Development of a VR STEAM Welding Project Course

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Abstract. This research aimed to develop the teaching mode, ability indicators, and course content of a "VR STEAM Welding Course" for the Engineering Department of Universities of Science and Technology. The students of the Electric Welding Course in Universities of Science and Technology were taken as the subjects for the integration of the STEAM education concept, in order to integrate the VR technology into the teaching of the welding course. The Fuzzy Delphi Method was adopted as the research method, and an expert questionnaire analysis was conducted. The conclusions are summarized as follows: (1) a three-part, "student-centered" teaching mode was developed, which included welding knowledge and skills training, STEAM integrated learning, and the practical application of VR; (2) Eight ability indicators of the "VR STEAM welding course" were established; (3) the "welding construction" ability indicator for VR-assisted welding teaching was the most feasible; (4) the ability indicator of "welding construction" for STEAM education had the highest integrality into welding teaching; and (5) the mobile learning platform of the VR STEAM welding course had high real-time characteristics. The findings can serve as a reference for the subsequent content design, teaching activity planning and the implementation of the experimental teaching of this course.

Keywords: VR · STEAM · Welding · Education reform · Welding project course

1 Introduction

The rapid development of science and technology has brought about all kinds of conveniences that people can enjoy. The digitalization of science and technology knowledge makes it more convenient for people to accumulate, share, analyze, and apply it, and it also expands the horizons of mankind and enables people to grasp knowledge and information more accurately and predict the future [1]. A talent for

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innovation and invention, as well as a breakthrough and advancement in knowledge, will also be required for technological advancement, especially in the 21st century. Therefore, Virtual Reality (VR) is often used in operational learning activities; it allows learners to repeatedly operate the technology, there-by overcoming the limited operation times of such skills [2, 3]. VR can also present a real situation that is very similar to the actual situation, so it can effectively improve the motivation to learn and the effectiveness of learning [4, 5].

However, according to a statistical survey of the U.S. Federal Department of Education, most of the talent required for innovation and invention in the next 10 years will be related to the fields of Science, Technology, Engineering and Mathematics (STEM) [6]. In recent years, elements of Art (art and design thinking) have been integrated into STEM education, which aim to promote the students' problem-solving, critical thinking and innovative abilities. Engineering or design methods that are based on Mathematics and Science can be used to solve real-world problems, to restructure art education into an inquiry-based and discovery-oriented discipline, and to encourage creative problem-solving. This has become a new interdisciplinary STEAM course [7]. The integration of art encourages students to take risks, to tolerate different opinions, and it attracts more young people to invest in the fields of Science, Technology, Engineering and Mathematics. It can be seen that the educational orientation of STEAM contributes to the development and learning of an integrated curriculum in Engineering education [8].

Furthermore, the most basic course in Engineering education is the Factory Internship course. The main content of the course includes the training of students in correct and safe working habits, as well as in the knowledge and skills related to machine manufacturing, such as fitting, electric welding, lathing, mill machining, and so on. In the above-mentioned machine-operated skills, the training of electric welding skills is a primary and indispensable processing method in modern industry. Students can be also coached to pass the Technician's Certification examination that is organized by the Labor Development Agency for welders, cold work, general manual electric welding, electric welding, semi-automatic electric welding, argon gas tungsten electrodes, etc. [9, 10]. At present, the professional skills of the welding personnel in industry are considered for recruitment. Although there are currently robotic arms that can support electric welding, their accuracy is still not as good as that of professional masters. Welders need eye-hand coordination, and there are a wide range of employment opportunities for those with this skill [11, 12]. Coupled with the current government policies of promoting offshore wind power and national shipbuilding, the demand for welding manpower is still rising, which shows the necessity and importance of improving the effectiveness of welding courses in this plan.

In view of this, in order to verify the effectiveness of the learning model, this study planned to develop STEAM integrated welding courses and to teach design, and it also emphasize the application of emerging technology and virtual technology to courses and teaching [13], in order to construct the "VR STEAM welding course" curriculum and ability indicators for future Universities of Science and Technology to carry out practical applications and research. It is hoped that it will enable the students of Universities of Science and Technology to get early exposure to the application of VR technology and to opportunities for practical exercises and innovative ideas.

2 Research Design

This research was mainly divided into two parts, namely, the construction of ability indicators, and the development of courses. Firstly, through a literature analysis and research team meetings, the ability indicator framework of the "VR STEAM welding course" was developed to prepare the "VR STEAM" expert questionnaires related to welding courses. In addition, experts and members in related fields, such as VR applications, STEAM education, welding, and other related fields, were invited to participate, provide consultation, and implement the Fuzzy Delphi Method (FDM) expert questionnaire survey and analysis, as well as to complete the construction of ability indicators, which were used as the basis for curriculum development. For curriculum development, the expert focus group interview method was used to collect and gather opinions from all parties, and the literature analysis and research team meeting results were used as the reference basis for this.

This study used the FDM to construct curriculum ability indicators. By combining the Delphi method and the Fuzzy theory, the FDM makes use of triangular fuzzy numbers that can improve the shortcomings of the traditional Delphi method and also solve the limitations and ambiguity of human nature, and it is also an effective method for constructing indicators [14, 15]. Therefore, this study invited 15 experts to conduct an FDM expert questionnaire survey, in order to gather expert opinions. Then, ability indicators were constructed, and curriculum models, teaching strategies, teaching activities and a reference basis for the mobile learning platform were developed.

3 Results and Discussion

According to the purpose of this research and the literature review, the teaching mode, course content, ability indicators, teaching strategies, mobile learning platform, etc. of the "VR STEAM Welding Course" for the Engineering students of the Universities of Science and Technology are described as follows:

3.1 Developing the Teaching Mode of the "VR STEAM Welding Course" for the Engineering Students at Universities of Science and Technology

The teaching mode of the "VR STEAM Welding Course" in this study is mainly "student-centered", as shown in Fig. 1. Curriculum planning, which incorporates Problem-based Learning, includes three parts, namely, welding knowledge and skills training, STEAM integrated learning, and VR Practical application. In the student learning process, teachers can use virtual welding equipment, a digital learning platform and welding factory classrooms and other diversified environments and equipment to assist in their teaching, all of which emphasize the "learning-by-doing" mode. This allows students to carry out the inquiry-based learning of STEAM welding knowledge and skills in an appropriate way, to make a critical analysis of the data obtained by various media, and then to construct their own knowledge, to carry out meaningful learning, and to enhance their teamwork and problem-solving abilities. The

main role the teacher is to assist, and a real and virtual hybrid method is used to become an innovative teaching mode of the VR STEAM welding course. In the follow-up, the research results will be evaluated to verify the effectiveness of the student's learning and the completeness and applicability of the curriculum design.

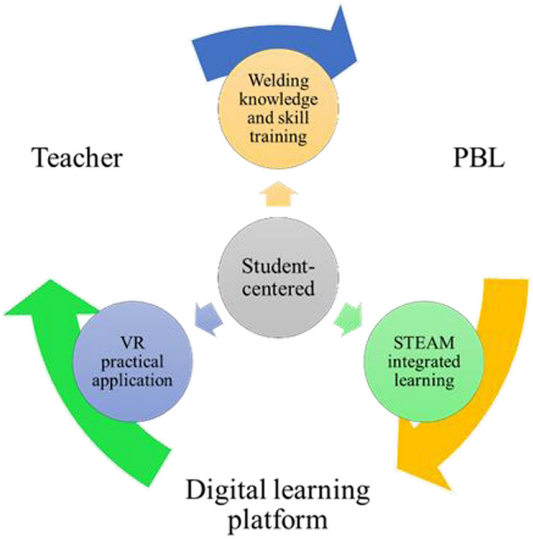

Fig. 1. Teaching mode.

3.2 Developing the Course Content of the "VR STEAM Welding Course" for the Engineering Students at Universities of Science and Technology

The course content of this "VR STEAM Welding Course" plans to apply VR technology mainly to the welding practice course, and it includes three major features, namely, Immersion, Interaction and Imagination. This course uses the VR Welding Simulator device to implement VR welding teaching. It enables students to enjoy pre-learning in a high-safety, low-cost environment, while interacting with VR welding scenes and interface devices, it provides a sense of presence, fun, immersive effect, exploration, maneuverability, dynamic interaction and real-time visual feedback, and it is a student-centered learning mode. While learning the skills of electric welding, students can also understand the development and application status of VR technology, so as to improve their scientific and technological literacy.

Fifteen experts and scholars were invited to give subjective scores on the "feasibility of the teaching of VR technology-assisted electric welding ability indicators", based on the current situation of electric welding knowledge and VR technology teaching applications, so as to obtain their evaluation of each question. The FDM expert questionnaire analysis results from 11 valid questionnaires (with the effective questionnaire recovery rate of 73%), are shown in Fig. 2. The teaching feasibility of

VR technology-assisted general manual welding scored between 0.635 points and 0.750 points. The item with the highest feasibility score was "welding construction", with a score of 0.750, followed by "drawing reading and drawing", with a score of 0.710, "test material processing and combination", with a score of 0.694, "welding inspection", with a score of 0.690, "operation preparation", with a score of 0.687, "industrial safety and hygiene", with a score of 0.677, "welding bead cleaning", with a score of 0.640, and "professional ethics of electric welders", with a score of 0.635.

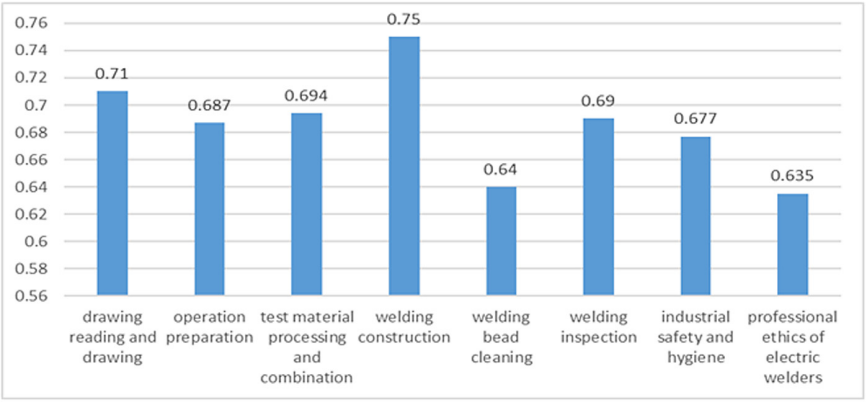

Fig. 2. Histogram of the feasibility of ability indicators of three major characteristics of VR auxiliary welding teaching.

3.3 Developing the Teaching Strategy of the "VR STEAM Welding Course" for the Engineering Students at Universities of Science and Technology

The teaching strategy of the "VR STEAM Welding Course" plans to integrate STEAM education mainly into the welding course, so that students can develop integrated thinking in Science, Technology, Engineering, Art, Mathematics, as well as other disciplines. Furthermore, the plan to replace the traditional welding course with VR welding courses and mobile learning platforms is to guide students to learn and provide them with diversified learning channels.

Fifteen experts and scholars were invited to give a subjective score of the "Integrality of STEAM Education and Welding Ability Indicators", based on the current status of the teaching application of welding knowledge and STEAM integrated thinking education, in order to obtain the evaluation value of experts and scholars for each question. The results of the FDM expert questionnaire survey on 11 valid questionnaires (with an effective questionnaire recovery rate of 73%) are shown in Fig. 3. The integrality scores of the STEAM education and welding ability indicators were between 0.633 and 0.736 points. The item with the highest integration score was "welding construction", with a score of 0.736, followed by "welding inspection", with a score of 0.715, "drawing reading and drawing", with a score of 0.708, "test material processing and combination", with a score of 0.692, "industrial safety and hygiene",

with a score of 0.686, "operation preparation", with a score of 0.665, "welding bead removal", with a score of 0.664, and "the professional ethics of electric welders", with a score of 0.633.

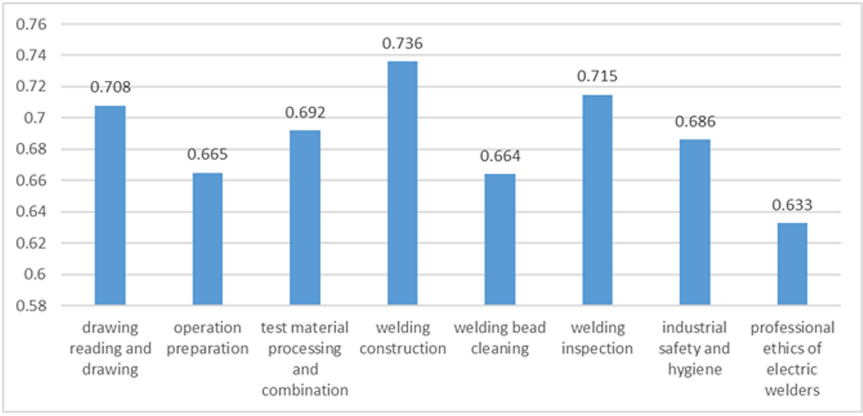

Fig. 3. Histogram of integrality of STEAM education and welding ability indicators.

3.4 Constructing a Mobile Learning Platform for the "VR STEAM Welding Course" for the Engineering Students at Universities of Science and Technology

In this study of the "VR STEAM Welding Course", the mobile learning platform, called the "Line Virtual Classroom", was built. Students were encouraged to join the "Line Virtual Classroom" course group, which provided them with a diverse learning environment, with a high real-time performance and no time-and-space constraints. At present, the most commonly-used communication software in Taiwan is the Line application [16]. The mobile learning platform of this course was built on the Line system because many teachers use Line social media to assist them in their teaching. The Line's group chat-room, notepad, photo album, reply, announcement, vote, and other functions, were used to build a "Line virtual classroom", as shown in Fig. 4. After students join this course, teachers can set learning assignments in the virtual classroom, according to the curriculum design, they can encourage students to explore, or have flipped teaching and other learning activities. It also allows students to hand in homework, they learn to give back and they can share their learned work.

1. **Notepad:** links to the textbooks of each unit, assignment announcement and submission, topic discussion.
2. Photo album: pictures of each unit course and submission of students' actual works.
3. File: sharing of each unit's extended learning files.
4. Other functions: voting, picking days, climbing ladders, etc. to be used by group students.
5. Chat room: teacher-student interaction, consulting service.

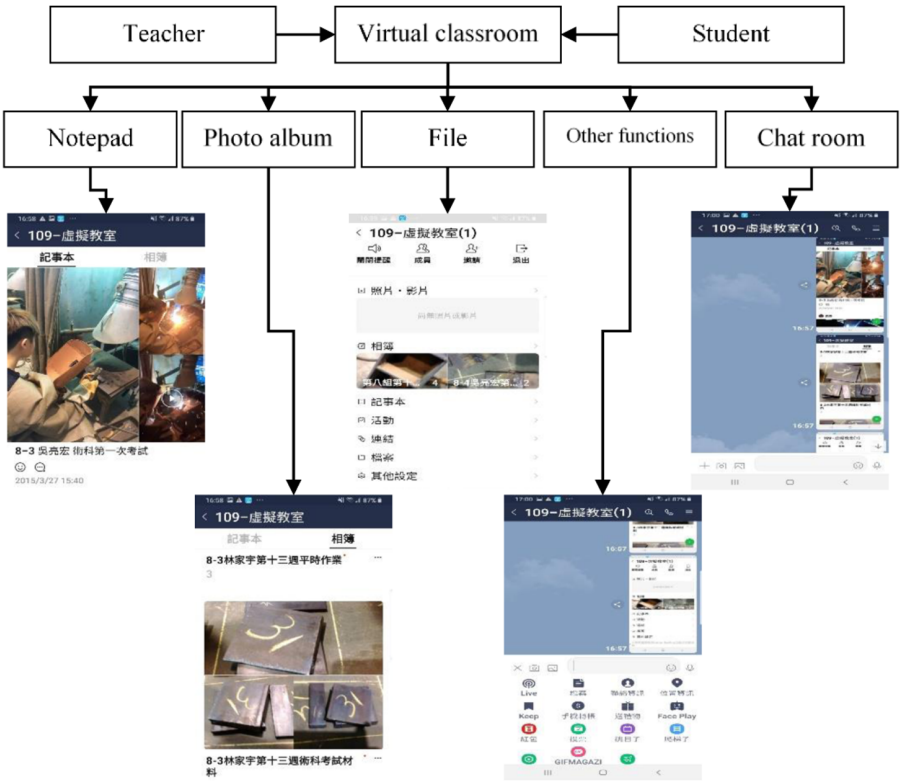

Fig. 4. VR STEAM welding course mobile learning platform.

4 Conclusion and Suggestions

This study aimed to integrate STEAM education into welding courses, and to apply VR technology and a mobile learning platform to assist in the teaching of welding. According to the analysis results of expert questionnaires, the conclusions are summarized as follows:

4.1 The "VR STEAM Welding Course" Develops a Student-Centered Teaching Mode

This "VR STEAM Electric Welding Course" is a student-centered teaching model. The key points of the course must include three parts: welding knowledge and skills training, STEAM integrated learning, and a practical VR application. The course planning was carried out from two directions, namely students' perspective and teachers' assistance. The problem-oriented learning and teaching strategies were used to guide students to learn electric welding knowledge and skills, to gain STEAM integrated knowledge, as well as related knowledge and skills that are related to the VR practical application.

4.2 The Item "Welding Construction" Had the Highest Feasibility in the Teaching of the VR Technology-Assisted Electric Welding Course Content

The course content of this "VR STEAM Welding Course" was determined by an FDM analysis. In terms of the feasibility of using VR technology to assist the teaching of the electric welding course content, the item with the highest score was "welding construction", followed by "drawing reading and drawing", "test material processing and combination", "welding inspection", "operation preparation", "industrial safety and hygiene", "welding bead removal", and "professional ethics of electric welders". In this way, the students were guided to learn welding-related knowledge and skills through the application of VR technology in the course planning and auxiliary course teaching.

4.3 The Item "Welding Construction" Had the Highest Integrality in the Teaching Strategy that Adopted and Integrated STEAM Education into the Welding Course

This research design integrated STEAM education thinking into the teaching activities of the welding courses. After an FDM expert questionnaire survey and analysis, in terms of the integration of this "VR STEAM Welding Course" and STEAM education, the item with the highest score was "welding construction", followed by "welding inspection", "drawing reading and drawing", "test material processing and combination", "industrial safety and hygiene", "operation preparation", "welding bead cleaning", and "the professional ethics of electric welders". These were used to develop a teaching strategy for students to learn welding courses with STEAM integrated thinking and to deepen the value of the students' STEAM learning and application.

4.4 The Mobile Learning Platform of the VR STEAM Welding Course Had High Real-Time Characteristics

The mobile learning platform of this course is based on the Line application, which is the most commonly-used communication software in Taiwan. It uses the Line group chat room, notepad, photo album, reply, announcement, vote, and other functions to build a "Line Virtual Classroom", it provides students with a diversified learning environment that is not limited by time and space, and it is highly real-time. It also provides a consultative and interactive communication platform between teachers and students, as well as between students and students.

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