Regarding the Virtual Reality Environment Design and Evaluation Based on STEAM Learning

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Abstract. This study aims to design a STEAM virtual reality (VR) learning environment for engineering students, as well as evaluate the practicability of the learning environment. This study adopted Fuzzy Delphi Method by inviting six experts in the fields of VR application, STEAM education, and engineering education to execute the expert questionnaire survey, in a bid to build up a capability indicator of STEAM education and carry out the STEAM VR environment practicability evaluation serving as a foundation of the further development of curriculum. According to our study findings, the most important capability indicator in STEAM is "Hands-on Skills", followed by "Problem Solving", "Daily Life Application", "Sensory Learning" and "Interdisciplinarity". In terms of the practicability evaluation of STEAM VR learning environment establishment, the highest scoring element is "Interactivity", followed by "Engagement", with "Imagination" being the lowest. This study serves as a reference for future educators and researchers in establishing a STEAM VR learning environment.

Keywords: Virtual reality · Environment design · STEAM · Education reform · STEAM learning

1 Introduction

The public's reliance on the convenience brought by technology exacerbates as our information and communication systems develop and improve. Upon the impact of the COVID-19 epidemic, breakthroughs and improvement in knowledge and skills require urgent support by technology, which highlights the importance of education and development in the engineering field. Nonetheless, in this century with ever-changing technology, more and more innovative and creative talents are desired. It urges the cultivation of STEAM students to become a critical education practice among governments [1].

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To this end, an increasing number of countries are proposing divergent education strategies to train students in their interdisciplinary STEAM skills, including using intelligent studying products [2] such as Skilled-based Learning, Robot-based Education, Artificial Intelligence, Augmented Reality and Virtual Reality. It is hoped that students can be equipped with interdisciplinary integrating minds when nurturing their problem-solving skills in daily life and arousing their creativity and imagination through the assistance of technical tools to prepare for transformations in the social environment.

Despite STEAM education integrates subjects in different areas, it can be challenging for sole educators to implement the approach and develop STEAM ability in students [3]. It was pointed out by many that designing student-centered situated teaching can effectively cultivate their abilities in STEAM such as Interdisciplinarity, Hands-on Skills, Daily Life Application and Problem Solving [4]. Therefore, it is predicted that the application of sensory stimulation and highly interactive and immersive VR technology in education will be the major development trend in assisted instruction in the future [5, 6].

In conclusion, this study will design the STEAM VR learning environment and carry out its evaluation while adopting the emerging technology of VR and holding the prime aim of educating engineering students. Two objectives included are as below:

(1) Constructing a STEAM capability indicator
(2) Evaluate the practicability of a STEAM VR learning environment

2 Literature Review

STEAM- and VR-related literature revolving around our objectives are reviewed. Demonstrations are as below:

2.1 Definition of STEAM

STEAM is the integrated education combining scientific investigation, technology, engineering design, artistic creations and mathematics analysis [7]. It aims to improve problem-solving and critical thinking skills and creativity among students using mathematic and scientific based engineering and designing practices in order to remedy problems in the real world. It also encourages the reconstruction of current art education into inquiry-oriented teaching, as well as creative problem solving [1]. It is to equip the students with the five abilities in STEAM specified in Table 1.

To conclude, this study held the notion that to promote STEAM learning of students, a VR environment can be established to guide the students through entertaining simulation independently. During the exploring process, students can improve their five primary abilities of Interdisciplinarity, Hands-on Skills, Daily Life Application, Problem Solving and Sensory Learning.

Table 1. Definition of STEAM Capability Indicator.

No	Capability Indicator	Definition
1	Interdisciplinarity	Nurture practical ability in interdisciplinary learning through task-based learning
2	Hands-on Skills	Nurture hands-on skills and active inquiring ability
3	Daily Life Application	Able to integrate information and resources and apply knowledge in daily life
4	Problem Solving	Willing to resolve issues with positivism and problem-solving skills
5	Sensory Learning	Able to make use of the five senses, namely touch, sight, hearing, smell and taste, to learn

2.2 Definition of VR

VR is the technology to stimulate the reality world, with visualized expression being the most compatible with the instinctive visual exploration. It could promote experience and connection between learners and their practical reality environment [8]. VR possesses three features, according to Table 2, to provide users with a first-person perspective in a virtual situation, therefore allowing users to enjoy its merriment as experienced personally [5, 6, 9].

To sum up, this study brought the Immersion, Interaction, Imagination features of VR technology into play to establish a study-friendly STEAM environment for students in order to boost learning effectiveness in STEAM.

Table 2. Definition of VR.

No	Features	Definition
1	Immersion	Allow users to immerse in virtual scenes as if experiencing personally
2	Interaction	A prerequisite for virtual environment
3	Imagination	Simulation of the reality, filled with extra imagining possibilities

3 Research Design

Citing the result of literature review, the framework of "STEAM capability indicator" and "STEAM VR learning environment" practicability evaluation respectively are as below:

3.1 Research Structure and Subjects

This study framework (as shown in Fig. 1) adopted the Fuzzy Delphi Method by inviting six experts (more than six years of experience) in the fields of VR application, STEAM education and engineering to collaborate jointly and provide consultations in order to execute the Delphi expert questionnaire survey. Thus the STEAM capability indicator construction and the STEAM VR learning environment establishment practicability analysis are completed and serve as a foundation of future development of the curriculum.

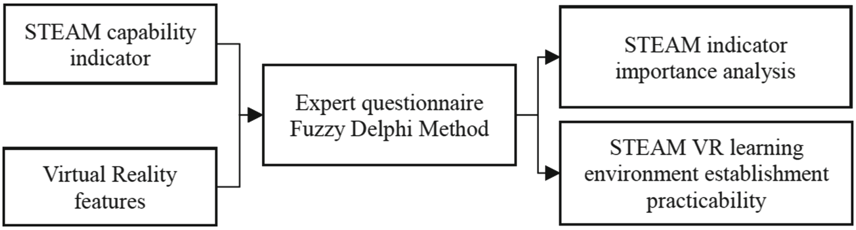


Fig. 1. Research structure.

3.2 Research Method

Fuzzy Delphi Method (FDM) is the combination of Delphi Method and Fuzzy Logic to use Triangular Fuzzy Number for ameliorating the shortcoming of traditional Delphi Method. It eliminates the limitations of humanity fuzzification and is an effective way to establish an indicator [10]. Hence, this study adopted the Fuzzy Delphi Method in the construction of STEAM capability indicator and STEAM VR learning environment practicability analysis.

4 Results and Discussion

The result analysis of executing the Fuzzy Delphi expert questionnaire survey based on the objective in establishing a STEAM VR learning environment is below:

4.1 Analysis of the Importance of STEAM Capability Indicator

For the "Establishment of STEAM capability indicator", after obtaining subjective value judgments and assessing scores from six experts of the Fuzzy Delphi expert questionnaire survey, the analysis results are as in Table 3. The scores in the importance of STEAM capability indicator ranged between 0.718 and 0.757. The highest scoring item is "Hands-on skills" with a score of 0.757, followed by "Problem-Solving" scoring 0.757, "Daily Life Application" scoring 0.753, "Sensory Learning" scoring 0.744, and ends by "Interdisciplinarity" scoring 0.718.

4.2 STEAM VR Learning Environment Practicability Analysis

This study delved into the practicability of establishing a STEAM VR learning environment. The analyzed result by Fuzzy Delphi Methods experts is shown in Table 4.

Table 3. Scores in the importance of STEAM capability indicator.

Number	Item	*L*-value	*R*-value	Total	Rank
1	Interdisciplinarity	0.379	0.816	0.718	5
2	Hands-on skills	0.339	0.853	0.757	1
3	Daily life application	0.343	0.849	0.753	3
4	Problem solving	0.339	0.853	0.757	2
5	Sensory learning	0.352	0.840	0.744	4

In respect to the practicability of Interdisciplinarity VR learning, the scores ranged from 0.718 to 0.730. The item with the highest practicability is Interactivity, which scored 0.730.In respect to the practicability of Hands-on Skills VR learning, the scores ranged from 0.733 to 0.773. The item with the highest practicability is Interactivity, which scored 0.773.In respect to the practicability of Daily Life Application VR learning, the scores ranged from 0.724 to 0.759. The item with the highest practicability is Interactivity, which scored 0.759.In respect to the practicability of Problem Solving VR learning, the scores ranged from 0.718 to 0.766. The item with the highest practicability is Interactivity, which scored 0.766.In respect to the practicability of Sensory Learning VR learning, the scores ranged from 0.703 to 0.750. The item with the highest practicability is Interactivity, which scored 0.750.

Table 4. Scores in STEAM VR learning environment practicability analysis

NO	Item	VR Feature	*L*-value	*R*-value	Total	Rank
1	Interdisciplinarity	Immersion	0.379	0.816	0.718	3
		Interaction	0.367	0.827	0.730	1
		Imagination	0.377	0.818	0.720	2
2	Hands-on skills	Immersion	0.339	0.853	0.757	2
		Interaction	0.322	0.868	0.773	1
		Imagination	0.363	0.830	0.733	3
3	Daily life application	Immersion	0.343	0.849	0.753	2
		Interaction	0.336	0.855	0.759	1
		Imagination	0.373	0.821	0.724	3
4	Problem solving	Immersion	0.339	0.853	0.757	2
		Interaction	0.329	0.862	0.766	1
		Imagination	0.379	0.816	0.718	3
5	Sensory learning	Immersion	0.352	0.840	0.744	2
		Interaction	0.346	0.846	0.750	1
		Imagination	0.395	0.801	0.703	3

4.3 STEAM Competency Assessment Criteria and VR-Assisted Learning Planning

According to the above-mentioned expert consultation and fuzzy Delphi analysis results, the "Learning Effectiveness of STEAM Skills Questionnaire" is developed, and "STEAM VR Assisted Learning Activities" are planned, which are described as follows:

1. Learning Effectiveness of STEAM Ability Questionnaire
   In order to understand students' learning status of STEAM skills, the "Learning Effectiveness of STEAM Skills Questionnaire" is developed, which includes 5 dimensions: cross-domain, hands-on, life application, problem solving, and five sense learning. This research invites two experts and scholars to test the expert validity of the questionnaire, evaluate the validity of the initial draft of the questionnaire, and revise it according to the suggestions. In terms of reliability analysis, after the inconsistent items are deleted, as shown in Table 5, which has 21 questions in total. The overall Cronbach's alpha value of "Learning Effectiveness of STEAM Skills Questionnaire" is .861; among them, there are 3 questions (.860) in the "cross-domain" dimension, 4 questions in the "hands-on" dimension (.882), and 4 questions in the "life application" dimension (.821), 5 questions (.875) in the "problem solving" dimension and 5 questions (.840) in the "Five Senses Learning" dimension, which indicates that this questionnaire has good reliability and high consistency.

Table 5. Reliability analysis of STEAM ability learning effectiveness questionnaire.

Dimension	Item
Interdisciplinarity	1 I learn interdisciplinary knowledge and application in the curriculum
	2 I will integrate more than two kinds of interdisciplinary knowledge and thinking operations
	3 I think it is important to learn the interdisciplinary integration capability
Hands-on skills daily	4 I can practice and explore the principles of curriculum knowledge
	5 I construct knowledge from hands-on practice
	6 I like hands-on practice
	7 I am good at using hands-on practice to learn knowledge
Life application	8 This curriculum can cultivate my curiosity about daily life problems
	9 I can disassemble and analyze daily life problems
	10 I can apply the curriculum knowledge to my daily life
	11 I can judge the effect of problem-solving methods under certain conditions
Problem solving	12 I can identify problems and make systematic statements
	13 I can collect data and take appropriate information to collate the problem

(*continued*)

Table 5. (*continued*)

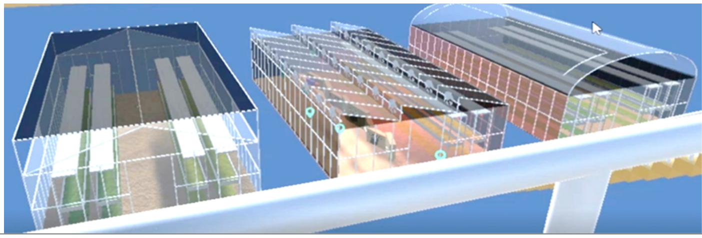
Dimension	Item
	14 I can put forward assumptions and multiple feasible solutions according to problems
	15 I can carry out the division of labor, process planning, and planned operation
	16 I can test and correct according to the proposed assumptions
Sensory learning	17 This curriculum can provide me with diversified learning stimulations
	18 This curriculum can cultivate my comprehensive learning through my 5 senses
	19 This curriculum can stimulate my potential and learning capabilities
	20 This curriculum can cultivate my imagination
	21 This curriculum can cultivate my creativity

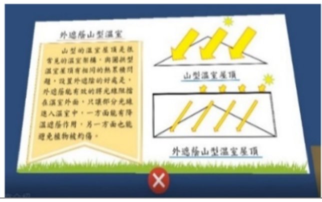
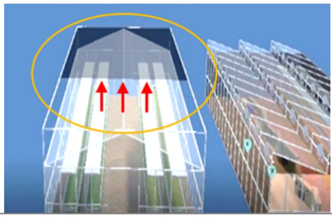
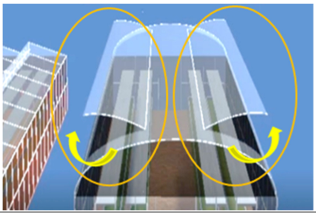
2. STEAM VR assisted learning activity planning

   Taking the auxiliary teaching material "STEAM VR Smart Greenhouse" as an example, this research carries out STEAM curriculum design and VR-assisted teaching in accordance with the course objectives, course content, and expert advice of the "Smart Greenhouse" unit, and plans three-stage auxiliary learning activities, "Teacher Show", "Student Exercises" and "Student test". As shown in Table 6, it can help students develop practical ability in smart greenhouse practice. The instructions are as follows:

   - Teacher presentation stage: The teacher will show the teaching of "STEAM VR Smart Greenhouse" to let students understand the relevant functional design of the smart greenhouse and to develop their interest and curiosity in the field learning of the smart greenhouse in the future, and cultivate the students' ability to apply what they have learned to the real field.
   - Student practice stage: "STEAM VR Smart Greenhouse" assists students in their course of learning and provides students with hands-on practices and repeated exercises. Students can explore the knowledge of smart greenhouses, construct knowledge and understand the principles. "STEAM VR Smart Greenhouse" also strengthens students' hands-on practical ability.
   - Student test phase: This research plans the "STEAM VR Smart Greenhouse" student test to assist them in the ability verification, including smart greenhouse category selection, artificial lighting system, ventilation system (the right photographs in Table 6), inner shading system (the left photographs in Table 6), and sprinkler system, as a reference basis to examine whether students are qualified for the practical examination of the smart greenhouse.

Table 6. STEAM VR assisted learning activity planning.

<table>
<tr><th>Name</th><th>Description</th></tr>
<tr><td>Teacher presentation stage</td><td>The teacher introduces their functions and displays according to the types of smart greenhouses
</td></tr>
<tr><td>Student practice stage</td><td>Students explore the functions of the smart greenhouse and construct related knowledge on their own



</td></tr>
<tr><td>Student test phase</td><td>Students participate in the simulation test for smart greenhouses to verify their familiarity with the operation steps
 </td></tr>
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5 Conclusion and Suggestions

This study adopted VR technology in assisting STEAM ability cultivation and learning environment scheduling. After investigations and analysis of the Fuzzy Delphi expert questionnaires, in regard of building emphasis in the five STEAM abilities with the aid of VR technology, the highest scoring item is "Hands-on Skills", followed by "Problem Solving", "Daily Life Application", "Sensory Learning" and "Interdisciplinarity". Among the items, for the practicability of the featured VR-aided "Hands-on Skills" education, the highest scoring element is "Interactivity", followed by "Engagement" and "Imagination". By this means, this study serves as a reference for future educators and researchers in scheduling students' STEAM ability cultivation, as well as interdisciplinary studying and developments.

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