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Development of Interactive Textbooks by Applying STEAM and Virtual Reality Concepts*

CHIH-CHAO CHUNG
General Research Service Center, National Pingtung University of Science and Technology, 1, Shuefu Road, Neipu, Pingtung 91201, Taiwan. E-mail: ccchung@g4e.npust.edu.tw

BO-YUAN CHENG
General Research Service Center, National Pingtung University of Science and Technology, 1, Shuefu Road, Neipu, Pingtung 91201, Taiwan. E-mail: oakley.cheng@mail.npust.edu.tw

YUH-MING CHENG
Department of Computer Science and Information Engineering, Shu-Te University, Kaohsiung 82445, Taiwan.
E-mail: cymer@stu.edu.tw

SHI-JER LOU**
Graduate Institute of Technological and Vocational Education, National Pingtung University of Science and Technology, 1, Shuefu Road, Neipu, Pingtung 91201, Taiwan. E-mail: 9915916@gmail.com

This research aims to explore the impact of STEAM on VR-based interdisciplinary courses and the course satisfaction of students from a sci-tech university. To achieve the goal, this study took students taking interdisciplinary courses at a sci-tech university in south Taiwan as the research subject and carried out an 18-week "STEAM course about the development of VR-based textbooks" through small-group cooperative learning. To investigate the impact of the STEAM course and the course satisfaction of students, this study adopted both quantitative analysis and qualitative analysis, such as questionnaire analysis and file analysis, to evaluate students' performances on the products and grades. This study creatively combined the interdisciplinary and convergent thinking of STEAM with the course about the development of VR-based textbooks. Based on the student-centered and teacher-facilitated concepts, this study designed the STEAM course about the development of VR-based textbooks and found that most students think highly of the impact of STEAM, course satisfaction, and the assistance of VR-based textbooks to STEAM. Lastly, this study proposed some practical advice on how to combine STEAM with VR-based course teaching.

Keywords: STEAM; human-computer interactive; textbooks; virtual reality; education reform

1. Introduction

The rapid advancement of science and technology is bringing great convenience to people's life. In this era of innovations and intellectual breakthroughs, interdisciplinary talents in science, technology, and engineering are in great demand. As integrated education, which combines science, technology, and engineering with mathematics, is highly valued in the United States, STEAM education is now at the core of the knowledge integration of each discipline and leads the world trend in education [1, 2]. STEAM education is a set of interdisciplinary and integrated courses that incorporates artistic thinking and design thinking into science, technology, engineering, and mathematics [3]. It provides important guidance on developing interdisciplinary talents with convergent thinking [4]. Hence, promoting and developing STEAM education greatly help at developing scientific and technological talents and ensuring competitiveness in the global economy.

A STEAM course places emphasis on integration among disciplines and connection with life experiences. Designed through systematic topics, this course starts from students' life experiences, connects with daily issues, and makes uses of available resources to present the overall knowledge structure [5]. A STEAM course also stresses the integration of knowledge from science, technology, engineering, art, mathematics, life, and education. Under the guidance of the student-centered concept, STEAM focuses on cultivating students' ability to solve problems in daily life through learning by doing. During the process, students can acquire complete knowledge, improve abilities, and develop good attitudes [2, 6]. Considering the above-mentioned advantages, many experts encourage learners to study through their own technological equipment, which can create a friendly learning environment [7].

Since 2016, virtual reality (VR) technology, has been widely used in many fields. VR is a technology that simulates vision, hearing, and feeling in the real world. Its visualization especially conforms to human beings' instinct of visual exploration. VR

** Corresponding author.

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connects learners with the applied environment and enriches their experience through images [8]. The application of VR to education is booming due to its impact on improving learning motivation [9]. VR features immersion, interaction, and imagination, thus providing learners with multi-sensory stimulation and immersive simulated situations. In this way, learners can independently construct knowledge through situational learning amid a simulated learning environment before becoming experts [10].

This study therefore developed a STEAM course about the development of VR-based textbooks (hereinafter referred to as STEAM-VR textbook course) based on STEAM convergent thinking. Through experimental teaching, this study guides students to design and produce creative VR textbooks according to their respective specialized courses. By doing so, students can master VR technology and develop the ability to integrate interdisciplinary STEAM knowledge and to solve problems. This study aims to:

(1) develop the STEAM-VR textbook course;
(2) explore the course satisfaction of students from a sci-tech university;
(3) discuss the impact of the STEAM-VR textbook course on the study of students from a sci-tech university.

2. Literature Review

This research aims to develop the STEAM-VR textbook course and to explore the course satisfaction of students from a sci-tech university. Further discussions are listed as follows.

2.1 The Implication of STEAM

STEAM education, which is based on mathematics and science, is exploratory and discovery-oriented. It aims to help students solve problems in real life with methods from engineering and art. STEAM education also aims to develop students' ability at critical thinking, creative thinking, problem-solving, and innovation through solving problems creatively [11]. Buquette and Bequette [12] found that the interdisciplinary situation in STEAM lifts students out of the familiar and ordinary learning environment and into an open, exploratory, or even disharmonious situation, aiming to probe complicated social issues and to form a holistic and authentic opinion. Moreover, STEAM is a kind of integrated teaching that knits together scientific and technological exploration, science and technology, engineering design, artistic creation, and mathematical analysis [3]. With a mixed-use of learning strategies such as cooperative learning, exploration-driven teaching, educational technology, and diversified evaluation skills, STEAM education helps students solve problems in real life so as to develop their ability at exploration, thinking, analysis, innovation, and learning. In this way, students can integrate and make flexible use of scientific, technological, engineering, and mathematical knowledge [4, 13].

Student-centered STEAM, which is based on constructivism, encourages students to think creatively and critically in traditional courses. STEAM provides a platform to students for their reflection, expression, and discussion about creativity. When students think of a subject from different perspectives, they are developing the abilities of creativity, deep consideration, and reflection, which will endow them with more skills [11].

2.2 The Connotation of VR

Having already been applied to medicine, education, training, and industry, VR is able to construct a real world through visualized objects with the help of computers [10]. There are three features of VR to help a user be immersed in the virtual environment with the first perspective [14]:

(1) Immersion: Make the user immersed in the virtual environment and provide a sense of presence by using some equipment.
(2) Interaction: The virtual environment must be interactive. Taking inertia in our daily life as an example, a door will open after being pushed, and a ball will bounce back once knocked into the wall.
(3) Imagination: VR creates an imaginary world. Though simulating the real world, VR allows it to be filled with more imagination.

To summarize, guided by the integrative knowledge education of interdisciplinary STEAM, this research develops the STEAM-VR textbook course through immersive, interactive, and imaginary VR. This study expects learners to cooperatively experience and explore the simulated learning environment and provides them with an authentic sensory experience [8] as well as an immersive experience [9, 15]. In this way, students who are inspired by creative imagination and aesthetic feeling will take action to design the VR textbooks.

2.3 Research about the Integration of STEAM into the Connotation of a VR Course

As shown in Table 1, this study referred to Bartholomew [16]; Chung, Lin, & Lou [5]; Chung, Tung, & Lou [17]; Huang, Lou, Cheng, & Chung [10]; Johnson, Adams Becker, Estrada, & Martín [7]; Lin, Yu, Sun, & Jong [9]; Olshannikova, Ometov, Koucheryavy, & Olsson [8]; Unfried, Faber, Stanhope, & Wiebe [18]; Zhao, LaFemina, Carr, Sajjadi, Wallgrün, & Klippel [15]; Pellas, Dengel, & Christopoulos [19]; Yeung [20] for a discussion on the integration of STEAM into the principle of VR and its technology. Specifically, STEAM education guides students to integrate the science and technology of VR as well as scientific and technological exploration with mathematical calculation to creatively solve problems through engineering design. In this way, students can design innovative VR textbooks, further developing the abilities of critical thinking, systemic thinking, creative thinking, imagination, and VR operation. Moreover, students can refer to the teaching architecture that combines STEAM with VR to focus on applying the creative design of VR textbooks.

Furthermore, the research results show that in most cases, VR application positively impacts learning in different fields. This finding may be explained in that VR provides an immersive, interactive, and imaginary virtual environment that makes learners feel as if they are personally on the scene and understand abstract theoretical knowledge, such as medicine, science, and art [8, 9, 15, 20]. In addition, VR can provide a safe, cost-effective, and repeatable way of learning – for example, in engineering, technology, and welding operations. VR can also help beginners familiarize themselves with the process of skills they are trained for [10, 17]. Therefore, this study attempts to apply VR technology to students' interdisciplinary, integrated learning in STEAM.

To sum up, the interdisciplinary STEAM education, which provides artistic situations, endows students with divergent thinking and convergent thinking. The teaching method of the STEAM-VR textbook course is to integrate the courses of science, technology, engineering, art, and mathematics and to design VR textbooks [19]. By doing so, students can integrate and use both VR knowledge and technology. Based on the student-centered concept, teachers can develop students' ability to learn actively, break disciplinary boundaries, and make use of interdisciplinary integration ability in STEAM so as to increase students' learning willingness, develop their problem-solving ability, and activate the learning process.

3. Research Methods and Implementation

This study develops the STEAM-VR textbook course to explore the course satisfaction of students from a sci-tech university and to probe into the impact of STEAM on their study. Research design and implementation are described as follows.

3.1 Research Framework

As Fig. 1 shows, this study integrates STEAM education into a VR-based course, adopts small-group cooperative learning, plans 18-week experimental teaching of the STEAM-VR textbook course, observes students' learning process, collects data, and analyzes data quantitatively and qualitatively. By doing so, this study discusses the course satisfaction of students and the impact of STEAM on the study before modifying the STEAM-VR textbook course.

3.2 Research Subjects

The research subjects were 36 students who have been involved in VR-based interdisciplinary courses at a sci-tech university in south Taiwan. Covering 36 departments and different grades, these students were randomly divided into groups with three to four students in each group to adopt small-group cooperative learning. Based on this, this study planned the STEAM-VR textbook course and carried out 18-week experimental teaching.

3.3 Research Method

This study adopted both quantitative analysis and qualitative analysis. By collecting quantitative and qualitative data during the teaching process, this

Table 1. The connotation of integrating STEAM into a VR course

Aspects	Connotation
Scientific aspect of VR	Unity simulates various physical properties such as physics, light and shadow changes, material properties, gravitational acceleration, friction, elastic force, gravity, light and shadow, reflection, refraction, and transparency, enabling students to learn and apply simulated physics.
Technological aspect of VR	This course introduces various emerging equipment of science and technology such as smartphones, VR handsets, somatosensory cameras, and Cardboard, enabling students to operate and apply emerging technology.
Engineering aspect of VR	This course inspires students to design a 3D scene, select material, and make a program about interaction so as to cultivate students' ability to develop projects.
Artistic aspect of VR	During the design of the VR textbook, the material, 3D model, 3D scene, UI interface, and particle effects can provide an aesthetic experience to students and help develop their visual beauty.
Mathematical aspect of VR	During VR development, the animation editor can provide a time axis and adjust such parameters as vector, matrix, quaternion, distance, direction, random number, and probability to develop students' ability of logical thinking.

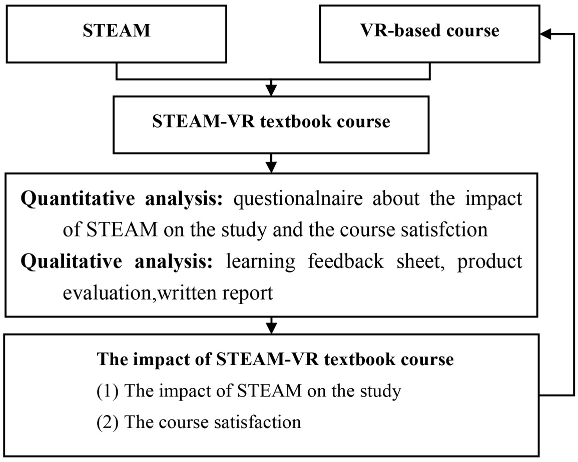

Fig. 1. Research process.

study conducted comprehensive analysis and discussion to explore the impact of STEAM on the STEAM-VR textbook course and the course satisfaction of students. Data in this study were collected mainly through observations, file analysis, and questionnaire. They are explained as follows.

3.3.1 Observations

As a preliminary investigation on integrating interdisciplinary and convergent thinking of STEAM into a VR-based course, this study gave priority to observations. Driven by the research purpose, the researcher observed the students purposefully and systematically amid natural or controlled circumstance before taking notes. This study carried out experimental teaching according to the requirements in the syllabus and observed the research subjects purposefully and systematically with an aim to understand the overall learning process of the STEAM-VR textbook course and the feedback of learning. After taking this as a reference, the course can thus be further improved.

3.3.2 File Analysis

This study carried out the experimental teaching of the STEAM-VR textbook course, where the researcher observed the teaching process and collected learning materials and learning feedback sheets. Hence, file analysis was used to draw a conclusion through file collection and analysis. Moreover, this study analyzed the VR-based textbook in each group and evaluated the creativity of the products, the mastering of STEAM knowledge, and the application of VR technology before comparing with the results from quantitative analysis.

3.3.3 Questionnaire

After the STEAM-VR textbook course, this study conducted a questionnaire survey through the Questionnaire about STEAM-VR Textbook Course designed by the researcher to gather information from the research subjects as planned. The questionnaire served as a tool to collect the data about the impact of experimental teaching. The questionnaire involved three aspects: students' satisfaction with the designed textbook and the impact of STEAM to discuss the influence of the STEAM-VR textbook course on students and to compare with the results from qualitative analysis.

3.4 Research Tools

The research tools are the questionnaires about the STEAM-VR textbook course and the learning feedback sheet. They are explained as follows.

3.4.1 The Questionnaire about the STEAM-VR Textbook Course

Based on the research purpose, the questionnaire about the STEAM-VR textbook course was designed from students' satisfaction with the designed textbook and the impact of STEAM and implemented through a Likert five-point scale.

The validity of the questionnaire was tested by experts. After the first draft of the questionnaire was finished, two experts were invited to evaluate the validity before offering suggestions for modification. The preliminary item analysis of the questionnaire was carried out among 86 students. The reliability of the questionnaire is good since the Cronbach's alpha values of students' satisfaction with the designed textbook (15 items) and the impact of STEAM (15 items) are 8.96 and 8.98, respectively, after the deletion of some lowly recognizable items, making the overall Cronbach's alpha value of the questionnaire increase to 8.96. As a result, the questionnaire about the STEAM-VR textbook course was completed.

3.4.2 Learning Feedback Sheet

This study designed a learning feedback sheet based on the course unit. This study encouraged students to record their thoughts and experiences during the learning process of STEAM and VR on the learning feedback sheet. By doing so, this study can be clear about students' learning and conduct qualitative analysis on the learning process.

The "Student Learning Feedback Sheet" analyzes data by open coding, axial coding, and selective coding. It includes the following five questions: (1) "Please list the Unity software functions you have learned and explain how your Steam-VR teaching materials project can be used"; (2) "Please explain the importance, necessity, and feasibility of your VR teaching materials project and how it can be connected to STEAM"; (3) "Please list the problems encountered during the project production and the solutions taken"; (4) "Please explain the STEAM interdisciplinary knowledge application plan of VR teaching materials project"; (5) "Please explain which VR teaching materials project impressed you the most in the final result presentation, what its advantages are and its parts that can be improved".

3.5 Teaching Design

Based on previous studies, this study designed the STEAM-VR textbook course with the theme of developing a STEAM-VR textbook. The STEAM-VR textbook course belongs to interdisciplinary and integrated STEAM courses and connects with real-life experiences through VR technology. The syllabus of the 18-week course is shown in Table 2 and can be explained as follows.

3.5.1 First Week

The course first introduced the connotation of STEAM education with interdisciplinary and convergent thinking, illustrated the STEAM-VR textbook course, stressed the STEAM-VR textbooks in the final examination, and divided students into groups.

3.5.2 2nd to 8th Weeks

The first eight weeks, which aim to develop the basic ability of VR technology, consist of eight units. The course introduced interdisciplinary STEAM knowledge and practice based on the course attribute of each unit. In this way, students can understand the value of science and technology on problem-solving and the connotation of STEAM-VR. During the course, this study was assisted by the learning feedback sheet to make sure of students' learning situation and learning progress.

3.5.3 9th Week

The week for mid-term examination was used to evaluate whether students are equipped with the basic ability through comprehensive practice. The STEAM-VR textbook course requires each group to work out the subject and finish the mid-term report so as to evaluate the direction and the feasibility of the products. Those students who fail in the mid-term examination can be tutored by group members and teachers after class to live up to the effect of small-group cooperative learning.

The learning objective of this course is to cultivate students' virtual reality development ability. This mid-term exam will cover the technical skills of modeling, lighting control, material texture, material introduction, particle effects design, and animation adjustment in Unity. In addition, it will cover the ability to set and operate VR headsets, controllers, trackers, cardboard, and other hardware devices.

3.5.4 10th to 17th weeks

The courses after the mid-term examination focus on the comprehensive application of students' VR ability. Aside from the established practice courses, the STEAM-VR textbook course got underway. Students first understood the purpose of designing textbooks through the theme of the textbook and the teaching objectives. Second, students made an overall evaluation about developing textbooks, including the scope of application, the discipline, the number of units, and the requirements of developing textbooks. Third, students established the rules of interaction, designed the teaching module, and explained the interaction according to the attribute of each unit in their textbooks. Fourth, students evaluated the source of teaching materials.

3.5.5 18th week

This study used the final examination for the students to present their products. Each group made a final report in sequence. They clarified the design philosophy of developing the STEAM-VR textbook, the problems, and solutions before peer reviewing and cross-examination to communicate with each other and share their experience. Finally,

Table 2. Syllabus of the STEAM-VR textbook course

Week	Course unit of VR operation	Descriptions of STEAM education
1	Introduce VR, AR, and development tools.	Introduce STEAM and describe the activity; Divide students into groups.
2–8	The development environment of Unity3D; design a 3D scene and make a guide map; collect a model; select material and set a light; select a camera and set a visual effect; design particle effects; make an animation.	Develop basic ability through each VR unit; Introduce the connotation of STEAM-VR in unit teaching; Learn through group discussion and cooperation; Discuss and work on a subject and collect data; Collect learning feedback sheet.
9	Mid-term week.	Work on the subject and prepare the mid-term report.
10–17	Development environment; design 3D VR interaction; design all-around VR interaction; practice.	Start to design the STEAM-VR textbook.
18	Finals week.	Finish the final report and questionnaire survey.

a questionnaire survey was conducted to be clear about students' satisfaction with the course.

According to the learning objectives of this course, students are trained to apply VR technology and develop VR teaching materials. The evaluation includes the application of virtual reality technology, innovation of teaching material development, completeness of teaching materials, the degree of connection with STEAM, and the feasibility of assisted learning.

4. Results and Discussion

This study developed the STEAM-VR textbook course and discussed students' satisfaction with the course. This chapter describes the qualitative analysis of the learning process and the quantitative analysis of students' satisfaction with the course.

4.1 Analysis of the Learning Process

This study analyzed students' knowledge acquisition and application of science, technology, engineering, art, and mathematics during the design of the STEAM-VR textbook through such learning materials as learning feedback sheet, the syllabus of the VR-based textbook, and written report. This study also concluded four procedures of the STEAM-VR textbook course. Two examples are listed as follows.

4.1.1 Integrate STEAM Education into Intellectual VR Course

After 9-week basic VR ability development and mid-term examination, most of the students are able to operate VR. By introducing the STEAM knowledge during the VR technology courses, teachers encouraged students to apply the STEAM education to the STEAM-VR textbook course.

A student recalled the process they previously learned regarding "physical metallurgy". In this process, they had experienced many difficulties in understanding abstract knowledge, such as material structure, crystal bonding, plastic deformation, grain boundaries, empty holes, annealing, and solid solutions. Most students responded to the test by rote memorizing. Therefore, the student expected that VR could simulate the metallurgical process and develop more concrete auxiliary learning materials to help students understand the course content.

The learning feedback sheets and mid-term reports show that students have finished the courses of basic VR technology and understood the connotation of applying STEAM to VR. Hence, this study encouraged students to solve learning problems through weeks of discussion. After that, students can design VR-based textbooks to facilitate learning. The VR-based textbook can be evaluated from such items as the importance of the subject, the necessity of the VR-based textbooks, the feasibility of assisting teaching, and the connection with STEAM. The theme of the VR-based textbook can also refer to such items. This study expects students to make the best of what they have learned and upgrade skills through their knowledge

Students' feedback:

S0201: We want to design a VR-based textbook about Material Science. Against the backdrop of rapidly advancing science and technology, new material embarks on a new civilization. From the stoneware in ancient times, the following bronzeware and ironware, to the modern semiconductor, the evolution of material marks new milestones for human beings.

S0202: Physical metallurgy is a part of Material Science. Even for us with engineering knowledge, the basic metallurgical methods are difficult to learn. Hence, we want to design a VR-based textbook to familiarize students with the metallurgical process and acquire metallurgical knowledge quickly.

4.1.2 Explore Problems, Apply VR, and Construct STEAM Knowledge

After making sure of the theme, students in each group started to explore problems and collect data to lay a foundation for the construction of STEAM knowledge. During the process, students' current knowledge and available information are not enough to design textbooks considering that a massive amount of authentic data is required. For instance, students need to discuss the scope of the textbook and list materials, resources, and the unit to be designed. However, students can collect data, write scripts, design drafts, explain the textbooks, design textbook interaction, draw 3D pictures, and record videos through small-group cooperative learning to construct and apply the knowledge and skill of STEAM and VR. Taking the physical metallurgy textbook as an example, the textbook is applicable to senior high school and vocational school students. As can be seen from Fig. 2, there are 6 units in the textbook, including the origin, metal extraction, melting, casting, forging, and grinding.

Therefore, it is apparent that in designing VR auxiliary teaching materials in accordance with STEAM, students have different content planning for a single subject. Thus, "physical metallurgy" comprehensive problem exploration and interdisciplinary learning design will instead be conducted to

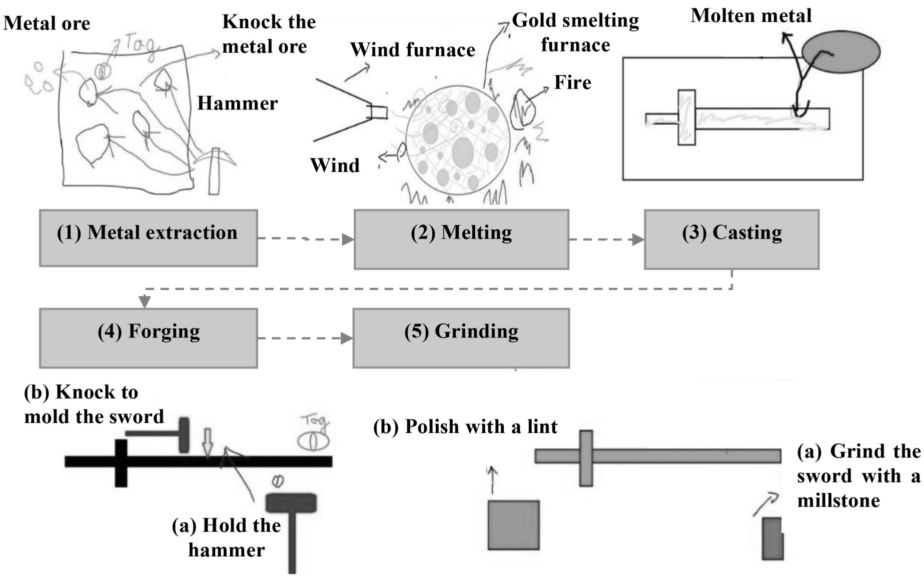

Fig. 2. Student design sketches of "Physical Metallurgy" VR teaching materials.

improve students' understanding. In this way, students can learn, experience, and interact with abstract knowledge related to "physical metallurgy" through VR features.

Students' feedback:

S0201: We think the essence of metallurgy lies in the procedures. Though introduced in the textbook, it is hard to understand the three-dimensional crystal in the two-dimensional plane.

S0204: We hope to design a VR-based textbook from the 3D perspective to help students understand the metallurgical process and acquire knowledge during the process.

S0203: We teach the metallurgical process by designing a plot of legendary sword casting in ancient times to cultivate a relaxing atmosphere.

S0204: The perceptive function of Unity such as knowledge graphs and cards, procedure descriptions, guidance, and instructions enables students to interact with the virtual world.

4.1.3 Solve the Problems of VR-based Textbook Development through STEAM Application

Teachers encouraged students to understand their views and feelings about the theme of the textbook through interviews or investigations before finding out solutions. Moreover, teachers encouraged students to solve problems by applying interdisciplinary and integrative STEAM knowledge and VR skills, including the application of VR technology, the modeling of 3D Unity software, the setting of the interactive formula, and the selection of the color and material.

Based on their previous learning experience and needs, students used VR technology to simulate realistic scenarios and discussed interactive learning content planning. In the process of making VR-assisted learning materials, students obtained integrated learning of STEAM's cross-field knowledge.

Finally, students were required to verify the smooth interaction of the VR-based textbook. As Fig. 3 shows, students simulated the metallurgical process, added instructions for the correct procedure, and added instructional videos and quiz questions. By doing so, students are able to evaluate the impact of applying interdisciplinary and integrative STEAM knowledge, which is listed in Table 3. Teachers evaluated and analyzed the connotation of STEAM in students' products.

Students' feedback:

S0202: During the interview, we were suggested to add a learning model and to illustrate the knowledge, procedures, and notices during the metallurgical process.

S0203: It is really difficult to simulate the 3D metallurgical scene. First of all, we need to collect data, pictures, and videos about metallurgy to understand the metallurgical process. After that, we need to work out teaching plans and design appropriate textbooks to guide students to learn metallurgy.

S0201: To design a popular textbook, we used phones and VR head-mounted display for guidance and learning.

S0204: We used Unity software to optimize the materials, integrate 2D pictures with 3D models, and simulate the scenes, equipment, and instruments of ancient sword casting.

S0202: The smooth interaction of textbooks

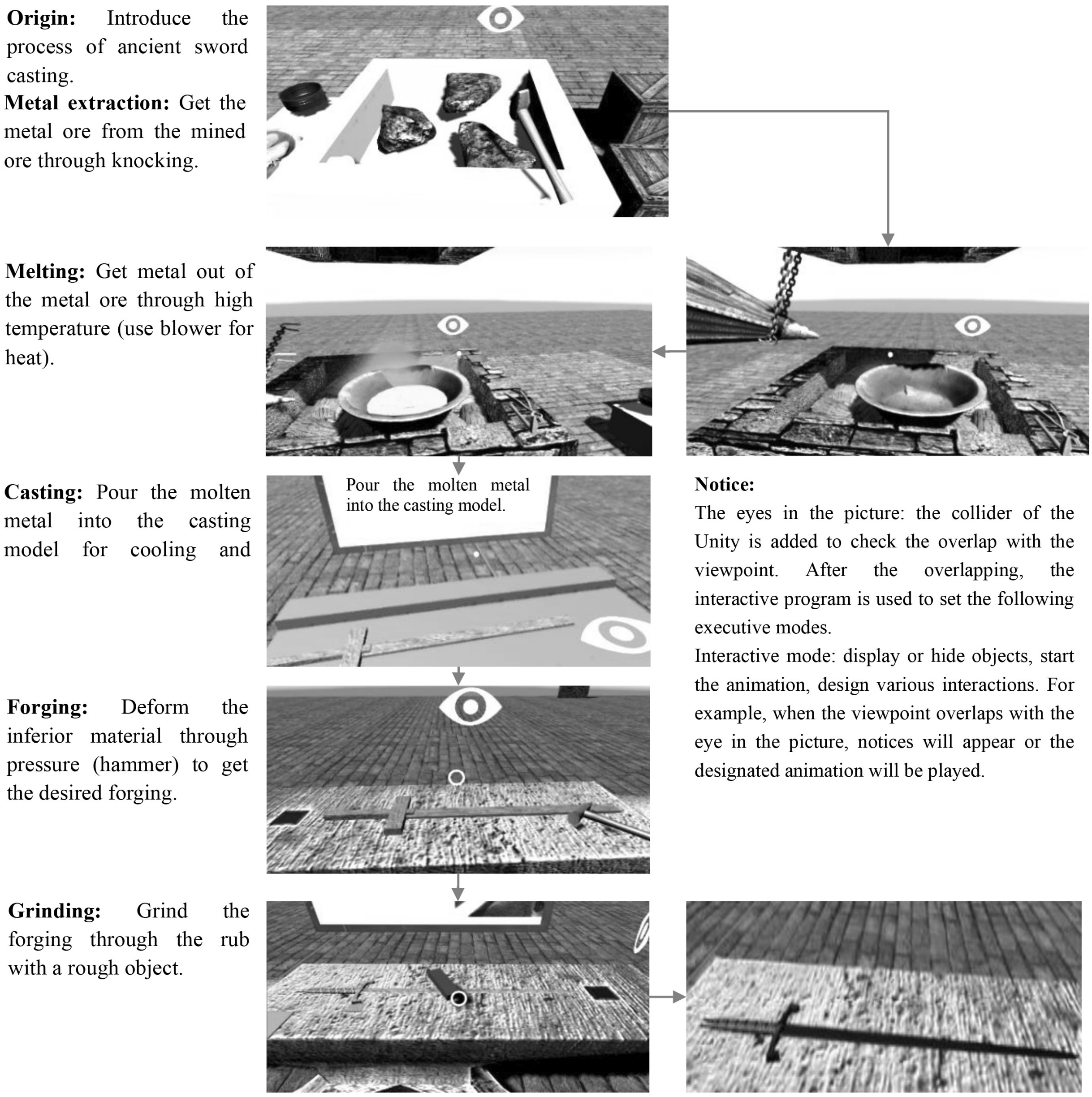

Fig. 3. Description of student works of "Physical Metallurgy" VR teaching materials.

requires accurate animation design. Therefore, we used the time axis and move objects to achieve the effects of knocking metal, the blowing of the blower, and the change of the metal color.

4.1.4 Share the Experience and Products of VR-based Textbook to Digest STEAM Knowledge

This study plans to publish the products at the end of the term when students present their VR-based textbooks and give a detailed introduction. In the written report, students need to elucidate their creative design philosophy, solutions to problems, the applied STEAM knowledge, and VR skills. As can be seen from Table 3 and Table 4, the teaching plan, the animation programming, the setting of the interactive man-machine interface, and the construction of the 3D scene are included.

The effect of small-group cooperative learning can be achieved through peer review, teacher evaluation and analysis, and student communication about designing, solutions, and learning process. From this, it can be seen that teams of students applied STEAM's cross-field knowledge in developing VR teaching material and interactive course content design. Students of each group can learn about innovating different VR teaching materials development, VR technology application, interactive design, and presenting assisted learning through the results report and exchange to stimu-

Table 3. The connotation of STEAM-VR textbook – a case of Ou Yezi's know-how of sword casting

Aspects	Connotation
Science	The textbook introduces the ancient sword casting (Metallurgy) and material (Material Science) such as extracting metal ore, extracting metal through high temperature, and making bronze out of mixed copper and tin or mixed copper and plumbum.
Technology	The textbook uses VR technology and technological equipment such as VR head-mounted displays and phones to provide fixed-point guidance and animation, enabling users to learn metallurgy in an immersive environment.
Engineering	When designing the textbook, students need to be clear about the place, instruments, and principles of sword casting to design the scenario, plan the process, and provide mechanical principles relevant to ancient metallurgical scenarios with a 3D model.
Art	Students need to design simulated and artistic metallurgical scenes in the VR-based textbook. To achieve the goal, students need to collect, learn, and convert relevant models and pictures before combining 2D pictures with 3D models.
Mathematics	VR-based textbook stresses interaction and animation. A few mathematical calculations are required to make the time axis consistent with object movement, thus achieving such simulated effects as knocking metal, the blowing of the blower, and the change of the metal's color.

Table 4. The connotation of the STEAM-VR textbook "The Secrets in VR Ecological World"

Aspects	Connotation
Science	Students introduced ecosystems in nature science such as marine ecosystem, polar ecosystem, and grassland ecosystem. Students also introduced organisms in the ecosystem to enable learners to understand the relationship among organisms.
Technology	The VR technology used by students such as phones and VR head-mounted displays can switch different life scenes to enable students to observe the behaviors of different organisms.
Engineering	Students need to be clear about the components of each ecosystem before designing different scenes with a 3D model. For example, students can simulate the grassland by designing plants and landscapes with the terrain editor.
Art	Students can collect various pictures and the data of 3D modeling based on the requirements of different ecosystems before designing the learning feedback sheets and the artistic and interesting ecosystems. In this way, users can understand the ecosystem quickly.
Mathematics	The simulated animation effect, like the movement of the penguin and the cloud and the swimming speed of the whale, can be achieved by making the time axis consistent with object movement with the help of mathematical calculation.

late more creativity. Finally, questionnaires about learning satisfaction are collected for statistical analysis and qualitative analysis to discuss students' satisfaction with the course.

Students' feedback:

S0501: Some students developed a nature textbook for the primary school named "The Secrets in VR Ecological World" to introduce marine organism, polar organism, and grassland organism.

S0201: I am interested in VR, and so I have learned a lot about animation production and logical reasoning, etc. Thanks a lot for the teacher's devotion.

S0204: I have acquired many Unity skills during this term such as VR, AR operation, modeling, designing, and animation programming. Each lesson is lively and informative. The teacher answers my questions gladly to offer us the utmost help. The guidance and devotion benefit me a lot.

4.2 Analysis of the Questionnaire Survey

This study carried out the questionnaire survey to understand students' satisfaction with the 18-week STEAM-VR textbook course. The questionnaire adopted the Likert five-point scale and carried out a single sample t-test with the test value of 3. The statistic results from 36 students were analyzed from the students' satisfaction with the designed textbook and the impact of STEAM, which are explained as follows.

4.2.1 The Analysis of Students' Satisfaction with the Designed Textbook

Students' satisfaction with the designed textbook was evaluated through peer review. This study mainly discussed the integration of VR, which features immersion, interaction, and imagination into STEAM education, which features inter-discipline, operation, application, problem-solving, and five senses learning.

After the STEAM-VR textbook course, the average value of each item on the questionnaire is above 4.17, suggesting it is statistically significant. As Table 5 shows, most of the students are positive that their VR-based textbooks can be of help in STEAM education in terms of inter-discipline, operation, application, problem-solving, and five senses learning. The average value of five senses

Table 5. Analysis of students' satisfaction with the STEAM-VR textbook course

VR	Assistance to STEAM education	Mean	*SD*	*t*
Immersion	Inter-discipline	4.17	0.77	9.04***
Interaction				
Imagination				
Immersion	Operation	4.36	0.64	12.77***
Interaction				
Imagination				
Immersion	Application	4.25	0.65	11.5***
Interaction				
Imagination				
Immersion	Problem-solving	4.33	0.76	10.58***
Interaction				
Imagination				
Immersion	Five senses learning	4.41	0.69	12.29***
Interaction				
Imagination				

Table 6. Students' satisfaction with the impact of STEAM

VR	Assistance to STEAM education	Mean	*SD*	*t*
Immersion	Science: Explore the principles of nature.	4.23	0.99	8.17***
Interaction				
Imagination				
Immersion	Technology: Make the designed tools and products into reality for people's convenience.	4.00	0.96	6.38***
Interaction				
Imagination				
Immersion	Engineering: Explore and design tools that are necessary for society.	3.97	0.97	6.01***
Interaction				
Imagination				
Immersion	Art: Integrate art and creativity with beauty and encourage students to take risks and accept different opinions.	4.38	1.02	9.34***
Interaction				
Imagination				
Immersion	Mathematics: Combine with science to conduct analysis.	3.92	0.87	6.29***
Interaction				
Imagination				

learning reaches the highest at 4.41 (SD = 0.69) with a t value of 12.29, followed by the operation with the average value at 4.36 (SD = 0.64) and a t value of 12.77. The average value of problem-solving ranks third at 4.33 (SD = 0.76) with a t value of 10.58.

4.2.2 Analysis of Students' Satisfaction with the Impact of STEAM

The topic of students' satisfaction with the impact of STEAM mainly discusses students' satisfaction with the influence of the immersive, interactive, and imaginary VR technology on STEAM interdisciplinary integration ability. The average value of each item, which ranges from 3.92 to 4.38, is statistically significant. As shown in Table 6, most of the students are positive that the STEAM-VR textbook course is helpful to acquire STEAM knowledge. The artistic ability improvement has the highest score with an average value of 4.38 (SD = 1.02) and a t value of 9.34. The scientific ability improvement ranks second with an average value of 4.23 (SD = 0.99) and a t value of 8.17. The technological ability improvement ranks third with an average value of 4.00 (SD = 0.96) and a t value of 6.38.

5. Discussions

After the experimental teaching of the SREAM-VR textbook course, this study conducted qualitative analysis of students' learning process and quantitative analysis of students' satisfaction with the course. They are explained as follows.

5.1 Teaching Observation and Reflection

This study plans the STEAM-VR textbook course, which is a VR-based course that includes four procedures. This study integrates STEAM education into VR-based course design and guides students to explore problems and learn VR technology so as to strengthen the STEAM knowledge structure. After that, this study encourages students to apply STEAM knowledge to develop VR-based textbooks and solve problems. Finally, this study helps students digest the STEAM knowledge by sharing the experience and achievements of VR-based textbook development. The learning process and the learning sheet feedback suggest that the course can help students learn step by step, activate their motivation and interest in learning, assist them in learning interdisciplinary STEAM knowledge and VR technology, and work out VR-based textbooks with high quality.

The 18-week observation and the comprehensive qualitative and quantitative analyses suggest that the STEAM-VR textbook course, which integrates STEAM education into a VR-based course, can develop students' divergent thinking and creative thinking through inter-discipline, integration, and a combination of vision, art, beauty, and simulated scenario [21]. Hence, this study finds that the STEAM-VR textbook course, which is guided by teachers, helps students improve their learning motivation, develop their imagination in a 3D-simulated scenario, and cultivate their creativity and problem-solving ability. The finding is consistent with the result from Keefe and Laidlaw [22].

5.2 Student Learning Feedback

The innovation and advantage of combining VR technology with interdisciplinary and integrated STEAM are that VR technology can present such theoretical courses as science, technology, engineering, art, and mathematics in a virtual way. Aside from providing an immersive learning environment, it can also integrate courses, make flexible use of knowledge and technology, design VR-based textbooks, and apply the emerging VR technology [23]. After the 18-week STEAM-VR textbook course, most of the students are positive about students' satisfaction with the designed textbook and students' satisfaction with the impact of STEAM, holding the opinion that the simulated scenario presented through VR is helpful to learning. Students also think highly of their practical and interactive textbooks. When talking about interdisciplinary STEAM learning, they believe that VR technology can help them learn abstract and complicated knowledge such as science, engineering structure, application of science and technology, artistic imagination, and mathematical calculation. Most of the students hold the opinion that learning assisted by VR-based textbooks is systematic and that students can travel around the world while at home and acquire interdisciplinary knowledge regardless of the space and the resources. Moreover, dangers and problems during outdoor teaching and the experiment can also be avoided.

5.3 Summary of Teaching Practice Key Points

This study therefore concludes the following 4 characteristics of the STEAM-VR textbook course as follows.

5.3.1 Inspire Students to Mull over Learning Problems and Create Learning Motivation to Integrate VR Technology with STEAM Knowledge

In this study, teachers guide students to mull over previous learning problems. For instance, the textbook seldom presents three-dimensional objects and helps the abstract learning process [24]. Students cannot be immersed in the environment described in Geography and Biology. This study enables students to explore a meaningful problem, to create learning motivation, and to discuss and solve real problems with STEAM convergent thinking before achieving the learning goals [4, 11].

5.3.2 Encourage Students to Design Textbooks with VR Technology and Focus on STEAM Knowledge

This study encourages students to develop textbooks with the acquired VR technology and to design teaching plans [25]. Through interdisciplinary STEAM knowledge and the strategy of learning by doing, students can learn efficiently and effectively [5]. This study stresses students' inner motivation, encourages cooperative learning, and allows them to improve their designed textbooks such as the knowledge structure and the interaction and fluency of the textbook. Students can exchange the solutions to learning problems and share their respective experiences through small-group cooperative learning.

5.3.3 Advocate Students to Lead the Textbook Development, Activate STEAM Knowledge, and Apply VR Technology

This study advocates student-centered learning, where students share a learning process, and group members put forward and describe the problem before defining it. For instance, students can discuss the problem during the metallurgical process, draw a draft of the teaching plan, design the textbook, verify the function and interaction, and finally optimize the textbook [26, 27]. Through cooperative learning and division of responsibility, students can understand the connotation of STEAM knowledge, which is necessary for problem-solving so as to construct knowledge and develop critical thinking [2, 13].

5.3.4 Facilitate Students to Enhance their Integration of STEAM Knowledge into VR Technology

This study regards a teacher as a facilitator during the courses to provide essential guidance about STEAM learning instead of direct teaching or knowledge transfer [18, 28]. Teachers should timely participate in the learning process of each group, discuss and solve problems with students, and provide appropriate feedback so as to help students clarify the problems and bring the discussion and thinking to a higher level. In this way, teachers can help students promote learning activities and accumulate abundant educational knowledge during self-exploration and problem-solving.

6. Conclusion and Suggestions

While STEAM integrated thinking can provide students with interdisciplinary, integrated learning, VR can provide students with immersive, interactive learning and repetitive exercises, which can help them understand abstract knowledge and improve their learning motivation. The advantage of this "Steam-VR Teaching Materials Project" is its instruction on integrating a STEAM perspective into the curriculum, which helps students develop VR teaching materials. Students apply what they have learned in class in developing VR teaching materials based on the 4-stage steps in solving problems they have difficulty with and understanding abstract knowledge. According to the teaching observation and student feedback, students have acquired the ability to integrate and apply STEAM across disciplines, and they are positively satisfied with the teaching materials and STEAM learning results. This study summarizes four implementation priorities of STEAM into VR teaching, including the introduction of real problems into VR projects, guidance of STEAM interdisciplinary knowledge integration learning, practical application of VR technology in project-making, problem-solving, and learning-experience-sharing. Furthermore, this provides teachers with a reference for future interdisciplinary teaching.

In terms of future research, VR teaching materials are made based on students' free choice of courses. Although we can observe diversity among students' creative designs of their teaching materials, the quality and depth of the teaching materials are slightly insufficient and peer discussion and communication are too divergent. Therefore, it is suggested that in the future, teachers designate one or two courses for students to choose from. Then, each group can be assigned with one or two units for VR teaching material development to focus on the quality of the VR teaching materials, content designs, and the depth of group discussions.

Finally, since this study takes students having interdisciplinary courses at a sci-tech university in south Taiwan as the research subject, the results are not necessarily applicable to other areas. It is suggested that when planning and designing VR-based courses in the future, teachers can make use of STEAM education and immersive VR technology to provide students with a simulated and safe environment for 3D structure, experiment, and repetitive exercises, making learning more attractive. Moreover, it is suggested that teachers who do not specialize in VR should refer to the findings to adopt interdisciplinary and collaborative teaching (co-teaching), integrate the STEAM knowledge into VR technology, and promote the application of VR technology to education so as to enhance the learning effect of interdisciplinary STEAM knowledge and VR technology.

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Chih-Chao Chung is an Assistant Professor Rank Research Fellow of the General Research Service Center in the National Pingtung University of Science and Technology, Taiwan.

Bo-Yuan Cheng is an Assistant Research Fellow of the General Research Service Center in the National Pingtung University of Science and Technology, Taiwan.

Yuh-Ming Cheng is a full Professor of the Computer Science and Information Engineering in the SHU-TE University, Kaohsiung, Taiwan.

Shi-Jer Lou is a full Professor of the Graduate Institute of Technological and Vocational Education in the National Pingtung University of Science and Technology, Taiwan.