A Virtual Reality Scaffolding Prototype for College Students Self-directed Learning in STEAM

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Abstract. Self-directed learning (SDL) is an effective method to model the core technology for STEAM college students. However, STEAM includes immersion technologies and many fields, and learning usually crosses semesters, which is difficult for students to construct personal skill models. The VR scaffold developed based on SDL theory, hints, and expert modeling visualization help students construct their core technical models. The prototype is editable and sets up tasks and levels in a gamified way, and finally shows the learning results.

Keywords: VR Scaffold · Self-directed Learning

1 Introduction

STEAM has extended from K-12 education to higher education. In addition to engineering technology, it also includes business, design, etc. STEAM has appeared discipline integration specialty in higher education. Innovation, integration, and production have become prominent characteristics (Innella and Rodgers 2017). In the context of integration and intersection, STEAM includes wide and complex learning content, and the learning activities are separated into multiple semesters.

Self-directed learning (SDL) is an autonomous learning model with students' self-driving and self-management as the core. It usually completes learning activities with the help of peers or instructors. In the learning process, students independently evaluate their learning needs, find their learning materials, formulate learning plans, select and implement learning methods and strategies, and reflect and evaluate their learning outcomes. There are four general characters in SDL models. Learners tend to self-realization and learning responsibility; learners are the main managers and monitors of the learning process; learners at different stages have different levels of autonomous learning; the subject of learning is the learner.

Self-management and monitoring are not only important features of self-directed learning but also the key link for learners to complete self-learning. For a long time, the difficulty of self-management and self-monitoring lies in the lack of visualization and unclear key nodes.

The Virtual Reality (VR) scaffolding prototype developed according to the SDL theory visualizes the hints and expert technology model, which help students independently complete the modeling of core technology learning according to the STEAM

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syllabus while learning (Andrea Bravo and Cash 2021). The prototype sets the tasks and levels of the syllabus gamification so that learners can model their learning in the open open-source environment and finally display the learning results.

2 Background

2.1 Related Work

The popularity of VR has opened up opportunities for more educators to understand its educational advantages. Although VR environments with avatar personifications have been used quite effectively when designing games for recreation and education (Squire and Jenkins 2003), the education research on more open-ended, higher education-focused applications is less developed. Younger individuals, based on their prior virtual experiences, will be more motivated to participate in virtual settings because of the remote video teaching. A VR environment is merely the background for what can be a rich, interactive experience. McManimon (Mok et al. 2001) purports how virtual environments, when used with constructive principles, can support pedagogically sound activities, such as situated learning, role-playing, cooperative/collaborative learning, problem-based learning, and creative learning. From the perspective of constructivism, self-directed learning is the unification of internal processes and external process.

With the development of modern information technology, the research on self-directed learning has paid more and more attention to the application of information technology. The concept of a self-learning circle under network conditions with online self-learning is closely related to cognition, control, commitment, and content (Yen 2005). A self-directed learning model was developed using online education (Badilova 2018). And right now, VR/AR is being treated as a tool for self-directed Learning (Gregor Rozinaj et al. 2018) focuses on game-based virtual reality in education. As an example, a game-based VR application describing the functionality of the "Firewall" application is discussed.

2.2 Foundations for VR Scaffolding

Between the real level of development and the potential level of development, there exists a zone of proximal development. This zone can be regarded as an area where scaffolds are needed to promote learning.

There are three properties of the scaffold: 1) The scaffold is a temporary support for the learner to ensure the success of a learning activity; 2) The scaffold is extensible and can be offered through interactions between the learner and the learning environment. 3) The scaffold should be removed in time after the learner can accomplish the learning task independently.

While a single scaffolding strategy is not enough for a wide variety of learners, here are six scaffolding strategies to mix and match. The six strategies are, 1) Show and tell, 2) Tap into prior knowledge, 3) Give time to talk, 4) Pre-teach vocabulary, 5) Use visual AIDS, 6) Pause, ask questions, pause, review.

As mentioned in point 5 above, visual AIDS help students visually represent their ideas, organize information, and grasp concepts such as sequencing and cause and effect.

The application of virtual reality in education is a leap forward in the development of educational technology. It creates an environment of "self-directed learning", replacing the traditional learning mode of "teaching to promote learning" with a new learning mode in modelch learners acquire knowledge and skills through the interaction between themselves and the information environment. In a sense, VR scaffolding can play the role of visual teaching AIDS well. In this research, VR scaffolding is used to help students construct their core technical models. To this end, the interactive 3D content production tool Creator is introductory to visualize the draft.

2.3 SDL Elements for Immerse Technology College Student

Many studies provide evidence that learners need to immerse themselves in authentic learning environments and gain expertise through participation.

Immersive technologies can greatly help educators implement pedagogical approaches that are aligned with the situated-constructive learning theories. Well-designed simulations and games provide immersive environments with appropriate tools, content, feedback, and scaffolds.

Educational games and simulations can also provide pedagogical contexts. For example, SimCity, is one of the best-known and most commercially successful simulation games and has established the genre of city builder games. Its use as a planning tool has been discussed from the first release (Arnold 2019). The use of SimCity for planning can also be expanded to specific planning disciplines such as water infrastructure, urban planning, Geographical Information systems. The VR scaffolding prototype in this paper helps students build their technology prototype across disciplines and semesters through gamification.

Learning from the success computer gaming achieves with the young generations, the principles of gamification can be applied to educational applications, too, to boost engagement and enhance the learning process. Moreover, an educational application can be easily included in novel learning paradigms, like self-directed learning.

Self-directed learning means allowing students to manage their own in the educational process, maybe be successfully applied to all levels of education. For self-directed learning, the following benefits may be listed, 1) Increased interest in learning through student's active participation, 2) Raised awareness of learning styles and which learning styles work best, 3) Obtaining additional, workplace-required skills, such as problem-solving, planning and decision making, 4) Boost appreciation of learning, 5) Improve motivation, satisfaction, and academic achievement.

Several limitations may be identified for self-directed learning that has to be challenged, 1) Shift and limitation of educational focus from learning towards preparing and passing the examination, 2) Heavy teacher workload, requiring individual approach teach student, 3) Difficulty of adjusting the learning modules or creating new ones.

The VR scaffolding constructed by immersive technologies represented by virtual reality can avoid limitations 2 and 3 to a certain extent. VR scaffolding help college students build technology prototypes that belong to them. Everyone's archetypes are different, but the way they are constructed leads to similar patterns that can lighten the workload of educators. The creator is the visual programming software. Its feature is that scenes are easy to delete and add. Therefore, it is not difficult to adjust the learning module corresponding to the scene.

3 From Program Syllabus to Students Skills Models

3.1 Higher Education in STEAM

STEAM education originated in the United States and has gone through the three stages of STS, STEM, and STEAM. Its fundamental purpose is to enhance college students' ability to integrate scientific disciplines, provide comprehensive talents for scientific and technological undertakings.

Innovation, integration, and make are the three philosophical views of STEAM courses. The important meaning of making lies in the integration of knowledge and practice. Through STEAM learning, students can connect the knowledge they have learned in and out of class with the real world, making it easier to find STEAM-related careers and opportunities (Zaher and Hussain 2020). The STEAM curriculum is conducive to cultivating artistic design, creative abilities, problem-solving, flexible thinking, and courage to assume responsibility in the process of artistic creation.

STEAM is interdisciplinary and interesting, experiential, contextual, collaborative, artistic, empirical, and technological enhancement. Recently, it has been extended from K-12 education to higher education, which adds computer science, computational thinking, investigation and research, creation and innovation, global communication, collaboration, and other emerging knowledge (Belland et al. 2017). This is aimed at maximizing the benefits of STEAM courses and striving to pursue the individual, society, and the whole of mankind a happy attempt has a distinct utilitarian color.

In China, STEAM education research started late, and related research did not appear until 2008. In 2018, the "China STEAM Education 2029 Innovation Action Plan" was launched. Focusing on STEAM education, different researchers have researched the aspects of the online teaching model, the establishment of teaching platforms, online courses, the development of learning projects, and the online teachers' training.

3.2 From STEAM Program Syllabub to Students Skills Models

The professional curriculum system constructs curriculum modules according to the educational goals and the student's graduation requirements. The curriculum modules are set according to the difficulty of knowledge and skills, and the students' understanding and mastering as well. They are open in different semesters. Taking immersion technology as an example, the teaching goal is to to the digital creative industry and train developers who both have the abilities to apply information technology and engage in the design and development of virtual reality, augmented reality, and mixed reality. From the curriculum aspect, it includes four modules: virtual reality programming, graphics and image technologies, digital video technologies, and project design. Table 1 shows the courses included in each of the four modules, such as (Table 1).

In VR programming module, it contents two U3D programming courses and one VR project course. In Interactive Design course, it gives a general and common interaction introduce and practice using software and hardware. In the graphic & image technology module, students learn to create 2D and 3D computer graphics which might be used in a VR environment. The third module, digital video technology includes the two parts, basic digital video technology, and visual programming. There have three courses in the

Table 1 Curriculum module.

Course module	VR programming	Graphic & ImaTechnology	Digital video technology	Project design
1	Basic U3D programming	Basic graphic	Technology	Creativity design
2	U3D 3D programming	Information graphic	Programming	Maker project
3	VR project	3D model & Animation		Senior project
4	Interactive design			

project design module, creative design, maker project, and senior project. All of these three are integrated and project-based.

According to the level of technical difficulties and the process of immersive project development, the courses in the four modules are separated into 5 semesters. Four colors represent the four modules above (Fig. 1).

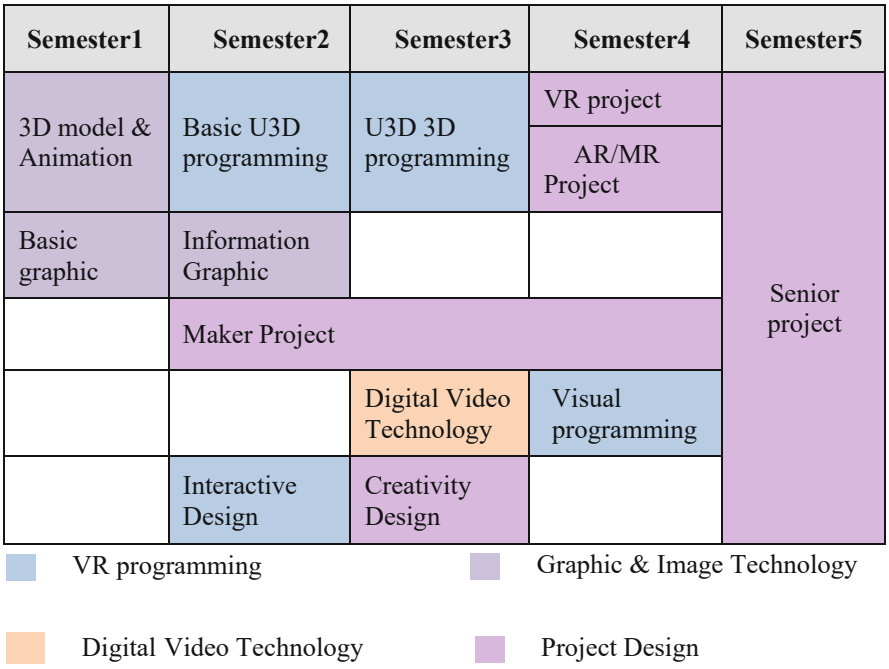

Fig. 1. Core courses in fours modules

4 VR Scaffolding Prototype Development

4.1 Five Steps of Scaffolding

According to the scaffolding instructional design and the notion of the zone of proximal development (ZPD) theory, instructors construct a conceptual framework that could interact between a 'more knowledgeable other' and an apprentice. The main function of scaffolding is training learners to be self- during the learning process and helping them exceed their previous abilities.

Three strategies could support learners learning progression, questions, prompts, and feedback (Mamun, et al. 2020). POE (predict, observe, explain) strategy has been considered a successful pedagogical model in both physical and virtual learning environments. In instructional design, the scaffolding was constructed between student-content, student-teacher, and student-student interaction.

Modeling for students is directed learners' key in scaffolding. In this paper, VR scaffolding was developed in 4 steps, show and tell among instructors and students, activate prior knowledge, transfer new technologies into personal learning outcomes and quizzes, share, and review.

1) Show and tell among instructors and students
In scaffolding education, learners are first required to understand the main modules of the core courses in the university stage and connect them with society and life by reading the student manual and resource search. Students share their professional knowledge and ask questions through the show and tell. In the teacher participation stage, by answering questions and asking questions, learners can more clearly understand the relationship between the above four skill modules and the final learning outcomes.

2) Activate prior knowledge
Prior knowledge refers to the knowledge that learners already know before new learning. It is the knowledge, skills, and literacy that learners already have before the new learning activities. It is related to learners' educational background, social and life experience. Prior knowledge is very important. It is the basis of new knowledge. Activating prior knowledge helps students understand the connection and relations between previous learning and new learning. It can provide learners with a framework for better understanding new knowledge, skills and information, and provide instructors with formative assessment information to adapt to teaching.

This process helps students establish a connection between new information and what they already know. Students who already know some background knowledge know in many fields are usually easier to understand relevant materials and obtain new information. They usually predict what they will encounter in learning and connect these new ideas with their existing knowledge.

3) Transfer new technologies into personal learning outcomes and quiz
In this research, learners have understated the four technologies modules in this period, we integrated gamification into prototype development. Gamification refers to the use of game elements in a non-game environment to increase the interaction between people

and computers and effectively solve problems. Gamifithe cation of the learning process can be considered as the use of game fragments to motivate learners, which involves the use of game-based mechanisms, aesthetics, and game thinking to attract learners, stimulate action, promote learning and solve problems. Gamification is an integral part of scaffolding because its main goal is to improve user efficiency and understanding through interesting and pleasant learning, it can ensure the effectiveness of its usage in a learning environment.

When the learners set game stages, they matched technologies they had learned and game elements based on learning outcomes. The most commonly used elements of the game were badges and points systems. The learning environment can also support these and allow the teacher to select appropriate scaffolding learning tools based on the game-like elements in the game to promote certain desired behaviors.

Based on students' preferences, a gamification prototype was developed. Gamified archetypes have five attributes. The first attribute is called "stage" and it is assigned based on elements from the basic courses. The second attribute is called "level." This attribute has four elements for each concept or sub-concept, including a concept layer, an explanation layer that explains how to use the concept, and an exercise layer that provides more examples for each concept to enhance students' understanding. The third property is the timing system. The fourth attribute called "display" calculates the total score for all the questions. Based on the total points accumulated, each student at the presentation step will receive a badge based on the total points and ranking to be displayed on the leaderboard. The final attribute called "report" shows the overall learning progress report for each student and describes whether the student will continue to the next level, while also showing the student's progress in the form of a graphical graph.

In this paper, the VR scaffolding prototype has three stages and contented five key skills that immerse technology students need to learn.

4) Share and review

Share and revies an effective way to check whether students understand new technologies. Usually, questions are prepared in advance to ensure that students are open-minded. Students discuss what they have learned, what they have found, or what problems they have mentioned. Students can actively participate. This paper creates a VR scaffolding prototype, which supports students sharing their prototype source documents in learning groups. Students could review their learning in and after learning.

4.2 Tools and Implementation

In this paper, researchers use a VR software, Creator to develop a scaffolding for immerse technology college students learning. Creator a codeless virtual reality editor that can integrate multiple elements such as 2D/3Dpictures, panoramic pictures, videos, 3D models, and sounds. It supports publishing on multiple hardware platforms, for example, VR glasses, mobile phones, and computers. This research transferred four curriculum modules into a VR scaffolding prototype with gamification elements. Take a student project of A college, for example, students created a virtual reality garden based on their campus environment. In Chinese culture, because schools are places to cultivate people, they are often metaphorically compared to gardens, Teachers are likened to gardeners, and

students are generally likened to flowers. In the VR garden, students were likened to a sunflower, they set three stages for every two semesters. In each stage, they developed 3 to 5 quizzes according to the courses they learned and the courses' outcomes. After the lunch the program and answer correctly, they got water, sunlight, and nutrient, and the sunflower would grow up.

Students constructed a flowchart at first. A flowchart is used to show the operation process to achieve a certain goal, the sequence of user steps required visually. It also needs to connect the relationships between the various stages. The student's project, included the main three stages, "if…else" conditions, key skills students need to masted in stages (Fig. 2).

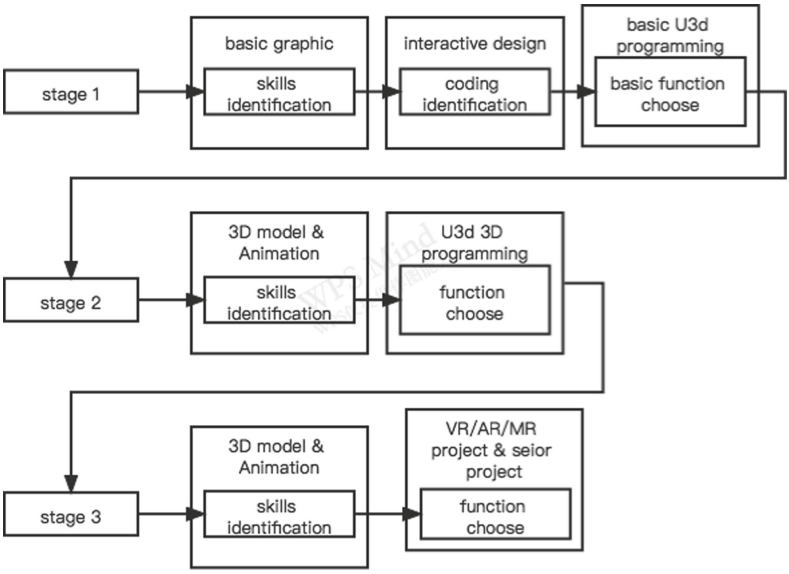

Fig. 2. Flowchart 1

In stage one, students separated graphic & image technology modules courses, basic graphic and 3D models into a quiz, which were skills identification (Fig. 3), tools in software identification (Fig. 4), functions chosen in some programming (Fig. 5). Students will award "soil" when they answered all questions correctly (Fig. 6). Stage two corresponds to students' 2rd-year learning. The type of quizzes is more diverse, which includes analyzing students' assignments and identifying tools and skills, functions choose and operate choose. All these quizzes contain digital video technology, VR programming, and project design modules courses (Fig. 7). Stage three are contained all project-based courses, for example, VR/AR/MR project, senior project. Skills identification and function choice are the main types of quizzes.

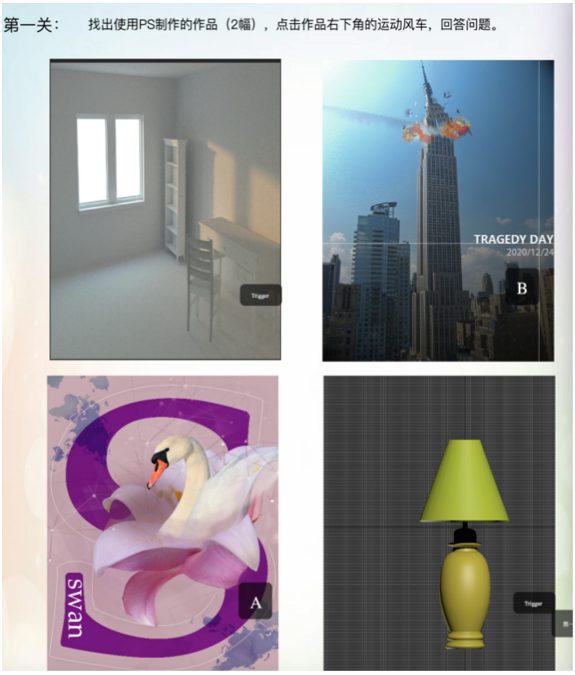

Fig. 3. Quiz1 in stage one

Fig. 4. Quiz2 in stage one

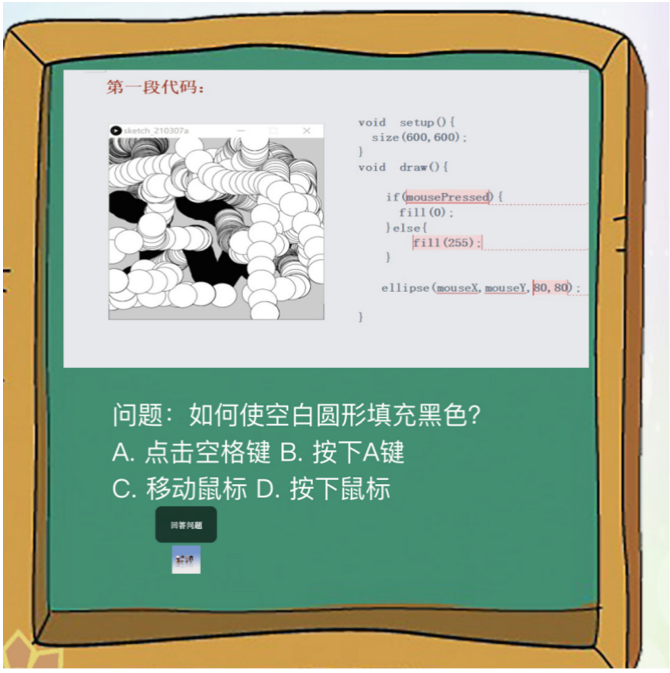

Fig. 5. Quiz3 in stage one

Fig. 6. Pic 5. Award “soil”

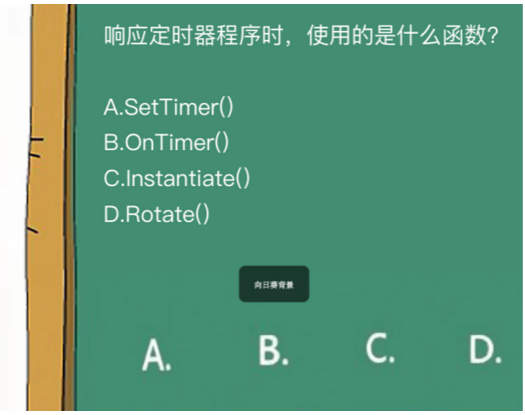

Fig. 7. Quiz in a project-based course

5 Discussion

In this study, we answered the research question of how to build VR scaffolding based on technical modeling for college students in STEAM. We interview technical learners and prototype developers at the same time. The interviewee is a second-year student in a VR major. She developed a game with three levels by learning the study manual and the three-semester courses she has studied. The interviewee reflected on her past learning experience. She was engaged in the various interactive cases and had a strong willingness to participate, she also expressed a strong willingness to learn AR technology courses next semester.

So far, we have not started experimental research with a sufficient number of learners' samples, the changes in self-monitoring and management abilities in the self-directed learning elements have not been obtained yet.

6 Conclusion and Future Directions

This study set out to combine scaffolding strategies and a self-built VR prototype, aiming at the difficulty of constructing a personal technical model for college students in STEAM. The paper took the virtual reality program as an example, sorted it out, and constructed a technology framework based on the curriculum syllabubs. The study proposed the five-step scaffolding development method in the prototype development, set hints and expert mode in the gamified prototype, set game levels according to the technical framework and rules. The hardware and software tools included pictures, video editing equipment, and rich media editors.

In the later stage, learners will use the VR scaffolding prototype to model their learning process and results according to the technology framework, and carry out teaching experiments, interviews, and works analyses.

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