moreover, in order to evaluate the effectiveness of the material, a formal study was implemented to assess whether users perceived the material as effective for learning robotics. Their feedback was also expected to help us to improve the multimedia instructional material in the future. Therefore, the goal of this research was to develop effective material for teaching robotics and to assess the user perception of the material.

2 Literature Review

2.1 Instructional Design Model: ARCS Model

John M. Keller, a major researcher in educational psychology, argued that motivated learners perform better than unmotivated learners. After testing an integrated model of motivational instruction and learning, he developed the ARCS model, which proposes that motivated learners require the following four conditions: attention, relevance, confidence and satisfaction [2]. However, Keller argued that the conditions of ARCS model should occur sequentially rather than independently or randomly [3]. We believed that the ARCS model is more effective when combined with the appropriate technology or human-computer interface [4]. Therefore, the ARCS model was chosen and applied in this study to examine learner motivation. The theoretical framework of the ARCS model includes the following four bases of motivation.

Gaining attention: Curiosity is a hidden power that pushes students to learn. However, after initially motivating students, maintaining their motivation is essential. In the ARCS model, Keller suggested that learner interest can be aroused by using novel, interesting or unexpected teaching methods. The proposed multimedia instructional material attempts to attract the attention and interest of learners by encouraging a sense of adventure.

Enhancing relevance: Keller described the enhanced relevance as the bridging of a topic with the life experience of the student. If a learner can understand their relationship with the learning experiences, their learning motivation can be sustained. This strategy was applied when introducing the experimental robot in this study, which can be further constructed as an automatic vacuum cleaner. Therefore, when studying the robot, students could easily relate it to an everyday application.

Building confidence: The third essential component of the ARCS model is building confidence. Confident learners are more likely to develop a positive learning attitude and to achieve the learning goal successfully. The demonstration video section was designed to introduce the required tasks and encourage students to think about how to achieve them.

Generating satisfaction: Satisfaction is the final element of ARCS model. Providing opportunities and standardized tasks requiring the students to apply the newly acquired knowledge and skills provides students with a sense of achievement and reinforces their learning. The multimedia instructional material in this study included a list of main tasks as well as detailed subtasks to be performed incrementally. The main task was broken into smaller subtasks so that beginners would not feel overwhelmed by the difficulty of the main task.

2.2 Instructional Design Model: ADDIE Model

Cheng et al. [5] compared the instructional design models shown in Table 1 and found that the Dick and Carey model was the most widely used. However, the five steps in the Dick and Carey model, which are analysis, design, development, implementation and evaluation, are also five critical elements of ADDIE model. Therefore, in this research, ADDIE model was applied for developing multimedia instructional material as well. Below, the ADDIE model is briefly introduced, and Table 2 compares the ADDIE model with the Dick and Carey model.

Table 1: Frequency of usage of instructional design models adopted from Cheng et al. [5].

Instructional design model	Frequency (articles cited)
1. Dick and Carey [6]	59
2. Gagne and Briggs [7]	33
3. Rapid Prototyping [8]	24
4. Smith and Ragan [9]	19
5. ASSURE [10]	16
6. Kemp [11]	10
7. Hannafin and Peck [12]	8
8. ADDIE [13]	7

In the ADDIE model, the designer of instructional material or activities follows the following sequence of steps:

Analysis: Designers must analyze the learners, learning target, instructional environment and instructional resources. The designer must identify the learning objectives and the required prerequisite knowledge.

Design: Materials and activities must be appropriate for learner capabilities, learning objectives, environment and equipment. The design concern is how learners learn.

Development: Following the ideas generated in the design phase, designers determine how to develop the instructional material.

Implementation: Designers must determine how to implement instructional material in the environment.

Evaluation: Designers must determine how to assess whether the learning objectives were achieved and the quality of the instructional material. The assessment results should be used as feedback for improving the material or activity.

Table 2: Comparison of Dick and Carey model and ADDIE model.

Dick and Carey	ADDIE
Identify instructional goals, conduct instructional analysis and identify entry behaviors	Analysis
Identify learning objectives and target outcome	Design
Develop or select criterion, instructional strategies, and instructional materials	Development Implementation
Develop and conduct formative or summative evaluation	Evaluation

3 Methodology

3.1 Multimedia Instructional Material

The multimedia learning material was developed by using FLASH animation software under the framework of the ARCS model and the ADDIE model.

The researchers applied the ARCS model to attract the attention of learners and interest them in the experimental robot adventure, relate it to an everyday task, provide a demonstration video and to break down the main steps of the task. The designed multimedia instructional material followed the ADDIE model in every phase of development. The research was performed as follows.

Before developing the multimedia instructional material, the researchers investigated the background and experience of all learners. None had ever studied robotics, and few had experience operating multimedia software. Because none of the learners had related background and experience, the instructional material was designed to include the following four sections: “Adventure of the Robot”, “Assembly”, “Programming” and “Demonstration Video”. Each section was expected to stimulate interest and engage the learners. Meanwhile, the learners could follow the steps of the “Assembly” and “Programming” tasks to advance from having no knowledge of robotics to being able to assemble a functional robot. Finally, the researchers provided a video of a successful example of a robot to enhance learner confidence. The researchers then began the design and development of the multimedia material, which was then reviewed and revised by three professional instructional material designers according to student feedback.

3.2 Participant

The six participants in this study were from a Center for Teacher Education in a national university in northern Taiwan. The six students were divided into two groups of three students. All participants were General Arts majors. Accordingly, none had prior experience in programming or robot assembly. The selected course was Introduction to Instructional Media, which is a 50-minute class that meets twice a week. Therefore, the participants spent 100 minutes learning robotics.

The FLASH 8 multimedia instructional material was used to teach the students how to assemble and program the robot. The designed material consisted of four main parts: the robot adventure, assembly, programming, and demostration. Each part included an instructional animation which taught students how to assemble and program the robots and how to use robots in their future teaching with the assistance of the designed multimedia material. After completing the course, each student was asked to complete an evaluation questionnaire which measured their perceived satisfaction with the designed material. On the survey date, one student was absent, and another declined to answer the questionnaire for personal reasons. Therefore, only four valid questionnaires were returned to the research team. Although, the sample size in this study was small, the research team compensated for the small sample by using triangulation method. The triangulation data included those for classroom observation, qualitative analysis of the participant feedback regarding the course and their reflective journals on the class blog, and quantitative analysis of the results of the questionnaire designed to assess their satisfaction with the materials. Accordingly, the designed material was considered reliable and valid.

3.3 Method

A triangulation method was applied to measure user satisfaction with the material. The triangulation data were obtained by classroom observation, qualitative analysis of participant feedback and the reflective journals in the class blog, and quantitative analysis of the questionnaire regarding their satisfaction with the designed material. The questionnaire used to quantitatively measure satisfaction was developed by the research team. The scale consisted of four sub-scales, including motivation, interface design, content, and feasibility. All questionnaire items were answered using the following four-point Likert scale: strongly disagree (1), disagree (2), agree (3), strongly agree (4) and unable to answer this question (0).

3.4 Procedure

Multimedia instructional material developed using FLASH 8 was used to teach the students how to assemble and program the robot. The participants therefore learned to assemble, program and use robots with the assistance of the designed multimedia instructional material. After completing the course, each student completed a questionnaire designed to measure their perceived satisfaction with the designed material.

4 Result

The topic of the designed learning unit was Investigation Robot. The objective of this unit was to design a robot which could successfully navigate a labyrinth without touching the walls then make a U turn, exit the labyrinth and return to the starting point. A possible daily life application of this robot is a robot vacuum cleaner, which detects and avoids obstacles while vacuuming the floor. Therefore, the instructional goal of this unit was to assemble and program the LEGO MINDSTROMS NXT robot to complete the tasks described above. The objective was to teach important robotics concepts such as the use of ultrasound as well problem solving and logical thinking ability.

The learning material was developed using several important concepts of instructional design. For example, a learning motivation method was to present the task as an "adventure". cooperative learning and problem-solving methods were applied in the assembly and programming sessions. Finally, students were able to gain a further sense of accomplishment by collaboratively debugging assembly and programming problems. The material included four sessions (Fig. 1 - Fig. 2): adventure of the robot, assembly, programming and demonstration of the robot navigating the blockades. These four sessions are described in further detail below.

Investigation Robot

Fig. 1: Index of investigation robot unit.

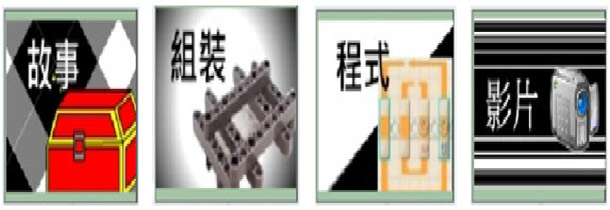

Fig. 2: The menu of adventure, assembly, programming, and demonstration.

4.1 Adventure Story of Robot

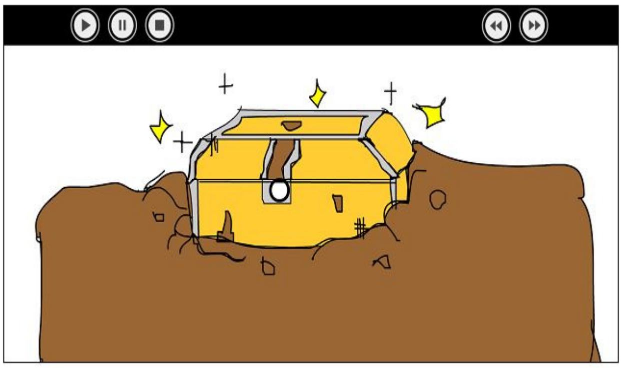

Fig. 3: The photograph of adventure story of robot.

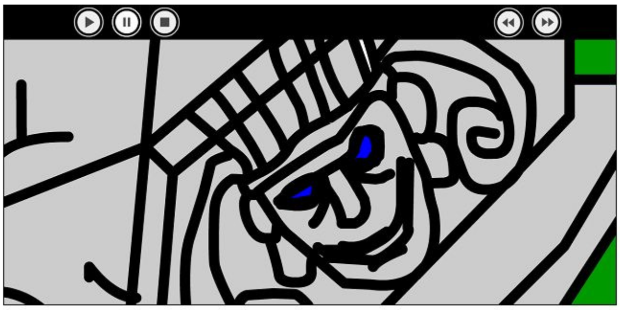

Fig. 4: The location of treasures.

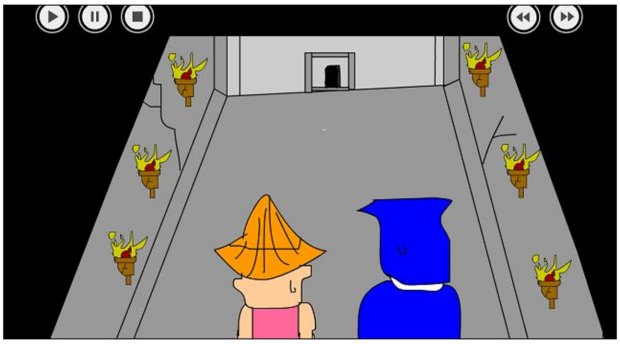

Fig. 5: The mission that must use investigation robot to find the treasures. (story adopted from [14])

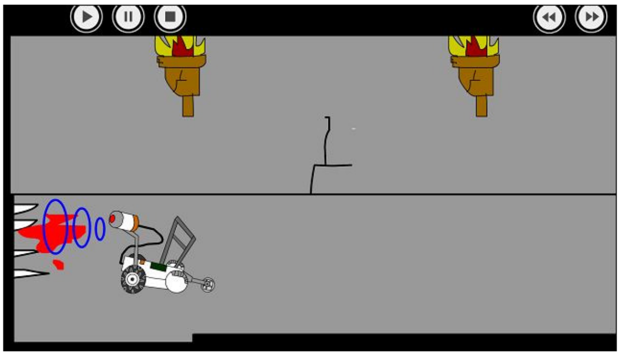

Fig. 6: The robot used to find the treasures. (story adopted from [14])

Among the strategies of ARCS model, story-telling is often used by instructors to gain the attention of students and to arouse their learning motivation. Accordingly, to motive the students to be interested in learning robotics, an animation entitled **The Adventure of the Investigation Robot** [14] was used to introduce the learning unit (Fig. 3 - Fig. 6). The interesting and dramatic introduction to the robot was intended to interest the students and reduce their learning anxiety.

4.2 Assembly

Detailed photos of each part (Fig. 7 - Fig. 8) were provided to students when teaching them to assemble the robot. Students were provided with a flowchart showing the four steps to assembling the investigation robot. Students could click the numbers shown in the main page as they assembled the robot step by step. The software provided detailed photographs of the parts required for each step and their assembly sequence. By following the instructions, students could systematically build their own robots.

Fig. 7: The menu of robot assembly.

Fig. 8: The step of assembly. (adopted from [14])

4.3 Programming
For the programming portion, students were also briefly instructed in using the programming software. On the left side of the screen was a list introducing each obstacle in the labyrinth. Students interested in programming the robot to complete these tasks could click the number of the obstacle to view the programming steps required to overcome it (Fig. 9).

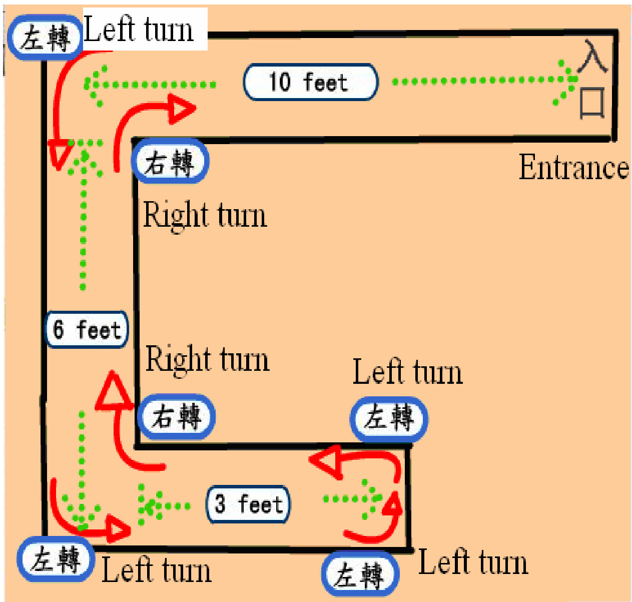

Fig. 9: The explanation of blockades in the labyrinth shown by a map. (adopted from [14])

Additionally, a detailed list of the main tasks (Fig. 10) and their subtasks (Fig. 11) were displayed following the instructions for avoiding the obstacles in the labyrinth. The list was presented in a logical order. Therefore, the students could follow the instructions and program their robot by following a sequence of steps. The explanations of each step (Fig. 12) and the screens that would appear when programming the robot were also provided so that students could program and tune their robots by following the instructions. This procedure enabled students to comprehend the logic of the program rather than simply using it.

Fig. 10: The task list of robot to complete. (adopted from [14])

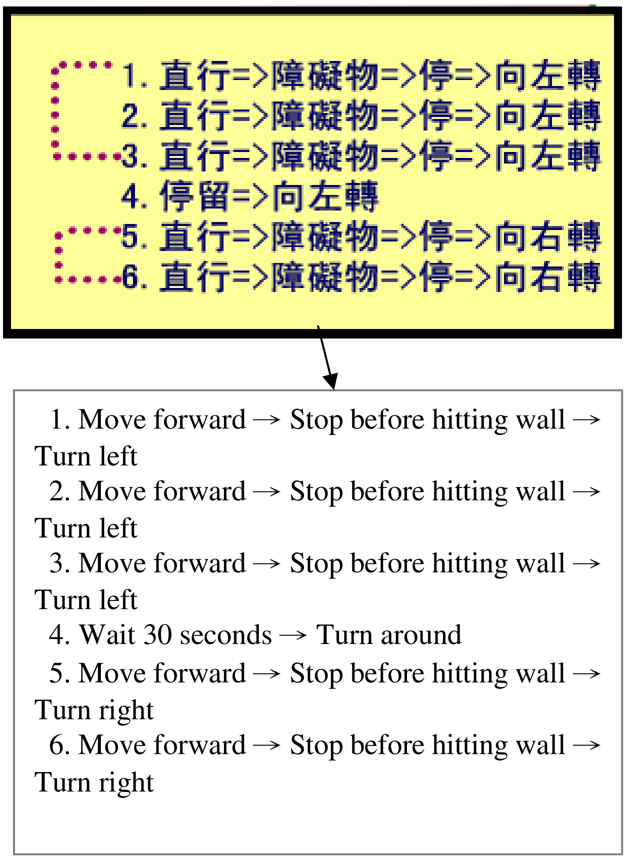

Fig. 11: Grouping the tasks. (adopted from [14])

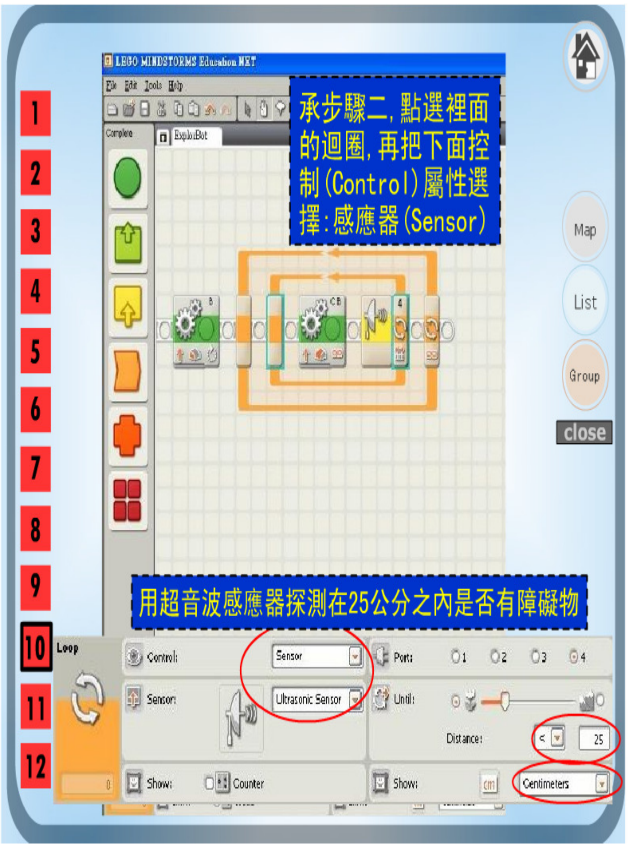

Fig. 12: The explanation of programming steps. (adopted from [14])

4.4 Demonstration

The final task of this learning unit was the successful navigation of the labyrinth after completing the assembly and programming stages. Therefore, in the closing phase of this multimedia instructional material, the students were given a video clip showing the robot accomplishing every task in the labyrinth. By viewing the video clip, students could visualize the objective and preview the conditions in the labyrinth (Fig. 13 - Fig. 16).

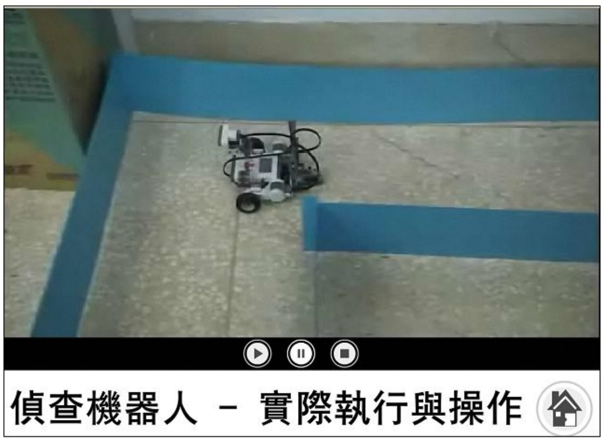

Fig. 13: The demonstration video of investigation robot. (part 1)

Fig. 14: The demonstration video of investigation robot. (part 2)

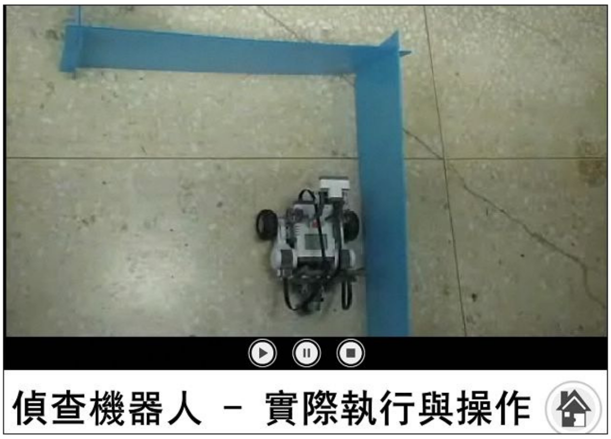

Fig. 15: The demonstration video of investigation robot. (part 3)

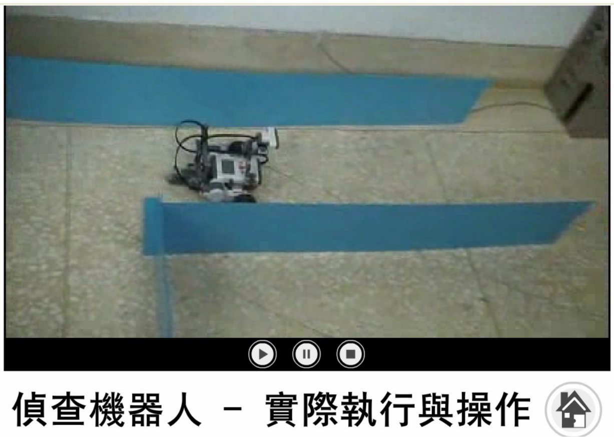

Fig. 16: The demonstration video of investigation robot. (part 4)

4.5 Results from Triangulation Method: Motivation

The data from the triangulation method were collected and analyzed. Because the median response in each item was 2.5, responses higher and lower than 2.5 indicated satisfaction and dissatisfaction, respectively, with the multimedia instructional material.

The students agreed most (ranging from 2.67 – 3.75) with the statement that learning is easier with multimedia instructional material (content) than with text-based material. In the class blog, some students also mentioned that, although they had not finished reading Chapter 3, after browsing the multimedia instructional material, they found the multimedia instructional material easy to understand. The black-and-white text and picture were unattractive, and the English explanation was difficult to comprehend in the course. The FLASH animation provided by the course was extremely helpful. During the class, the students learned to assemble and program the robot by using this multimedia instrucitonal material.

4.6 Results from Triangulation Method: Interface Design

The mean scores for satisfaction with interface design ranged from 2.67 to 3.25. The students all agreed with the statements of each item when evaluating the interface design element (Fig. 17 - Fig. 22) of the multimedia instructional material. Most agreed with the statement "The order of the material interface is appropriate." In the class blog, some students mentioned that the flow and order of multimedia instructional material made learning easy: "The FLASH material is very clear and superb! We follow the sequence and order of the flow to finish the program design easily (http://blog.totematncu.org/index.php?load=read&id=470)." On-site observation revealed that the students had no difficulty with using the multimedia instructional material.

Fig. 17: The easy to use user interface.

Fig. 18: The step 3 of assembling investigation robot. (adopted from [14])

Fig. 19: The step 4 of assembling investigation robot. (adopted from [14])

Fig. 20: The step 5 of assembling investigation robot. (adopted from [14])

Fig. 21: The step 6 of assembling investigation robot. (adopted from [14])

Fig. 22: The step 7 of assembling investigation robot. (adopted from [14])

4.7 Results from Triangulation Method: Content

Regarding satisfaction with content, most students agreed with the followings: The content reminds students to prepare spare parts before assembling the robot. In this course, the researchers provided LEGO MINDSTORMS NXT package, the multimedia instructional material and the material needed for building up blockades and labyrinth. Also, an additional robot package was provided for students to design, handle, test and practice at home to test their own ideas. As in the class blog, one student mentioned, “We felt excited when the teacher allowed us to take the robot package back to dorm. We will have more time to practice and try on when we have great new ideas (http://blog.totematncu.org/index.php?load=read&id=429).”

4.8 Results from Triangulation Method: Feasibility

The students responded positively to the following statements: “By following the instructional material, students can assemble the robot” and “The material inspires creativity.” These responses indicated that the students effectively learned the skills needed to construct a robot. In the class blog, one student mentioned, “I learned the concept of assembly by practically constructing the robot during the class. After the sensor was installed, we have a “robot”, and it’s really cute. I can not imagine what the teacher had mentioned that using robot to teach some concepts before, but today I knew a little bit. I came out some ideas for future teaching today such as 1.teaching the concept of direction: front, back, left and right, 2.teaching the concepts of angles (http://blog.totematncu.org/index.php?load=read&id=431).” In the learning process, most learners worked as a team to brainstorm new routes, tasks and missions which differed from those in the textbook [14].

Generally, the mean response to each question was over 2.5, and responses related positively with feedback on the class blog. These findings indicate that students were satisfied and had positively perceived the multimedia instrucitonal material. Because the satisfaction of students with the course was high, the multimedia instructional material can be considered adequately developed and effective.

5. Conclusion and Suggestion

The developed structures of the multimedia instructional material included the adventure, assembly, programming and demonstration. After the multimedia instructional material was satisfactorily developed, the researchers applied it in an educational setting. The students learned, designed, programmed and assembled the robot then debugged the program to successfully overcome obstacles by using the multimedia instructional material. The students then evaluated the material by completing questionnaire, which revealed very positive feedback regarding the course. But, in a future study we should modify the content according to the user opinions to further improve the effectiveness of the multimedia instrucitonal material for robotics education. Finally, the researchers advocate promoting robotics education by encouraging more contributions from educators, instructional material designers, researchers, and the government. The same evaluation procedures can also be applied to e-tutor program [15-16] and researchers can use the computer virus scale [17] to evaluate the effectiveness of the multimedia instructional material for teaching about the concept of computer virus.

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