Creating Virtual Reality and Augmented Reality development in classroom: Is it a hype?

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***Abstract*—The fast-growing number of high-performance computer processor and hand-held devices have paved the way for the development of Virtual Reality and Augmented Reality in terms of hardware and software in the education sector. The question of whether students can adopt these new technologies is not fully addressed. Answering this question thus plays an essential role for instructors and course designers. The objectives of this study are: (1) to investigate the feasibility of the Virtual Reality/Augmented Reality development for undergraduate students, and (2) to highlight some practical challenges when creating and sharing Virtual Reality and Augmented Reality applications from student's perspective. Study design for the coursework was given with detail. During a 16-week long, 63 Virtual Reality/Augmented Reality applications were created from a variety of topics and various development tools. 43 survey questions are prepared and administered to students for each phase of the projects to address technical difficulties. The exploration method was used for data analysis.**

***Index Terms*—virtual reality, augmented reality, user study, technology adoption**

I. Introduction

"We can't really do that...Hype!" - this is an inspiring quotation from the book of Biocca and Levy [1] which addressed the Vision of Virtual Reality in the 1900s. The unavailability of hardware and software at that time makes researchers in some areas (e.g., scientific visualization, flight simulation) uncomfortable with what Virtual Reality promised. The release of multiple consumer devices recently from expensive (e.g., Oculus Rift, HoloLens, HTC Vive) to affordable (e.g., Google Cardboard) has brought new promises to the area of Virtual Reality (VR) and Augmented Reality (AR). To take advantage of this emerging trend, the STEM fields (i.e., science, technology, engineering, and mathematics) have been putting a lot of efforts to adopt VR/AR technologies into classrooms to improve teaching and learning processes.

This adoption can be found in many studies in a wide range of subjects [4], [8], [13]. However, the majority of literature work is often restricted to the *use* of pre-developed VR/AR applications without having learners to **freely** explore alternatively available resources. Thus, the gap between available VR/AR technologies and students' ability to adopt those advanced technologies is still unexplored. This lack of research is astonishing because profound knowledge about how the lecture is designed to meet students needs would allow researchers and educators to successfully develop and implement VR/AR course in schools and colleges. Another important aspect is the perception of virtual/augmented reality from different perspectives such as students or learners. As pointed out by Psotka [10], an important need for students is the flexibility of students' choices; in other words, teachers should allow students to have the freedom of learning. As such, instructors are able to adapt their instruction to meet the needs of their students and increase their performance when the students' preferences are carefully analyzed.

From this point of view, this study focuses on the feasibility of the technology adoption in a classroom. In another word, to what extent can students create a wide range of VR/AR applications within time constraints? What are their choices among abundantly available technologies? What are the challenges in learning new technologies? And ultimately what are the motivating factors to help them accelerate the learning process? and to this end, is it a hype to create VR/AR applications in today's world? Understanding these questions from new learners' perspectives will be a good indicator for instructors to elaborate their lectures in the future. Finally, students are better prepared with broad knowledge and they select more suitable one for their careers in VR/AR development. For this purpose, a virtual reality class was carefully designed for students in one semester long to address the aforementioned research questions. As such, this paper contributes to the literature as follows:

- It explores the feasibility of developing VR/AR applications from undergraduate students' perspective;
- It extracts the challenges from students' learning process; and
- It provides an insight on students' feedback using qualitative method.

The rest of the paper is organized as follows: Sect. II reviews several studies in the literature. The study design is described in detailed in Sect. III. Research findings are presented in Sect. IV. Finally, we conclude our paper with future work in Sect. V.

II. Related Work

Zimmerman and Eber [15] reported a study for learning VR in classroom. An interdisciplinary VR coursework was designed consisting of lectures, artistic topics, hands-on lab sessions, and group-work presentations. The study pointed out that, the lack of authorization tool license and VR workstation was the major limitation to feed the needs of 16 students. Stansfield [11] presented a VR course that combined both lecture-based approach and a hands-on experience section. She argued that the VR course would provide students with more experiences for a capstone project in multidisciplinary fields regarding communication skills, research skills, and presentation skills needed for success after graduation. Zara [14] shared his experience on teaching VR courses over six years where students were mostly focused on creating computer graphic content without being immersed in the virtual world because there was no special hardware for VR. Nguyen et al. [9], [12] explored the potential of adopting VR technologies in classroom, particularly from the web-based context. Another education-focused approach is the study of Miyata et al. [6] where students collaboratively designed several VR applications as a group. Student's opinions on their learning experience and the course were investigated. During the course, students reported feeling creative and knowledgeable, developing as learners both individually and as a group, throughout the shared activity.

Several other efforts have been made to bring VR/AR into a classroom; from concepts, content, and hands-on learning experiences [5]. The challenges and difficulties found in most studies are the availability of headsets, a standard hardware platform for VR, as well as the multifaceted needs for programming knowledge and specialized software tools in VR/AR development. These difficulties are mainly due to the cost of the VR headset for testing, the compatibility of the application on the target devices, and the professional skills required for creating 3D VR content. In summary, most existing approaches primarily focused on a single software program or development framework in course design without allowing students to explore the alternatives. This study aimed to fill this gap.

III. Methodology

The general aim of the present study was to investigate the feasibility of the VR/AR technology adoption in the classroom from students' perspectives. It is a very challenging task for students to adapt state-of-the-art VR/AR hardware/software programs to their own app development based on their preferences and experiences within a time constraint and limited basic knowledge. To alleviate this issue, a teaching method should be carefully designed in such a way that it can maximize student learning and increase the learning curve. In our approach to the course design, students' engagement and motivation are the most critical factors contributing to the learning outcomes. Of the available teaching methods [2] (e.g., inquiry-based learning, situated-based learning, task-based learning, project-based learning, and studio-based learning), studio-based learning approach was chosen because its characteristics encompassed the critical factors. In this study design, students are heavily involved in three development projects, and each project is designated to answer the research questions in the following section.

A. Research questions

This study seeks to answer to following research questions(RQ):

- **RQ1**: To what extent can students adopt a wide range of VR/AR development tools to create their applications?
- **RQ2**: What are students' choices among the currently available VR/AR development tools?
- **RQ3**: What are the technical challenges from the students' point of view?

B. Participants

The present study was conducted with university students enrolled in the Virtual Reality course of computer science. Initially, there was a total of 41 students, after the first three weeks, three of them dropped from the course. As such, we had a total of 38 students, of which 33 students are undergraduate, 3 masters and 2 doctoral students. There were 32 males and 6 females. The average general programming experience is 3.5 years.

C. Study design and procedures

The study mainly utilized the studio-based learning approach [2] which has the following characteristics:

- **C1**: Project-based assignments should be provided to students.
- **C2**: Student learning outcomes should be periodically evaluated both formally and informally through design critiques.
- **C3**: Students should be required to engage in critiquing the work of others.
- **C4**: Design critiques should revolve around the artifacts typically created by the disciplines.

Based on the above guidelines, the entire coursework was divided into five main activities which were carried out for 16 weeks. In addition to the studio-based learning strategy, traditional lecture-based learning method was also considered. Each activity is described as follows:

1) *Activity 1 - Learning the basics*: Prior to project development, short lectures/tutorials were provided at the beginning of the course to present an introduction to VR/AR, the state-of-the-art of current VR/AR software tools, and the principles of visual design.
2) *Activity 2 - Self-learning*: To motivate and engage students in active learning, each student will be given a 5-minute talk on the current VR/AR technology. The topic can be drawn from a suggested list or from student's interest. Thus, a wide range of alternative resources would be presented.
3) *Activity 3 - Working with projects*: During the course, students are actively involved in well-designed three projects (characteristic **C1**). The first project is to create a simple 'dream' house web-based VR application by utilizing the idea derived from the sample project. In the

second project, learners take a further step by focusing on a more advanced topic (i.e., water). In the last project, students have a complete freedom to develop any types of VR/AR applications.

4) *Activity 4 - Scaffolding to support students*: Instructors and teaching assistants (TAs) are served as mentors to support students in learning. Since students are engaged in self-teaching and learning, a communication channel for them to ask, answer, and explore is essential. In our study, we use *Piazza*[1] as a platform to exchange information.
5) *Activity 5 - Evaluation and design critiques*: Four assessments are conducted to get feedback from students through the course. Students' opinions are collected by a means of an online survey tool (i.e. Google Form). The evaluation data are gathered at the end of each project, and then cleaned and coded for analysis. Each project is assessed by both instructor and students (characteristics **C2, C4**). In the first project, the survey questions capture students' choice for a web-based VR software program and their approaches to a simple problem. In the second project, a peer-review survey is conducted for each individual project (characteristic **C3**). The survey for the third project is similar to the second project's one. A comprehensive course evaluation survey is conducted at the final day of the course regarding the overall information on the course. The questionnaire is evaluated and updated by the instructor and the TAs (Teaching Assistant), to ensure that all questions are easy to understand and they are inclusive of students' knowledge on VR development. Survey items are based upon perceived utility and ease of use of the technology, which are the major constructs of the technological acceptance model (TAM) theory [3]. TAM has proven to be a useful theoretical framework in explaining certain aspects of information technologies as well as understanding user behavior toward using these technologies.

D. Project results

Project outputs: There are a total of 63 VR/AR applications as project outcomes, including 37 'dream' houses (Fig. 1) in the first project, 12 VR/AR applications (Fig. 2) in the second project as a team project, and 14 VR/AR applications in the third project (Fig. 3). The short descriptions, tools and application types of the projects are shown in Table I.

Project delivery. The VR/AR applications are presented by students' own device or Oculus Rift (upon requested). The running applications are shown on the projector as in Fig. 4. Students are requested to submit a report that addresses the issues and challenges faced during the project developments. These reports are also used for data analysis in the next section.

[1] https://piazza.com/

TABLE I
SHORT PROJECT DESCRIPTION DELIVERED BY EACH GROUP (G) IN PROJECT 1, 2 AND 3

P1	**Short description**	**Core tool/add-on**	**VR/AR**
G1-34	'dream' house	A-Frame	WebVR
G35-36	'dream' house	A-Frame, ThreeJS	WebVR
G37	'dream' house	Unity3D	WebVR
P2			
G1	Water management	Unity3D, Oculus Rift	VR
G2	Water contamination	Unity3D	VR
G3	Water reservation	Unity3D	VR
G4	Water management	Unity3D	VR
G5	Flood evacuation	Unity3D, Oculus Rift	VR
G6	Water formation	Unity3D, Oculus Rift	VR
G7	Water elevation	Xcode, ARKit	AR
G8	Water management	Unity3D, Vuforia	AR
G9	Water simulation	Unity3D	VR
G10	Climate change on water	Unity3D	VR
G11	Water management	Unity3D, Vuforia	AR
G12	Underground water	Unity3D	VR
P3			
G1	Electricity generation	Unity3D, Oculus Rift	VR
G2	First-person shooter game	Unity3D, Oculus Rift	VR
G3	Sponge Ball game	Unity3D, GEAR SDK	VR
G4	Space simulator	Unity3D	VR
G5	Meditation application	Unity3D, Google SDK	VR
G6	Social chat	A-Frame	WebVR
G7	Human Anatomy	Unity3D, Vuforia	AR
G8	Water elevation	Unity3D, Oculus Rift	VR
G9	Throwing balls game	Unity3D, Oculus Rift	VR
G10	Rescue game	Unity3D	VR
G11	Objects measurement	Xcode, ARKit SDK	AR
G12	Water management	Unity3D, Vuforia	AR
G13	Flood evacuation	Unity3D, Oculus Rift	VR
G14	Water management	Unity3D, Vuforia	AR

E. Surveys for evaluation

43 survey questionnaire items are constructed and administered to students for each phase of the projects. These survey items consist of three different sets depending on the type of projects. The first set of survey items in the first project explores the student's choices and their approaches to WebVR experience. Using the second set of items for the second and third projects, on the other hand, the peer-review assessments focus on highlighting knowledge dissemination and design critiques. The last set of survey items pertains to the overall evaluation of the course.

IV. RESULTS

The potentials of VR/AR development tools were explored in a classroom setting using descriptive statistics and qualitative analysis of survey data.

A. RQ1: To what extent can students adopt a wide range of VR/AR development tools to create their applications?

63 VR/AR applications ware obtained as project outcomes of the course, including 38 WebVR applications, 6 AR applications, and 19 VR applications as shown in Table I. The different levels of technology acceptance were observed across the different types of projects.

For the WebVR project, learners reported that their chosen tool was moderate to use (M = 5.08, SD=2.11) with a relatively high expectation (M = 7.47, SD = 2.18) to create their WebVR

Fig. 1. Web VR applications created by inter-discipline students for the class Project 1.

applications. Initially, the majority of students did not need advanced skills (97.22%) to complete the project, only 2.78% of students needed more efforts. On average, it took more than one week to finish the project concerning both learning and implementing the application. This estimation would have been more precise if we measured the duration in hours because some students might spend the whole day to accomplish their project while others would allocate this time on multiple days. For the second project, we evaluated the technology adoption based on the peer-review assessments. Overall, most students reported that other group projects were difficult (M = 8.24, SD = 0.75), due to the flexibility in choosing developments tools, types of applications, and boundless topics (as shown in Table I). Thus, by looking through students' lens we would argue that projects should not be too difficult nor too easy. For example, the usefulness of educating water (M = 7.89, SD = 1.06), interesting (M =7.94, SD= 0.80), innovation (M = 8.18, SD = 0.93), visual design (M = 8.28, SD = 0.93), sound effect (M = 6.85, SD = 1.87), usability (M = 8.10, SD = 0.60). These evaluation scores did not change much in the third project; project difficulty (M = 8.65, SD = 0.77), interesting (M = 8.62, SD = 0.93), innovation (M = 8.63, SD = 0.89), visual design (M = 8.94, SD = 0.66), sound effect (M = 8.53, SD = 1.52), usability (M = 8.76, SD = 0.78).

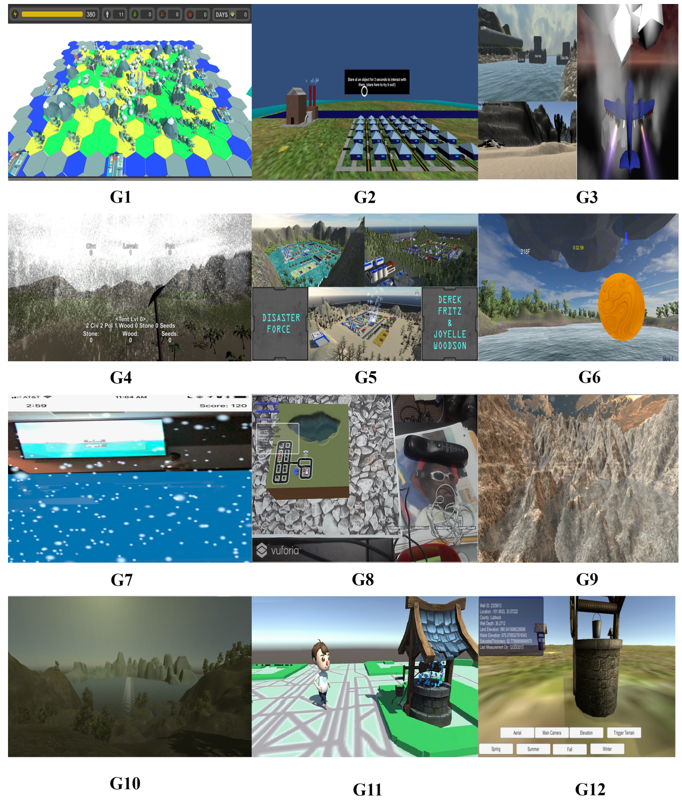

Fig. 2. Water-related VR/AR applications of 12 groups delivered for the class Project 2.

At first, 73.5% of students had poor and fair knowledge/skills of VR/AR, however, in the end, this percentage decreased to 3%. 14.7% of students felt highly confident about their VR/AR knowledge, 38.2% of them were very good at their understanding and 44.1% found it would be good enough. These findings would indicate that students were enriched with the learned VR/AR skills. The survey results also showed that 91.2% of students gained much knowledge about VR/AR through the course while completing the projects. Due to the flexible choice of topics and development tools, forming an idea for a project was moderate for most students (67.6%). However, when it comes to project development, nearly half of the class (41.2%) found it hard to develop due to learning new programming languages, while 47.1% of them found it moderate. Project deployment seemed to be challenged when 8.8% of students found extremely difficult.

B. RQ2: What are students' choices among the currently available VR/AR development tools?

For the first project, the majority of students (91.67%) chose A-frame as their library to accomplish the project, two students used both A-frame and Three.js, and only one student came up with Unity as shown in Table I. 77.78% of students reported that it was mostly due to instructors' suggestion. Although A-Frame claims to be one of the most natural libraries to create Web VR for everyone [7], 8.33% of students still found it difficult to use, part of the problem

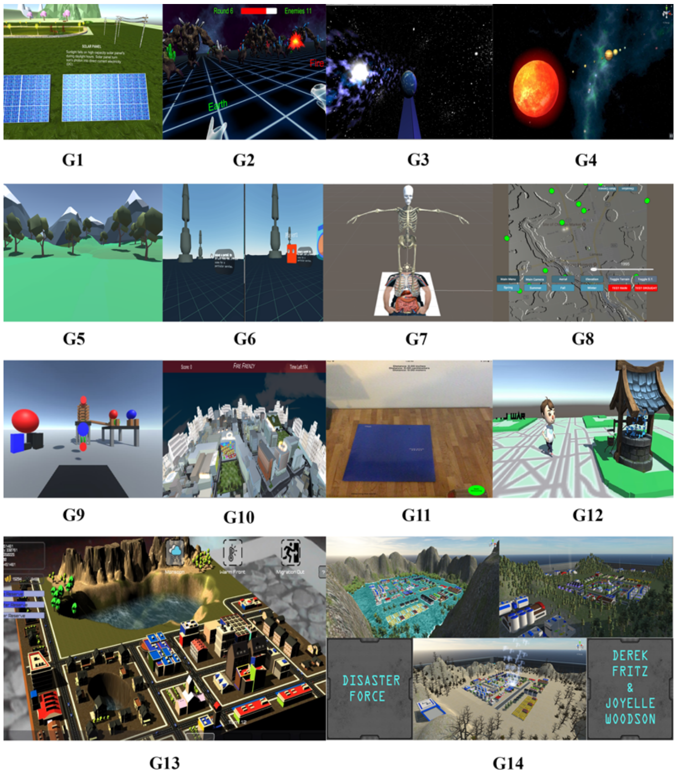

Fig. 3. VR/AR applications of 14 groups delivered for the class Project 3.

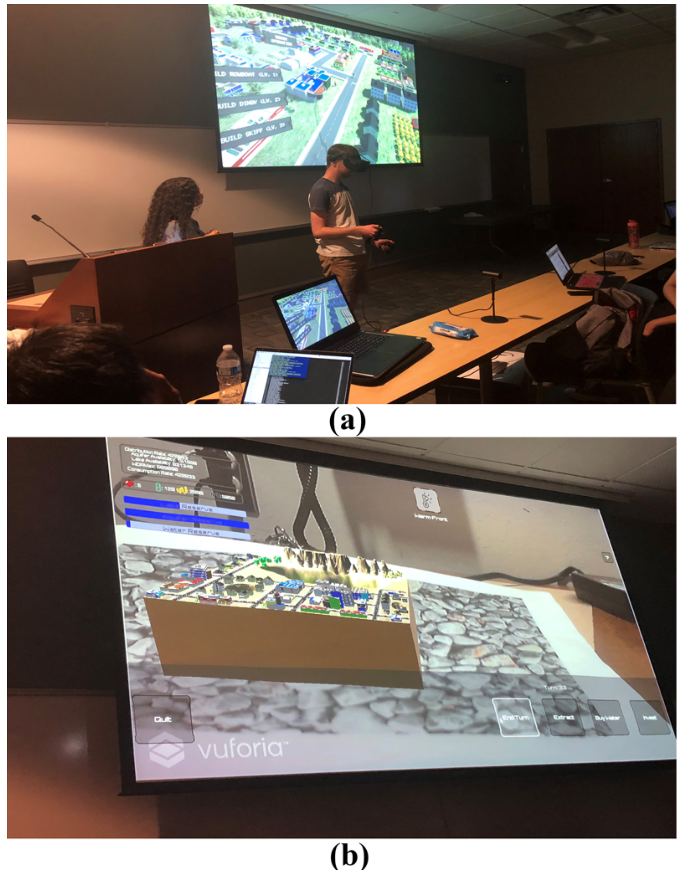

Fig. 4. Presentation delivered by students. (a) VR application on Oculus Rift device, (b) AR application on Android phone.

because they had never had experience with web development before. The most time-consuming part of the project was the content creations. Creating 3D models was a burdensome task, especially to those who were new to 3D model world, this odd job was one of the reasons why a large portion of students (25%) decided to download and reuse existing models from the internet. When evaluating protect created by each student, we found that creative students often made 3D models from the basic shapes (e.g., a cube, a sphere, and plane), these low poly models thus increased the performance of the application significantly compared to those downloaded from the internet in terms of rendering and interactivity. Only a few students wanted to challenge themselves by using third party software to create models (5.56%). Although an example project was provided at the beginning to accelerate the learning process, students' feedback showed that they still needed to go to the tutorial documents on the chosen library website (19.44%)

Data in Table I shows that 22 out of 26 projects (88.5%) for the second project were created in Unity3D, 2 (7.7%) in Xcode and only one project was created with A-Frame. This result indicates that most students came up with Unity3D when building VR/AR applications. After the course, when they were asked the preferable choice, 94.1% of them preferred Unity3D application development over other alternatives, only 5.9% of them liked to work with WebVR. Seven applications were created for Oculus Rift headset. For AR applications, the Vuforia package add-on was preferred compared to the native add-on application (Xcode).

Due to the limited time for the third project, the study found out that the behavior of students on picking up the developments tools depended mainly on three factors: (1) the availability of target devices, in which students preferred to develop an application that can run on their devices rather than others. (2) The needs to go in-depth in which they wanted to learn more about one subject (e.g., extended from the second project, improved the performance and visual design, or deployed the current app on multiple devices). And (3) the needs to go broader, where there was a desire to learn and experience different types of VR/AR (e.g., if their second project was VR, they wanted to try AR in the third project and vice versa).

C. RQ3: What are the technical challenges from the students' point of view?

Reports of the project which served as documentation were created to address the challenges, technical difficulties and lessons learned during the project development. There were some challenges that needed to be addressed in the WebVR application development: the first one was the fidelity of the 3D models, the more fidelity, the bigger its size and thus the longer time it takes to load. The second challenge was the stability of the library since web-based VR is still in the early day of development. And the third challenge was the feeling of dizziness after immersed in the WebVR environment.

For the second and third projects, we could summarize some typical challenges based on reports and survey response as follows: (1) **Collaboration**: This was the most challenge problem found in all groups, where each member of the group was responsible one part of the project. Although a common repository was suggested (i.e., Github, Google Drive, Dropbox) but for some reasons, those repositories did not work as expected (e.g., delayed in synchronization, file size upload limit) which in turn make it difficult to work remotely (‘*Upon completing work on separate branches, we ran into several issues when trying to merge everything into the master branch. Various scene aspects such as models, scripts and settings were not present*’). One group’s suggestion alleviated this problem as ‘*We ended up using Unity’s Collaboration which circumvented the problem of change management due to its simplicity and seamless integration with the Unity Environment*’. (2) **API version Incompatibility:** The first type of API version incompatibility was between the API developers kits with the current version of Unity (e.g., ‘*Dealing with library/hardware incompatibilities and fixing problems with the tools that we are using*’). Because each member of a group used different Unity’s version, an error occurred when the project was merged. The second type of API version incompatibility was between the API developers kits with the target devices which resulted in black screen on the target devices (e.g., current Vuforia API did not work with Apple iOS 11 or Android OS lower than 4.0) or *‘implementing models to match the environment in ARKit’*. Students had to find a compatible device to deploy their application since iOS did not allow to downgrade the upgraded OS, this problem was the main reason for project extension. (3) **Lack of supporting hardware:** Two Oculus Rift devices are always available, three groups said it would have been better if they have computer support hardware since ‘*no one on the team had a supported GPU and travelling to the lab to debug, attempt to set up VR, and debug again wasn’t viable, this was not possible*’ or ‘*using a computer that had a difficult time running 3D worlds*’. (4) **Learning curve:** As mentioned earlier, learning new programming languages takes time, especially putting them in practices ‘*It was learning the new IDE’s, learning to program in C was very new and my first attempt resulted in a 800+ line script which I should have broken down.*’. Most students’ reports showed that ‘*time was the biggest constraint*’ that they *‘they do not have enough time’* to work on projects as ‘*there are a lot of details we put in our project, and they took time*’. And (5) **Models and interactions:** Like project 1, creating a high fidelity model still takes time so in project 2,3 students mostly used free 3D models from the internet and they tried to focus their time on the interactions since ‘*the most challenging task was creating scripts for interactions.*’ because each type of target devices supports only a set of interactions (e.g., Google Cardboard supports interactions by a touch button and gazing whereas Oculus Rift allows two-hand control) and the availability of library.

V. Conclusion and Future work

This paper examined the feasibility of having students to learn a wide range of available VR/AR technologies for WebVR, VR, and emerging AR applications for 16 weeks. The course was structured based on five activities: *Learning the basics*, *self-learning*, *working with projects*, *scaffolding to support students* and *students’ evaluation*. A large number of VR/AR applications were developed with various topics, which indicates that students were able to adopt those necessary tools and create the applications in their own interest. Thus, we would conclude that **VR/AR is not a hype**. In future work, a more comprehensive user study on students’ VR/AR applications will be conducted to evaluate student learning outcomes more thoroughly and reliably using the extended technology acceptance model with task technology, perceived visual design, perceived usefulness, perceived easy of use, self-efficacy, and intention to use.

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