The Development of Evaluation Indicators for LEGO Multimedia Instructional Material

ERIC ZHI FENG LIU[1], SHAN SHAN CHENG [1,2], CHUN HUNG LIN[1],
YU FANG CHANG[1], and WEN TING CHEN[1]
[1]Graduate Institute of Learning & Instruction
National Central University
No.300 Jung-da Road, Chung-Li City, Taoyuan
TAIWAN
[2]Department of Information Management
Minghsin University of Science and Technology
No. 1, Hsin Hsin Road, Hsin Feng, Hsinchu
TAIWAN
totem@cc.ncu.edu.tw, yes5433@must.edu.tw, sjohn1202@gmail.com,
yakinsky@gmail.com, wenting.teresa@gmail.com

Abstract: - The robotics education is more and more important, but there is a lack of evaluation indicators for evaluating robotics multimedia instructional material. Therefore, the researchers developed evaluation indicators for robotics multimedia instructional material in this paper. The researchers applied content analysis in the first stage, and then applied Delphi technique and invited 2 robotics teachers and 4 experts of multimedia instructional material designer and 4 users of robotics multimedia instructional material to develop the scale. The well developed scale included 40 evaluative indicators can be classified into 4 factors that are motivation, interface design, content, and feasibility.

Key-Words: - LEGO, MINDSTORMS NXT, Robot, Evaluation indicator, Multimedia instructional material

1 Introduction

The robots have been widely applied to many fields in the world. In recent years, there are many students, educators, and researchers who are engaged in the area of robot in Taiwan. In addition, the Taiwanese students attended the World Robot Olympiad (in short, WRO) to earn the good results. Taiwanese teams got many award in WRO. The excellent results are listed below.

1. In 2002, Taiwanese team won 3rd place of the regular competition and 3rd place of the open competition for an age group of primary.
2. In 2005, Taiwanese team won 1st of the judges' award of the open competition.
3. In 2006, Taiwanese team won 1st and 2nd place of the regular competition and 3rd place of the open competition for an age group of primary. They also won an excellent award for an age group of senior high.
4. In 2007, Taiwanese team won 1st, 2nd, 3rd and 4th place of the regular competition for an age group of primary and also won 1st, 2nd and 3rd place for an age group of junior high and 2nd place for an age group of senior high. Additionally, Taiwanese team won 3rd place of the open competition for an age group of primary, junior high, and senior high.

Because of the gradual blooming of robotics education, more and more people engage in robotics education and producing instructional material of robot. This makes a variety of books (printed form of multimedia instructional material) or multimedia instructional material of robot available on the market. The problem now is not where to find the instructional materials, but how to choose a suitable one. The evaluation indicators for evaluating multimedia instructional material of robot are needed to guide the school teachers and parents to choose a suitable multimedia instructional material for their students and children.

The purpose of this study is to develop a set of evaluation indicators for evaluating robotics multimedia instructional material through content analysis and Delphi technique.

2 Literature Review

2.1 Robot and Education

Recently, more and more educators and researchers find that it is beneficial for students to learn how to design robots. Papert believed that learners can solve complex problem and tasks beyond their abilities as long as they work in a learning environment that provides suitable emotional and intellectual support [1]. The aim of Technology Education as learners could be able to understanding the logic and functional mechanism of everyday technology and can solve technological problems. From the constructivist theory point of view, learning occurs while learners take information from the environment and construct their own interpretations and meanings based on prior knowledge and experience [2-4]. From this viewpoint, teachers should offer sufficient information and opportunity for learners to make linking between instructional materials and learning elements.

Research in technology education has showed that student-centered learning environments supporting teamwork, and design generates better outcomes [5-6]. Using robots to be an educational medium can incorporates all of these aspects [7]. Besides, students can simply find robots exciting [8-10]. Many researchers found that robotics is a suitable subject for project-based education [11], and robots can be an excellent medium for teaching design, programming, and creativity [12]. Students can gain expertise and realize benefits of improved technical abilities from participating in robotics program [13].

2.2 Evaluation of Instructional Materials

The design of multimedia instructional material must consider three facets: instruction and learning, content and learning goals, and interface design [14].

Cognitive load theory explains why student can't learn well with too much and ill-structured information. How to help learners to absorb new knowledge with limited working memory is an important issue when design multimedia instructional materials. Clark and Mayer [15] propose some principles for designers to follow: Contiguity principle, modality principle, redundancy principle, and coherent principle. Contiguity principle expresses that it is better to place printed words near corresponding graphics. Modality principle expresses that it is better to present words as audio narration rather than onscreen text. Redundancy principle expresses that don't present words as narration and identical text in the presence of graphics. Coherence principle expresses that the items and sounds that are not related to the leaning content should be omitted.

When designing instructional material, the content must follow the learning goals, the knowledge in the material must be accurate [14], and the use of words in the content must correspond to learners' age.

User interface design is the discipline that holds theories about designing computer interfaces. Marcus [16] proposed some guidelines about graphical user interfaces: Strive for consistency, assist in navigation, use color in a functional way and keep the number of colors low.

3 Method

3.1 Content Analysis

In this research, the content analysis was used to analyze existing reference books and multimedia instructional materials about teaching robots. The books and multimedia instructional materials include Robot [17], LEGO MINDSTORMS NXT: The Mayan Adventure [18], Robot Tutorial [19], and the multimedia instructional materials (please refer to Fig. 1 – Fig. 10) that adopted from a book [18] and developed by our research team.

Fig. 1: The sample snapshot of LEGO MINDSTORMS NXT instructional material about a full view of robot.

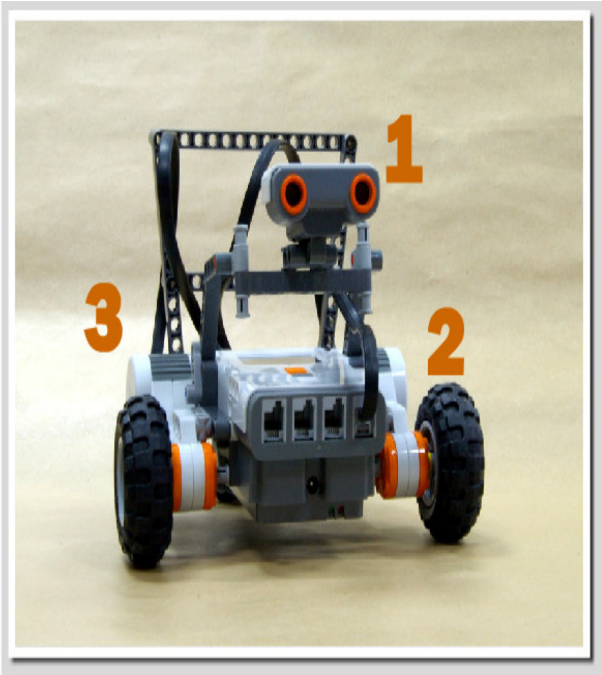

Fig. 2: The sample snapshot of LEGO MINDSTORMS NXT instructional material about each part of a robot.

Fig. 3: The sample snapshot of LEGO MINDSTORMS NXT instructional material about multiple choice menu.

Fig. 4: The sample snapshot of LEGO MINDSTORMS NXT instructional material about how to assemble a robot (step 1).

Fig. 5: The sample snapshot of LEGO MINDSTORMS NXT instructional material about how to assemble a robot (step 2).

Fig. 6: The sample snapshot of LEGO MINDSTORMS NXT instructional material about how to assemble a robot (step 3).

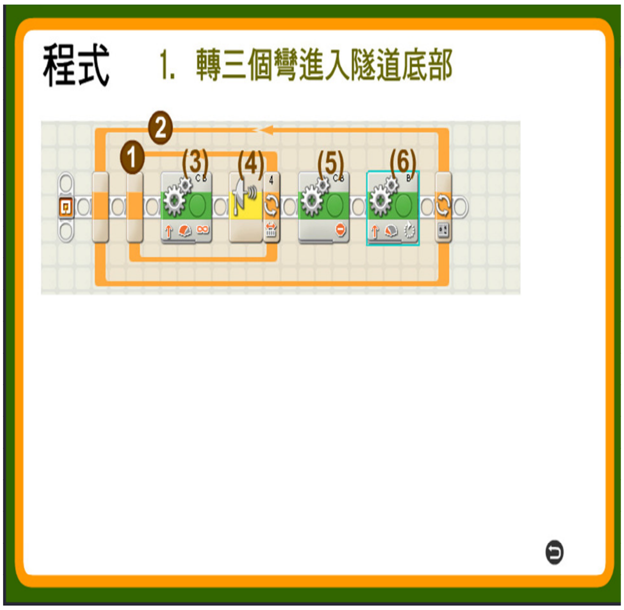

Fig. 8: The sample snapshot of LEGO MINDSTORMS NXT instructional material about a part of program of robot.

Fig. 7: The sample snapshot of LEGO MINDSTORMS NXT instructional material about play field simulation.

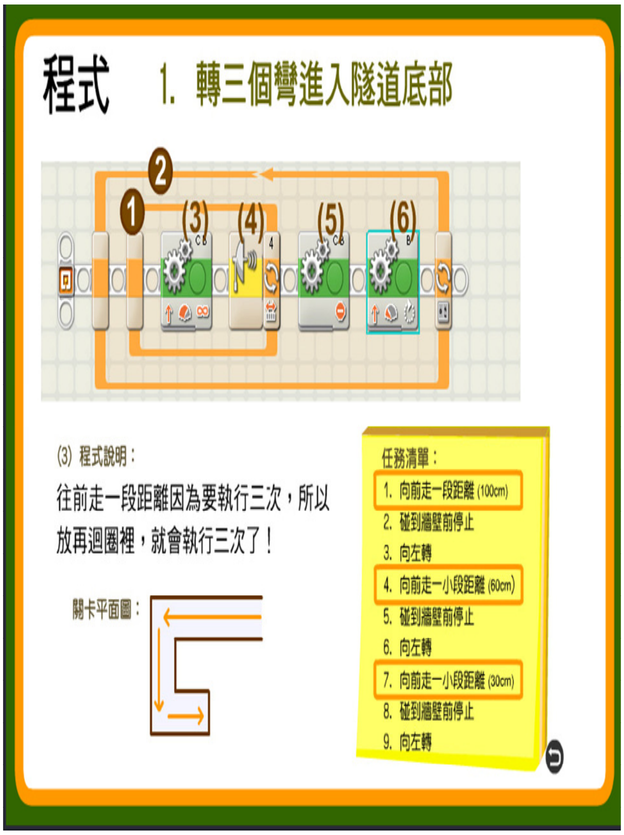

Fig. 9: The sample snapshot of LEGO MINDSTORMS NXT instructional material about how to define the parameters of servomotors.

Fig. 10: The sample snapshot of LEGO MINDSTORMS NXT instructional material about how to use the loop to control the robot.

3.2 Delphi Technique

The Delphi technique is a systematic interactive forecasting method for obtaining forecasts from independent experts in different fields. A questionnaire is administered in two or more rounds to a panel of carefully selected experts. By following specific procedures and steps, the Delphi technique can be used to integrate different experts' opinions, and ultimately, to reach a consensus.

In this study, the following people were invited to serve as experts in the Delphi survey: 2 robotics teachers and 4 experts of multimedia instructional material designer.

In the first round, based on the experts' opinions, the results of the content analysis of the reference books related to teaching robot, and the result of the literature review about teaching material development, the researchers listed the evaluation indicators for the experts to evaluate and provided their comments. The questionnaire for the second round was produced based on an analysis of these lists. The final results of the second round included four categories, motivation, content, interface design and feasibility, which comprised a total of 17 items. Similarly, after integrating the results of the second round, the final results of the third round included four categories, with 22 items. In the fourth round, after analyzing the results of the third round, the final results of the third round included four categories, with 40 items. In the fifth round, the opinions of the experts were found to be consistent, and the Delphi survey was concluded. Some evaluation indicators are listed as followings:

- **Motivation**
  - The content of this multimedia material matches learners' expectation for this course
  - The content of this multimedia material can trigger student's learning interests
  - The content of this multimedia material can enhance students' motivation toward learning robot
  - The content of multimedia material is more vivid than the traditional one
  - It is easier for me to learn with multimedia material (content) than with text-based one
  - …
- **Interface design**
  - The order of this material interface is appropriate
  - The material interface provides proper feedbacks
  - The material interface provides proper hints
  - The material interface is easy to browse
  - The material interface is easy to operate
  - The material interface is neat and clear
  - The tool bar in the material interface is consistent
  - The way of operating material interface is consistent
  - ...
- **Content**
  - The contents of this material match the instructional objectives
  - The content will remind the students of preparing the spare parts before assembly of the robot
  - The contents of this material provide the prerequisite information
  - The content of this material matches learner competence
  - The contents of the material are correct
  - …
- **Feasibility**

- Teacher could coach the students to complete the instructional activities on site
- Following the sequences of the material, the students can identify the needed tasks
- Following the sequences of the material, the students can assemble the needed robots
- Following the sequences of the material, the students can figure out the needed programs
- Following the sequences of the material, the students can test the functionality of robots independently
- …

3.3 Pilot Study

After the Delphi survey was concluded, the researchers used these evaluation indicators in a four-point Likert scale: strongly disagree (1), disagree (2), agree (3), strongly agree (4), and unable to answer this question (0) and invited four college students to use the evaluation indicators to evaluate multimedia instructional material developed by our research team of constructing robot. These participant students are from a Teacher Education Center in a national university in northern Taiwan. All the participants are liberal arts majors. Accordingly, they don't have any prior experiences of programming or assemble robot. The multimedia instructional material was used to teach these students how to assemble and program the robot. The designed material consists of four main parts, which are the adventure of the robot, assembly, programming, and demostration vedio. Each part was demonstrated by means of animation. The participants, hence, learned how to assemble and program the robots and how to use robots in their future teaching with the assistance of the designed multimedia material. During the course, those students were required to write their perception and suggestion of material on their personal blog. Then the researchers reviewed what they have written every day and found that the students have very positive perception of the material.

After the end of the course, the evaluation questionnaire consisted of these indicators was issued to each student to investigate if the results from the survey can match their positive perception toward this material. If the results were similar to what the students have written on their blog, accordingly, the evaluation indicators were assumed as reliable and valid. The followings are the descriptive statistics from the pilot study.

3.4 Motivation

Table 1: Statistical analysis of motivation.

Item	M	SD
1. The content of this multimedia material matches learners' expectation for this course	3.00	0.00
2. The content of this multimedia material can trigger student's learning interests	3.50	0.56
3. The content of this multimedia material can enhance students' motivation toward learning robot	3.25	0.00
4. The content of multimedia material is more vivid than the traditional one	3.50	0.56
5. It is easier for me to learn with multimedia material (content) than with text-based one	3.75	0.50
6. I can complete my learning independently via the assistance of this multimedia material	3.00	0.00
7. I can apply the knowledge acquired from the learning process	2.67	0.56

In the motivation session (Table 1), there was a question's score slightly lower than other questions. The evaluation indicator was I can apply the knowledge acquired from the learning process. After discussing with the students, there was one student grade (0) to this question. When asked why, she said that she thought the question cannot be answered because it would need time to prove what they had learned was useful for their daily life.

3.5 Interface Design

Table 2: Statistical analysis of interface design.

Item	M	SD
1. The order of this material interface is appropriate	3.25	0.50
2. The material interface provides proper feedbacks.	3.00	0.00
3. The material interface provides proper hints	3.00	0.00

4. The material interface is easy to browse	2.75	0.50
5. The material interface is easy to operate	3.00	0.00
6. The material interface is neat and clear	3.00	0.00
7. The tool bar in the material interface is consistent	3.00	0.00
8. The way of operating material interface is consistent	2.67	0.58
9. The allocation of the material interface is consistent	2.67	0.58
10. There are headings and path-flow in this multimedia material	3.00	0.00
11. The icons are simple and legible	3.00	0.00
12. The images are designed with proper visual or audio feedback	2.67	0.58
13. The colors of words and background fit each other appropriately	3.00	0.00
14. The font sizes are appropriate	3.00	0.00
15. The spaces between words and paragraphs are appropriate	3.00	0.00
16. The design of the interface can enhance student's learning motivation	2.67	0.58
17. The speed is proper when the material is displayed	3.00	0.00
18. The numbers of the colors used in the material are proper	3.00	0.00
19. The colors used in the material are with consistency	3.00	0.00

In interface design session (Table 2), although four questions: the way of operating material interface is consistent, the allocation of the material interface is consistent, the images are designed with proper visual or audio feedback., the design of the interface can enhance student's learning motivation had lower scores than other questions, there was no one viewed the indicators in this session unable to answer. Also, from the reflection of the students written in their blog, the material had some minor points needed to be improved. For instance, one student wrote down:

"The material is not bad although there were some miner defects… We can find what we want after one more try or more clicks. The design of the material is very good. Comparing with the text material, it is clearer when learning robot with this multimedia material. Although text can tell a lot, image sometimes tells more. We can follow the sequence and order of the flow, and easily complete the assembly of robot." (from student002)

3.6 Content

Table 3: Statistical analysis of content.

Item	M	SD
1. The contents of this material match the instructional objectives	3.33	0.58
2. The content will remind the students of preparing the spare parts before assembly of the robot	3.75	0.50
3. The contents of this material provide the prerequisite information	3.25	0.50
4. The content of this material matches learner competence	3.33	0.58
5. The contents of the material are correct	3.25	0.50
6. The order of the contents of this material is in proper sequence	3.00	0.82
7. The contents of the material are logical	3.25	0.96
8. The contents of the material are creative	3.50	1.00

In the session of content (Table 3), there were two questions graded as unable to answer. They are: the contents of this material match the instructional objectives and the content of this material matches learner competence. When discussing with the students, they thought that they did not have confidence in progamming robot and that's why the student viewed them as unable (or hard) to answer.

3.7 Feasibility

Table 4: Statistical analysis of feasibility.

Item	M	SD
1. Teacher could coach the students to complete the instructional activities on site	3.33	0.58
2. Following the sequences of the material, the students can identify the needed tasks	3.00	0.82
3. Following the sequences of the material, the students can assemble the needed robots	3.25	0.50
4. Following the sequences of the material, the students can figure out the needed programs	3.25	0.50
5. Following the sequences of the material, the students can test the functionality of robots independently	3.25	0.50
6. The students' creativity can be inspired by the material	3.25	0.96

In the session of feasibility (Table 4), the scores of each evaluation indicator are high. In the phase of test of validity and reliability, there were 40 evaluation indicators kept.

4 Conclusion

Based on the result from content analysis and Delphi survey, 40 evaluation indicators were collected, and were divided into four categories for evaluating robotics multimedia instructional materials: Motivation, design, content, and feasibility.

4.1 Motivation

1. The content of this multimedia material matches learners' expectation for this course.
2. The content of this multimedia material can trigger student's learning interests.
3. The content of this multimedia material can enhance students' motivation toward learning robot.
4. The content of multimedia material is more vivid than the traditional one.
5. It is easier for me to learn with multimedia material (content) than with text-based one.
6. I can complete my learning independently via the assistance of this multimedia material.
7. I can apply the knowledge acquired from the learning process.

4.2 Interface Design

1. The order of this material interface is appropriate.
2. The material interface provides proper feedbacks.
3. The material interface provides proper hints.
4. The material interface is easy to browse.
5. The material interface is easy to operate.
6. The material interface is neat and clear.
7. The tool bar in the material interface is consistent.
8. The way of operating material interface is consistent.
9. The allocation of the material interface is consistent.
10. There are headings and path-flow in this multimedia material.
11. The icons are simple and legible.
12. The images are designed with proper visual or audio feedback.
13. The colors of words and background fit each other appropriately.
14. The font sizes are appropriate.
15. The spaces between words and paragraphs are appropriate.
16. The design of the interface can enhance student's learning motivation.
17. The speed is proper when the material is displayed.
18. The numbers of the colors used in the material are proper.
19. The colors used in the material are with consistency.

4.3 Content

1. The contents of this material match the instructional objectives.
2. The content will remind the students of preparing the spare parts before assembly of the robot.

3. The contents of this material provide the prerequisite information.
4. The content of this material matches learner competence.
5. The contents of the material are correct.
6. The order of the contents of this material is in proper sequence.
7. The contents of the material are logical.
8. The contents of the material are creative.

4.4 Feasibility

1. Teacher could coach the students to complete the instructional activities on site.
2. Following the sequences of the material, the students can identify the needed tasks.
3. Following the sequences of the material, the students can assemble the needed robots.
4. Following the sequences of the material, the students can figure out the needed programs.
5. Following the sequences of the material, the students can test the functionality of robots independently.
6. The students' creativity can be inspired by the material.

In the future, the teaching material designers for robotics education should not only focus on the content, but also on students' motivation. Besides, the schools teachers and parents should choose suitable learning materials for their students and their kids.

In this study, the indicators for evaluating multimedia instructional material of robots were developed through content analysis and Delphi technique. In order to obtain more opinions, a wider range of user group should be interviewed. This will be beneficial for the development of instructional materials, and can obtain more complete idea about the indicators for robotics multimedia instructional material. The same method can also be applied to instructional material for e-tutor program [20-21], development of computer virus scale [22], and so on.

Acknowledgments:
The authors would like to thank the National Science Council of the Republic of China for financially supporting this research under Contract No. NSC 97-2631-S-008-003.

References:

[1] S. Papert, *Mindstorms: Children, computers, and powerful ideas.* New York: Basic Books, 1980.
[2] I. Harel, and S. Papert, Editors, *Constructionism.* Norwood, NJ: Ablex Publishing, 1991.
[3] E. Glaserfeld, *A constructivist approach to teaching*. In constructivism in education. Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers, 1995.
[4] J. Lindh, and T. Holgersson, Does lego training stimulate pupils' ability to solve logical problems?, *Computers & education*, Vol. 49, No. 4, pp. 1097-1111, 2007.
[5] F. Martin, Ideal and real systems: A study of notions of control in undergraduates who design robots, *Constructionism in Practice: Designing, Thinking, and Learning in a Digital World*, Y. Kafai, and M. Resnick, Editors, Lawrence Erlbaum, 1996.
[6] M. Lepper, and J. Henderlong, *Turning "play" into "work" and "work" into "play": 25 years of research on intrinsic versus extrinsic motivation*. Academic Press, 2000.
[7] E. Sklar, and A. Eguchi, Learning while Teaching Robotics, presented at the 2004 AAAI Spring Symposium on Accessible, Hands-on AI and Robotics Education, Stanford, CA, 2004.
[8] O. Miglino, H. Lund, and M. Cardaci, Robotics as an educational tool, *Journal of Interactive Learning Research*, Vol. 10, No.1, pp. 25-47, 1999.
[9] E. Sklar, J. Johnson, and H. Lund, *Children learning from team robotics: RoboCup junior 2000 educational research report*, Technical report, The Open University, Milton Keynes, UK, 2000.
[10] E. Sklar, A. Eguchi, and J. Johnson, RoboCup junior: Learning with educational robotics, In Proceedings of RoboCup-2002: Robot Soccer World Cup VI, 2002.
[11] J. Wikander, M. Törngren and M. Hanson, The science and education of mechatronics engineering, *IEEE Robotics and Automation Magazine*, June, pp. 20-26, 2001.
[12] E. Wang, Teaching freshman design, creativity and programming with LEGOs and Labview, In Proceedings of the 31st Frontiers in Education Conference, Vol. 3, 2001.
[13] I. Verner, D. Ahlgren, and J. Mendelssohn, Fire fighting robot competitions and learning outcomes: A quantitative assessment, ASEE Annual Conference, St. Louis. [Online

document] 2000, Available at http://www.asee.org/acpapers/20239.pdf

[14] J. Diederen, H. Gruppen, R. Hartog, G. Moerland, A. G. Voragen, Design of activating digital learning material for food chemistry education, *Chem Educ Res Practice*, Vol. 4, pp. 353-371, 2003.

[15] R. C. Clark, and R. E. Mayer, *E-Learning and the science of instruction: Proven guidelines for consumers and designers of multimedia learning*. West Sussex: John Wiley, 2002.

[16] A. Marcus, *Graphical user interfaces*. In Handbook of human-computer interaction, M. G. Helander, T.K. Landauer, P.V. Prabhu, Editors, Amsterdam: Elsevier Science B.V., pp. 423-440, 1997.

[17] Robot Club of Te Yin Elementary School, *Robot*, Chi-Lin culture, Taiwan, Dec. 2008. (in Chinese)

[18] J. F. Kelly, *LEGO MINDSTORMS NXT: The Mayan adventure,* Apress, 2006.

[19] Y. C. Chen, and M. T. Wu, *Robot tutorial*, Wang- Yi, Taiwan, 2008. (in Chinese)

[20] E. Z. F. Liu, and H. W. Ko, Implementation and evaluation of an e-tutor program, *WSEAS Transactions on Communications*, Vol. 6, No. 4, pp. 547-552, 2007.

[21] C. H. Lin, E. Z. F. Liu, H. W. Ko, and S. S. Cheng, Combination of service learning and pre-service teacher training via online tutoring, *WSEAS Transactions on Communications*, Vol. 7, No. 4, pp. 258-266, 2008.

[22] E. Z. F. Liu, A pilot study on college student's attitudes toward computer virus, *WSEAS Transactions on Computers*, Vol. 6, No.6, pp. 964-966, 2007.