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Designing and Implementing the Usability Engineering Course Based on STEAM Education

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ABSTRACT
In this article, we introduced the characteristics and advantages of STEAM education, and discussed the problems faced by the "usability engineering" course. We put forward three principles of curriculum design: comprehensiveness, innovation, and feasibility. According to these principles, we integrated STEAM education into this course, and designed and implemented this course with Project-Based Learning (PBL) method as the carrier. We found that students had improved their learning engagement and motivation in this process. And their final works quality, comprehensive ability and team cooperation ability have improved. This study confirmed the feasibility of STEAM education applied to university course design. In the part of teaching reflection, we made suggestions for further improvement of course design for further research.

Keywords: course design; STEAM education; usability engineering; teamwork

INTRODUCTION

STEAM education is an advanced educational concept with high comprehensiveness, which was first proposed by the United States. Its special feature is that five abilities can be improved in

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corresponding education, thus improving the overall quality of students (Wu & Huang, 2022). Subsequently, STEAM education quickly received wide attention and strong support from governments and educational organizations in various countries around the world. Countries extended the connotation of STEAM education and carried out various practices according to their own localization characteristics. In addition, many relevant professionals have jointly developed systematic education methods and evaluation mechanisms for STEAM education based on this theory, such as the 21st Century Skills Framework created by the National Research Council of the United States (Conradty & Bogner, 2020). Students majoring in digital media technology are compound talents, the cultivation of their innovation ability is particularly important. STEAM education emphasizes both knowledge and ability, advocates project-based learning, and emphasizes the cultivation of innovative thinking and creativity, which are consistent with the training objectives of the usability engineering course.

Therefore, we have integrated the relevant literature on the current situation of STEAM education and usability engineering course. According to the implementation status and existing problems of this course, designed and constructed “usability engineering” course based on STEAM concept was proposed by us. And we carried out relevant application research to cultivate students' innovative thinking and project practice ability.

LITERATURE REVIEW

STEAM education

STEAM education originated from the "Undergraduate Science, Mathematics and Engineering Education" report published by the National Science Board of the United States in 1986. The report put forward for the first time a programmatic proposal for education in "Science, Technology, Engineering and Mathematics" (Chai et. al, 2019). Later, Yakman proposed in 2006 the importance of art for personal career development and integration into society. At that time, he believed that the addition of art could balance the overweight science and engineering attributes in STEM education and provide creative thinking for science and engineering subjects. So far, the concept of STEAM has been formally formed.

STEAM education is a comprehensive education integrating science, technology, engineering, art, and mathematics. It supports students to understand the world and solve problems through multidisciplinary integration (Culén & Gasparini, 2022). It is interdisciplinary, experiential, situational, collaborative, and design-oriented, artistry and other characteristics. Although STEAM education is currently in the development stage as a training model for comprehensive talents in the future, its international and domestic advantages have become increasingly obvious. The integration of STEAM education and various disciplines has become one of the important ways to reconstruct the models of various disciplines. With the continuous extension of STEAM education, new concepts such as STREAM and STEAM+ have emerged successively. As an important comprehensive educational auxiliary method, it has widely used in many schools. Its purpose is to cultivate students' lifelong learning awareness and innovation ability, and to Synthetic and innovative ways to see the world and solve problems. Regarding the

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application of the STEAM education concept, most of the research focuses on the students in the K12 stage, and there are relatively few teaching applications for college students.

Current situation of usability engineering course

The usability engineering course is a project-oriented professional compulsory course. It is offered to undergraduate students majoring in digital media technology in various colleges and universities (Chunmeng et. al, 2022). This course is usually offered in junior year. It is precisely because of this that students lack innovative thinking. And they lack overall project practice experience. Even if they have a good idea, it is difficult to apply it to the actual project (Huang et al., 2022). Usability engineering requires students to master user-centered design and research methods and develop their teamwork skills (Lewis & Sauro, (2021). However, most of the current colleges and universities still use the teacher-centered teaching method. Moreover, during the course learning process, the professional knowledge and skills learned and used by students are still relatively single, and they cannot achieve diversified integration. The quality of the results of the students is low. At the same time, some students' learning engagement and learning motivation are low, and it is difficult for them to play a role in the team.

METHODOLOGY

Principles of course design

The "usability engineering" course involves user-centered research methodology and relevant knowledge of application practice. The richness and diversity of this knowledge determines that this course is suitable for integration with STEAM concepts. As a Project-Based Learning (PBL) course, it requires a high level of creative ability, which can improve students' innovative ability through the study of this course (Huang et al., 2022). Based on the STEAM education theory, we combined with the characteristics of the "usability engineering" course, and we have developed three course design principles: comprehensiveness, innovation, and feasibility. Then we classified the relevant knowledge and skills in this course into "science, technology, engineering, art, mathematics", and applied them in the teaching process and project practice process. The content of the "usability engineering" course includes two parts: theory and practice. The content analysis of STEAM in the practice part is shown in Figure 1.

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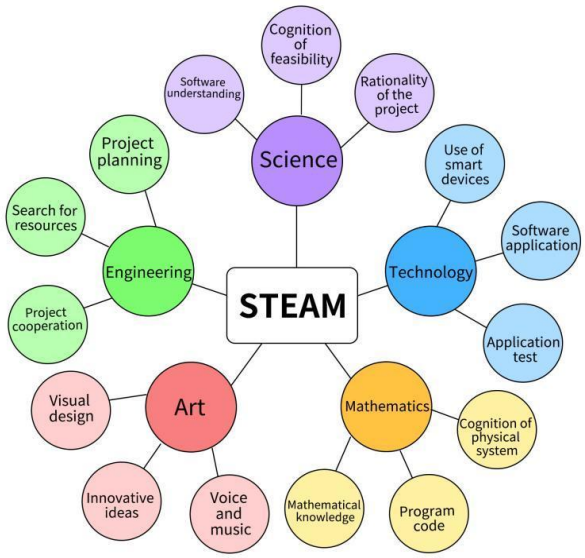

Figure 1: Analysis of STEAM content in the "usability engineering" course

Comprehensive principle

Realize the integration of STEAM education concept and "usability engineering" course. The study of individual subjects or the mastery of individual skills can no longer meet the needs of modern society for talents. Only interdisciplinary courses can allow students to understand the world from a comprehensive and comprehensive perspective and form a comprehensive cognitive level and problem-solving ability. Based on cultivating students' comprehensive ability to discover, analyze, and solve problems, curriculum design should pay attention to mobilizing students' interdisciplinary and interdisciplinary knowledge learning, which is also the content that STEAM education philosophy emphasizes (Kaan Bati et. al, (2018); Yin et. al., (2021)). The "usability engineering" course enables students to integrate professional theoretical knowledge, software development skills, programming language applications, project planning, and evaluation and reflection based on project iterations into comprehensive and innovative usability through project-based integrated learning. The project allows students to discover, analyze and solve problems from a comprehensive and systematic perspective, avoiding the knowledge fragmentation and thinking limitations caused by subject-based teaching in traditional teaching, and is more conducive to the formation of students' innovative ability (Huang, 2022).

Innovative principle

The curriculum makes full use of the characteristics of the STEAM education concept to develop students' innovative and creative thinking, thereby improving their creativity and project-based problem-solving ability. The principle of innovation is mainly reflected in topic selection, discussion, design, development, evaluation, improvement and so on. Teachers make suggestions based on students' learning situation, and students can choose several project topics they like according to their own interests and their own situation. Based on these selected topics, students

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can discuss in their own groups to finalize a project topic. In each subsequent project process, students need to maintain the principle of innovation. After the project is completed, the project team can iteratively optimize the works, and evaluate the works of other teams, to learn from each other and make progress together.

Feasibility principle

The entire implementation process of the usability engineering course needs to be combined with the Project-Based Learning method (PBL) to integrate the STEAM education concept into every link. This course is mainly to study a series of user-centered research methods (Tang & Yuan, 2010). The understanding, analysis and problem solving of users are the focus of the project. Based on this, the feasibility of the project must first be considered, that is, the implementation. At the early stage of choosing a theme, students should consider whether the whole theme is suitable for practical application and whether the results of the project can meet the needs of users. Including in the subsequent project process, the principle of feasibility should also be followed all the time.

Course design and construction based on STEAM education.

The target class of course design are 42 third-year undergraduates majoring in digital media technology from a university in Guangzhou, China. The course "usability engineering" is a compulsory course for their majors. Based on the content analysis of STEAM in the usability engineering course and the design principles of the course, the teaching mode of the course was designed and constructed. Students conceive, design, and develop projects through a "Project-Based Learning (PBL)" approach. The course design process was divided into four parts: teaching analysis, teaching principles, teaching implementation and teaching reflection. The specific design process of the course is shown in figure 2.

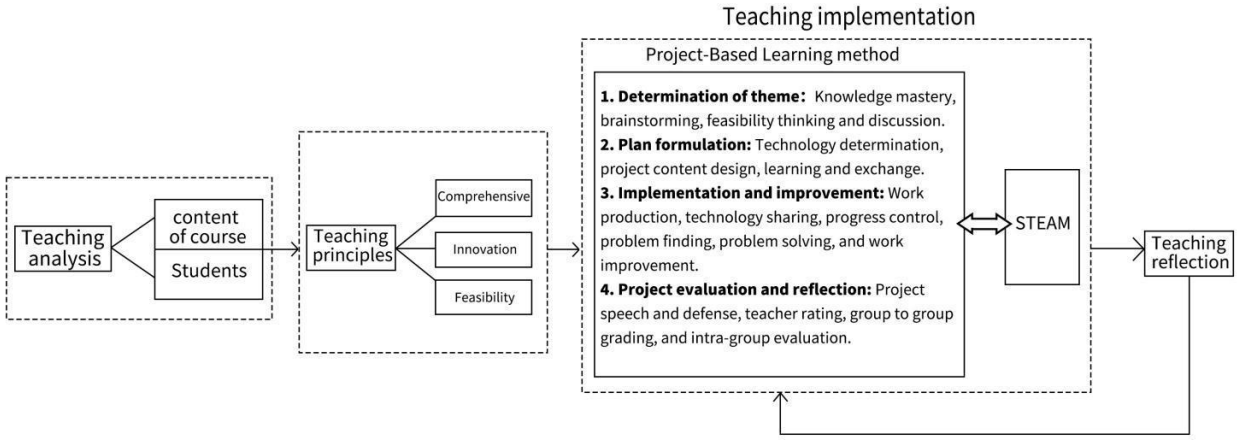

Figure 2: "Usability engineering" course design flow chart

Teaching analysis

The teaching analysis link is divided into two parts: course content analysis and student analysis. The textbook used in the usability engineering course is "Principles and Methods of Digital Media

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Interaction Design" published by People's Posts and Telecommunications Press. The content of the course includes explanation of theoretical knowledge, analysis of user experience, user research methods, interaction design process and practice. Teachers analyze these parts and formulate specific teaching plans suitable for students. Student analysis is divided into learning situation analysis, student individual and group analysis. Students are the main body of learning, and analyzing students is helpful to improve students' learning initiative and engagement. Students majoring in digital media technology are engineering students with no artistic foundation, and their innovation ability needs to be improved. Most students were more interested in the practice of the project, and they had a relatively shallow understanding of user analysis and research methods. These two parts need to be improved during the learning process of this course. In addition, this course adopted group project-based learning, and students could freely form teams according to their own abilities, but each team needed to learn from each other's strengths.

Project-centered course design

According to the constructivist learning theory and the connotation of STEAM education, the course of usability engineering mainly adopted the project-centered learning method, and the implementation of each round of projects was mainly divided into four steps: project theme determination, program formulation, project implementation and improvement, project evaluation and reflection. The concept of STEAM education was integrated into the entire course design process. The usability engineering course has a total of 48 class hours and lasts for 16 weeks.

The determination of the project theme is the key to embodying the concept of STEAM education. This session lasted for 2 weeks. In this study, we divided these 42 students into 6 groups according to their own interests and technologies they are good at, with 7 people in each group. All of them are undergraduate students with a certain knowledge base in science, technology, engineering, and mathematics. They like classes that are more practical, so project-centered learning activities are very attractive to them. The confirmation of the project theme should be centered on solving problems or projects, and it should be a semi-open theme that is conducive to stimulating students' innovative thinking. For example, based on the imperfection of the current large-scale smart garage system, it is difficult for car owners to find a suitable parking space and find their own car. Students can address this problem, research user needs, and design and develop a smart garage APP. For another example, to inherit a traditional culture that is on the verge of disappearing, it is digitally protected. Students can conduct in-depth research on this culture, and conduct research and analysis on the entire market and users, to digitally gamified the protection plan and make this culture into a game. In this link, students participated in learning activities in the form of groups. Students needed to search for information, brainstorm, discussed in groups, thought about feasibility, revised and improved the theme. And continued to cycle this process until the topic was finally determined. And defined and explain the project theme of your own group. The final game themes of these 6 groups are shown in table 1.

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Table 1
Game themes for 6 groups

Groups	Project theme
1	Design and Development of Large Intelligent Garage System
2	Self-driving car online app design
3	China Foshan Paper-cut Game App Design
4	Digital cultural creative product design based on Xiangchu culture
5	Harper's Bazaar Girls Diary Mobile Game Design
6	"Ninghuafu" brand visual image recognition system design

The formulation of the project plan needs to take the STEAM education concept as the starting point, and group cooperation as the main learning method exists in the entire project production process. This session lasted 2 weeks. Each team member should give full play to their own advantages to carry out the division and arrangement of project work. Coordinate different ideas and design styles among members. For example, in the project design process with the theme of "Network Booking System for Driverless Cars". Group members who are good at UI interface, team members who are good at interaction design, and team members who are good at user research and analysis can choose according to their own needs. Advantage to choose their own work content. After completing the development of the project proposal, we organized a public presentation defense activity for the entire class. Teachers gave guidance, advice and encouragement, and assisted students to finalize the project plan.

During the implementation and improvement of the project, students should integrate the STEAM concept into the project practice based on the best project scheme selected in the previous step. This link lasted for 10 weeks. For example, in the design of the "Ninghuafu" brand visual image recognition system, students need to first conduct market research on the brand of Ninghuafu and master some data. Then analyze the original products and find out the problems of Ninghuafu brand. After the solution is formulated, the visual design team first draws the new visual image sketch by hand, and then uses the design software and tools to make the logo and IP. Finally, the team members in charge of technology complete the final work through engineering, technology, and other means. Continuously improve in the process of practice to get the best work results. The implementation and improvement process of the project takes a long time, and STEAM concept is integrated into the whole process. Figure 3 shows some screenshots of the work of six groups.

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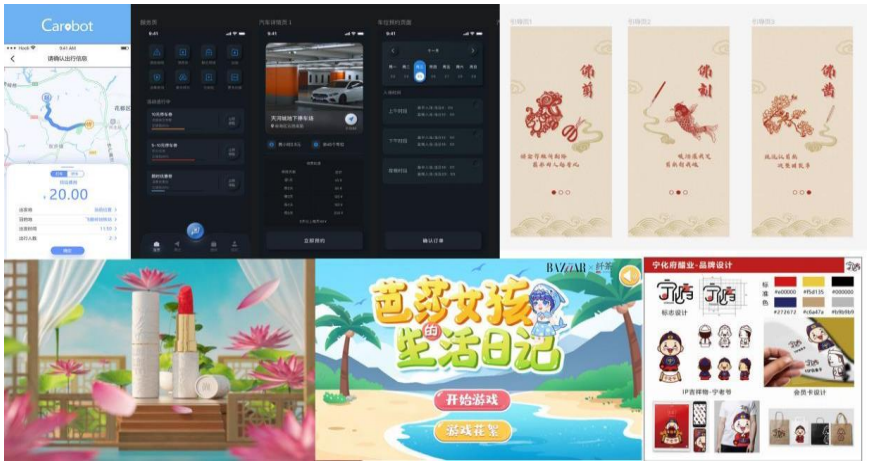

Figure 3: Some parts of screenshots in the work of six groups

Project evaluation and reflection were carried out after the project work was completed. This session lasted for 2 weeks. As we all know, in the project-centered course teaching mode, in addition to the project implementation process, the reflection process after the project is also important. First, evaluate the project. The class once again had a public presentation and defense. According to the order, the students of 6 groups have presented and defended in turn in groups. During this process, students from other groups could score them, and teachers scored and summarized their slides, works, and answering questions. After the defense, scores would be made among the members of each group. Final project reflection. After listening to the teacher's evaluation and feedback, and watching the presentations and defenses of other groups, the students discussed, reflected, and discussed their own project results. For example, whether the group cooperation and division of labor is reasonable, whether the project process control is reasonable, whether the project problem is solved properly, and whether students actively participate in the production process of the work, etc., conduct round-table discussions and reflections. This has played a positive role in promoting the project-centered teaching model.

Reflection on teaching

According to the constructivist learning theory and the connotation of STEAM education, the course of usability engineering mainly adopted the project-centered learning method, and the implementation of each round of projects was mainly divided into four steps: project theme determination, program formulation, project implementation and improvement, project evaluation and reflection. The concept of STEAM education was integrated into the entire course design process. The usability engineering course has a total of 48 class hours and lasts for 16 weeks.

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FINDINGS

After conducting a questionnaire survey and interviews with students, we came to the following conclusions: First, the works of these 6 groups participated in the 2022 China College Students Digital Media Works Competition, and won a gold award, a silver award, and two bronze awards. Second, through the online questionnaire, figure 4 shows the proportion of students using each module of STEAM during the project. We can see that the "usability engineering" course has basically realized the integration with the concept of STEAM, in which technology and art account for a large proportion (35%, 30%). This shows that most students believe that the application of art and technology has a greater role in completing the project. The other three modules are relatively few and average in proportion. During the project, the PBL method has largely stimulated students' enthusiasm and interest in learning and improved their classroom participation. From figure 5, we can see that 30 students are satisfied, and 6 student is very satisfied with their final works. There are 5 students who think that their learning results are general, and 1 student is not satisfied. No very dissatisfied.

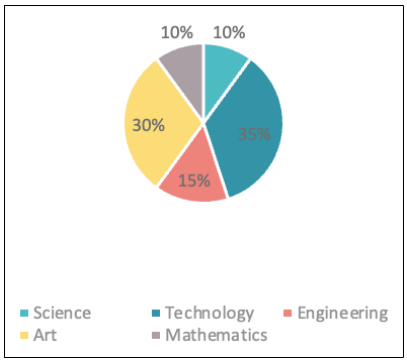

Figure 4: Proportion of students using each module of STEAM

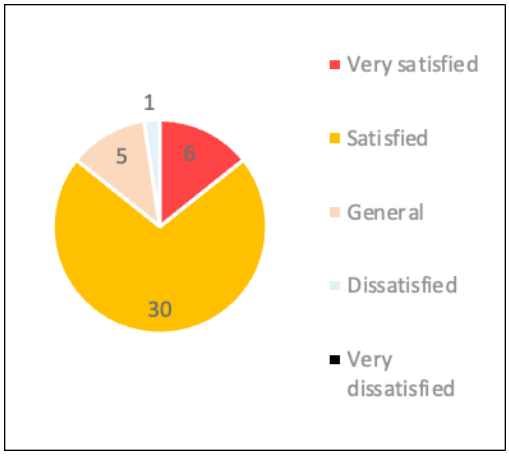

Figure 5: Student satisfaction with their final works

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In table 2, we can see the suggestions of these 10 students (simplified). Most students began to pay attention to the improvement of comprehensive ability. One student oversaw visual design because he was the only one in his group, and the workload of this part was huge, which made her unable to do what she wanted. Some students also pointed out their lack of innovation, creativity, and art, indicating that students majoring in digital media technology need to strengthen their art. Some students think that they have improved their ability to communicate with others, and they are willing to learn more knowledge and enhance their comprehensive ability. A classmate pointed out that the laziness of a small number of students in the team caused the hard work of other team members. This shows that the project-based learning method based on STEAM education is conducive to the improvement of students' communication and comprehensive ability. At the same time, there are also some problems. For example, the learning engagement of individual students has decreased in the group, which may be related to their personal ability and learning attitude, and unbalanced workload distribution.

Table 2
Interview suggestions from 10 students

Student's serial number	Summary of students' suggestions
1	The student said that he liked this course very much, because he learned a lot of knowledge in various fields, and it was very happy and lively for everyone to do homework together. He hopes to improve his comprehensive ability in the future.
2	This student believed that cooperation in the group requires certain communication skills, and the overall control is the part that he needs to improve and work hard on.
3	This student believed that the aesthetic feeling of the work is very important. She was the only one in the group who is responsible for the visual design. The workload of this part is huge, which made her tired.
4	This student was very confident in his innovative and creative ability but lacked in technology. He hoped to strengthen the application of software.
5	This student was relatively introverted. He believed that this course had given him the opportunity to develop his abilities and express thoughts. He was very happy.
6	This student's software application ability is very good. She couldn't accurately judge whether the visual design of the work can attract users. She hoped to supplement her art knowledge in the future.
7	This student is very interested in engineering. After graduation, he wanted to work in an engineering company. After this course, his comprehensive ability has been improved to a certain extent.

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Student's serial number	Summary of students' suggestions
1	The student said that he liked this course very much, because he learned a lot of knowledge in various fields, and it was very happy and lively for everyone to do homework together. He hopes to improve his comprehensive ability in the future.
8	This student's hand-drawing ability and innovative thinking are very good. Through the design of this project, his technical and engineering capabilities had improved to a certain extent.
9	This student had a good foundation in mathematics and is good at writing code. He hoped he has good logical thinking, but he often could not come up with good ideas. Through this opportunity, he learned a lot of creative ways of thinking from other students.
10	This student pointed out that a small number of students in the group were relatively lazy, which resulted in less workload for some students. She thought the selection of team members was somewhat difficult. However, in this project, she learned a lot.

DISCUSSION

From the above-mentioned course implementation effect of combining the STEAM concept with the usability engineering course, it is completely feasible to use the STEAM concept in relevant technical courses for undergraduates majoring in digital media technology. Although the combination of STEAM concept and curriculum will face many uncontrollable factors and difficulties, it still has the value of in-depth research. The STEAM education concept has a huge role in promoting the cultivation of students' teamwork ability, innovation ability and comprehensive ability. It is believed that in future educational research, the usability engineering course based on the STEAM education concept will develop in a better direction, and students will benefit a lot from this process.

CONCLUSION & RECOMMENDATIONS

According to the above study, it is feasible and has certain advantages to design and construct usability engineering course based on the STEAM concept. It is especially helpful for improving the comprehensive ability, innovation ability and teamwork ability of college students. However, because the sampling sample of this research is only 42 students majoring in digital media technology, and it only lasted for four months, it has some limitations. In the future, relevant research can consider more scientific sampling, and should consider extending the research duration, which is conducive to observation and collection of more and more detailed information.

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Conflict of Interest

No conflict of interest to disclose.

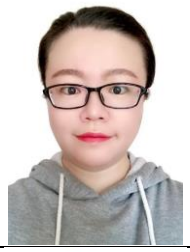
Acknowledgement

We thank teachers and students who have made valuable contributions to this study.

Authors' Contributions

This study confirmed the feasibility of STEAM education applied to curriculum design in colleges. Especially for Project-Based Learning course, it is helpful to improve students' comprehensive ability, to produce high-quality, innovative, and feasible works. In the results of this study, students have gained a lot in teamwork. However, there are also problems about the uneven distribution of work among group members and the difficulty in controlling the progress. For these problems, we hope that in future follow-up research, we can explore and solve them by perfecting and improving the details of course design.

About the Authors

	Xi Cailian, PhD student, Centre for Instructional Technology and Multimedia, Universiti Sains Malaysia. Her research interest lies in digital media art, instructional multimedia, educational game design and development.
	Prof. Dr. Wan Ahmad Jaafar Wan Yahaya, Professor & Director, Centre for Instructional Technology and Multimedia, Universiti Sains Malaysia. His research interest lies in instructional multimedia, persuasive technology, multimedia in education and ICT in education.

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