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Teaching College Classes with Virtual Reality

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***Abstract*—**Recent advances in virtual reality (VR) technologies have made it possible for students to experience a virtual on-the-scene or virtual in-person observation of an educational event. In an experimental class, the author uses VR, particularly 360° videos, to virtually engage students in an event, through a wide spectrum of educational resources, such s a virtual "bystander." Students were able to observe the event as if they were physically on site, although they could not intervene with the scene. The author will describe the adopted equipment, specification, and cost of building them as well as the quality of VR. The author will discuss (a) feasibility, effectiveness, and efficiency of using VR as a supplemental technology to teach college students and criteria and methodologies used by the authors to evaluate them; (b) barriers and issues of technological implementation; and (c) pedagogical practices learned through this experiment. The author also attempts to explore (a) how VR could provide an interactive virtual in-person learning experience; (b) how VR can possibly change traditional college education and online education; (c) how educators and balance six critical factors: cost, time, technology, quality, result, and content.

***Keywords*—**Learning with VR, virtual experience of learning, virtual in-person learning, virtual reality for education.

I. Introduction

THE authors and their colleagues frequently encountered a situation in which they wish to engage students in an event, a phenomenon, or a condition as a "bystander" to observe from the first-person perspective; therefore, the engaged students can exchange their findings, discuss their opinions, and critique one another based on their own judgments. The term "bystander" is defined as a person who is physically present at an event or incident but does not take part (no interaction, no participation, no intervening) in what is happening on the scene.

For quite some time, the authors rely on three media to show an event to students: (a) oral or written descriptions; (b) still images or photos; and (c) traditional 2-dimensional (2D) videos.

In the scenario that the authors choose to verbally describe or present to students what happened and how they happened, the authors' personal opinions, perspectives, and standpoints inevitably produce some bias on the descriptions they provided to students. As a result, students frequently drew conclusions based on the provided descriptions and seemed to be influenced by the authors' descriptions to certain an extent. Not only have students missed chances to investigate the topics from their first-person view, but also have lost opportunities to exercise their analytical and critical-thinking skills.

The use of still photographic image and video could provide first-person-perspective experiences. However, the limited dimension of images or screen size of video, which often forces photographers or cameramen to use close-up shots. Consequently, they typically cannot provide a trustworthy overview and might not pass the authors' "relevance tests." A "relevance test" is defined as the verification of content to ensure the relevance and authenticity as well as intention. Even students raise questions like "Is there anything outside the screen that you don't want us to see?" Reference [15] explained how a picture can lie. Fig. 1 illustrates how an image could twist one's viewpoint. Without the picture on the right for comparison, the picture on the left could mislead the viewers to assume that the picture was taken while the young man is sitting inside an airplane. Fig. 1 also leads the authors to believe that a surrounding view of a scene of an event or incident is probably what it takes to provide students with the opportunity to analyze the scene from a panoramic view. With the intention to minimize the influence an instructor can put on students, the authors have been searching for equipment, technologies, and techniques as well as best practices to serve as supplementary instructional tools. Recent advances in 360° VR technology seems to point a direction to the authors.

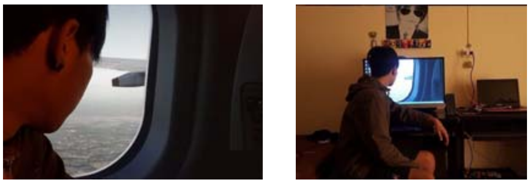

Fig. 1 An image that could mislead [16]

II. What Is VR, What Is 360° VR, and What Is 360° Video?

VR is the use of computer technology to simulate an environment, with or without the viewer interacting with the virtual content in the simulated environment. VR is usually achieved by wearing a VR headset, such as the Oculus Rift. It is necessary to distinguish VR from the rising Augmented Reality (AR). AR is the projection or integration of a layer of virtual content into a real environment. Although both VR and AR technologies attempt to immerse the viewers, AR blends the real world with virtual objects and requires viewers to interact with virtual objects with a clear distinction of what is real and what is virtual. VR is designed to isolate viewers from the real world by immersing viewers in a virtual world. In theory, a high-quality VR is difficult for viewers to tell the difference from what is real and what is virtual.

360° VR is a subset of VR that provides viewers with an audiovisual simulation of a surrounding environment in an altered, augmented, fabricated 360° virtual world to allow viewers to look around the environment in all directions, just as they do in the real world. 360° VR can be used for many purposes other than entertainment, such as virtual tour,

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advertisement, documentary, and ironically pornography.

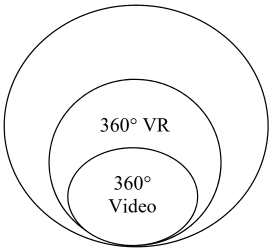

Fig. 2 “Has-a” relationship of VR and its subsets

Within the 360° VR subset, 360° video opens a new horizon for content producers to deliver omnidirectional video content of a scene for viewers to choose what direction to watch from, as if they are bystanders at the scene. Fig. 2 illustrates the “has-a” relationship among VR, 360° VR, and 360° video.

III. Why 360° VR?

As a matter of fact, educators and researchers have agreed that VR technology can be used in most types of training that involve a physical environment, such as pilot and driver training, surgery, human anatomy, remote controls of robots, and undersea or space exploration [7], [8], [10], [14]. The effectiveness of VR on students' learning outcomes has been reported by researchers [11], [13]. The authors found VR can effectively enable the conceptualization of abstract theories. In a Chemistry course, VR has been used to visually explain how two hydrogen atoms bonded to an oxygen atom. VR can also lower the complexities and cost of learning technical skills. The National Aeronautics and Space Administration (NASA) have been using VR to train astronauts [2].

In an attempt to guide college students to exercise their critical thinking skills, the authors often get students involved in controversial topics, and encourage them to wrestle with contradictions and dilemmas. Students will then struggle to validate multiple sources of viewpoints, try to avoid being influenced by judgmental perspectives, confront the force that tries to twist the students' own perspectives, analyze their own findings as results, and present their outcomes in the exercise. By limiting the scope to help students gain an experience as a bystander, the authors believe that the recent advances of 360° VR, particularly 360° videos, have reached a point that make them a good candidate of educational technology.

IV. Has VR Become a Reality for Education?

The availability of VR in education has been discussed for decades; however, it is not promising until 2016 when the price of VR headsets (goggles), applications, 360° cameras, supporting equipment (such as smartphones and tablets), and free sources of 360° VR content became reasonably affordable. To the authors, it is probably time to investigate the feasibility of using 360° videos as an education technology.

A VR headset is a goggle-type display unit that enables viewers to experience VR. Advanced headsets like the US$700 Oculus Rift, US$800 HTC Vive, and US$700 PlayStation VR are stereoscopic devices with built-in stereo sound speakers and head motion tracking sensors. They are also known as head-mounted displays (HMDs). In fact, even with no audio or head tracking features, an inexpensive headset like US$30 Google Cardboard that holds a Smartphone's display in front of a viewer is functionally sufficient to watch 360° videos [3]. Except for gaming or entertainment, an inexpensive headset, such as US$80 Google Daydream View or a US$100 Samsung Gear VR, allows viewers to experience 360° VR that used to require advanced headsets like Oculus Rift or HTC Vive. During the experiments, the authors used several headsets that cost less than US$20, including brand names like Celexon, MVMT, North, and EVO. Fig. 3 is a foldable EVO headset for smartphones used by the authors, which cost US$4.99 at the time of purchase.

Fig. 3 A low-cost, foldable VR headset used by the authors

On the software side, many open source or free 360° video players are available today. Table I is a sample list of them.

TABLE I
FREE APP

Application	Platform
YouTube	Android / iOS
Google Cardboard	Android / iOS
VRSE	Android / iOS
NYT VR	Android / iOS / Windows
Orbulus	Android / iOS
Jaunt VR	Android / iOS
Homindo	Android / iOS
RYOT VR	Android / iOS
VR Player	Android / iOS / Windows
LiveViewRift	Windows / Mac
5KPlayer	Windows / Mac
Total Cinema	Windows / Mac
GoPro Player	Windows / Mac / Linux
Janus VR	Windows / Mac / Linux
sView	Linux

As to the free sources of 360° videos, many web sites now provide 360° videos for multiple platforms including mobile devices with the YouTube.com site being probably the most comprehensive repository. Table II is a sample list of websites for 360° videos. To instructors of humanities and economics, the Economist, Time Inc., and National Geographic, and Discovery are also good resources.

In addition to the expensive 360° camera like US$60,000 Nokia OZO, US$25,000 Sphericam 2, and US$15,000 GoPro, many cameras are under US$700 for instructors to produce 360° movies if the resolution and video quality is not a critical issue. Table III is a sample list.

TABLE II
360 VR CONTENT PROVIDERS

Website	URL
New York Times	nytimes.com
Jaunt Cinematic VR	jauntvr.com
360 Rise	360rize.com
Little Star	littlestar.com
Discovery Channel	discoveryvr.com
WAVRP	wavrp.com

TABLE III
360 CAMERAS

Camera	Price
Nikon KeyMission 360	US$550
Giroptic	US$500
V.360	US$500
Allie Cam	US$500
Kodak PixPro SP360 4K	US$450
360 Fly	US$400
Richh Theta S	US$370
LG 360 Cam	US$200

The minimum personal computer (PC) specification required by both the Oculus Rift and HTC Vive is: (a) an Intel Core i5-4590 or better processor, (b) an Nvidia GeForce GTX 970/AMD R9 290 graphics card or better, and (c) 8GB or larger of RAM.

The authors built three testing VR-enabled PCs and rated then as "high end", "middle", and "low end". The "high-end" one has a total cost of nearly US$1,000 which is very close to the price suggested a CNET article [1]. Table IV is the specification of "middle" which costs approximately US$650.

TABLE IV
"MIDDLE" PC SPECIFICATION

Component	Description
CPU	Intel Core i5-6500
Motherboard	Gigabyte H170-Gaming 3
RAM	8 GB DDR3 2400 MHz
GPU	EVGA Nvidia GeForce GTX 970 Superclocked
SSD	250 GB Samsung 850 Evo
HDD	2 TB Seagate
Power Supply	EVGA 500B (500 W) 80+ Bronze

TABLE V
"LOW-END" PC SPECIFICATION

Component	Description
CPU	Intel Core i3-6100
Motherboard	ASRock Z170 Pro4s
RAM	8 GB DDR4 2400 MHz
GPU	2x Sapphire Nitro RX 480
SSD	12GB Sandisk Ultra
HDD	2 TB Seagate
Power Supply	EVGA 600B (600 W) 80+ Bronze

In reality, the "low-end" uses the Intel Core i3-6100, and in the authors' opinions, it works fine with the Oculus Rift Development Kit 2. Table V is the specification of the "low-end" PC which costs less than US$400.

V. IS QUALITY OF VR A CONCERN?

As results of the authors' experiments, blurry video is a pitfall, although it is not significant enough for instructors to renounce the option of using of 360° videos in the classroom. It is necessary to note that the quality of VR could vary from equipment to equipment, and the price could be a dominant factor of quality. The inexpensive headsets may not provide thrilled VR experiences that are designed for Oculus Rift or HTC Vive.

In terms of 360° video, one major complaint is the video quality--most 360° videos look pixelated and blurry. Being pixelated means individual pixels on a screen are apparent to the naked eyes. Reference [17] identifies three factors contributing to the video quality issue: (a) resolution, (b) quality of VR camera, (c) streaming technology. However, the authors believe bandwidth is the main cause of low-resolution, and the quality of headsets is an additional factor to be investigated. When the Internet connection is not fast enough, YouTube serves viewers with the low-resolution version of videos. By the way, many 360° video producers share an interesting finding--YouTube seems to lower the video resolutions after the producers uploaded their videos.

For smartphone viewers, Google provides five fixes and claims to be able to improve the visual quality. Results of the authors' experiments seemed favorable to these five fixes: (a) Viewer Distance, (b) Screen Settings, (c) App Settings, (d) The Lenses, and (e) Crappy Viewer [5].

By limiting the scope to the use of 360° video as a supplementary instructional tool, the authors believe that video quality is a concern, yet it is not an issue or a barrier.

VI. PEDAGOGICAL PRACTICES

The pedagogy is to virtually engage students to an event or incident related to the course objective as a bystander, and to require students to: (a) make observations from the first-person perspective, (b) collect data, information, and evidence to analyze from the first-person point of view, (c) think about the standpoints they are on and how authentic their observations could be, (d) describe their findings and results, and (e) offer recommendations if necessary.

The authors believe the use of first-person perspective in observing, analyzing, and speculating an event or incident is a privilege, because it reflects a student's authentic perspective regardless of being right or wrong. Being able to make judgments without being influenced by a judgmental source is probably a critical-thinking skill everyone needs in the information-overloaded digital world.

In a Project Management course, for instance, students watched a 360° video about how an aggressive project team member attempted to take control of the procurement decision. The authors allowed every student to choose whichever direction in the surrounding environment in which to observe the event; however, each student must individually describe her/his findings as a bystander, and offer recommendations based on the first-person viewpoint about the action a project manager should take. Throughout the activity, the authors did not intervene with students as much as possible by being bystanders to the bystanders.

In a Product Development course, students can watch a 360° video of a Tesla manufacturing plant to observe how robots are used in a highly automatic production line.

In an Operation Management course, students can take a virtual tour to an Amazon.com warehouse to observe how algorithmically controlled equipment handle tasks like product picking, packing, and package sorting. They need to evaluate the possibility for robots to completely replace humans in a warehouse. They will also observe how computers literally instruct human workers on what to do, where to put packages, and how to sort them. Then, write a report to explain who is controlling who from their first-person perspectives.

In a Sociology course, have students take a 360° peek into a rally during a street protest in New York city for a social event, and then offer their first-person viewpoints about the legitimacy of the protest in the classroom.

In an Environment Science course, instructors can guide students in conducting an investigation of a village in the Fukushima Prefecture of Japan, and then discuss whether the US should continue to have faith in nuclear power after years of the nuclear disaster on March 11, 2011.

In a Networking course, students can have a virtual field trip to a Google data center to see how company protects customers' privacy as well as the efforts to make the data center efficient and green.

It is now possible for all students to virtually sit in an Uber self-driving car to experience the technology they will soon enjoy in their real life.

Through the exercise, students move from making observations based on first-person perspective to identify and analyze facts, and to question and make inferences about the materials. The authors believe this is a good exercise for students to develop critical thinking skills. It helps students to be both critical and analytical as they read and examine documents and objects in the future. This is probably a skill everybody needs to acquire to live with the World Wide Web (WWW) in which "fake news" is excessively available.

VII. Effectiveness and Efficiency

Effectiveness reflects how the pedagogy produces a desired outcome, while efficiency indicates what is produced with the same consumption of resources. The methodology of the authors' experiments is to select two classes of the same subject as the "experimental group" and "control group". It is necessary to note that DeVry University encourages small class size to allow for an intimate, highly engaging learning environment. Most classes have sizes of five to 10 students; therefore, it is difficult to collect data from a large population for a more precise statistical analysis. Typically, there is only one class of a particular subject per session. If a group is selected as the "experimental group", then the "control group" is another class that is at least one session apart from the "experimental group".

Measuring the quality of a person's viewpoint on an event or incident is a subjective and often judgmental thing to do. With the purpose to guide students to observe, analyze, and judge using their first-person perspectives, the effectiveness and efficiency in the experiments are determined by how much an individual student's presented results were influenced by the instructors' intended bias. For example, the so-called "Umbrella Revolution" occurred in Hong Kong from 26 September to 15 December 2014. There are some news articles stated that "not many protesters" attended the gathering in the streets of Admiralty on October 1, 2014. Admiralty is an area at the eastern edge of the central business district of Hong Kong Island. Regardless who wrote the articles, one article was given to the "control group," while a 360° video of scenes of the streets of Admiralty on October 1, 2014, when the gathering occurred, was provided to the "experimental group." The experiment results favorably show that the use of 360° videos effectively and efficiently facilitates students to evaluate what "not many protesters" means to them.

VIII. Is Producing 360° Video Feasible for Instructors?

The authors believe this is a matter of movie production, not a matter of technology. 360° videos, in essence, are still video products. Without a good storyline, role acting, videotaping, and movie editing, the content may not fully meet the educational requirements; therefore, the time and efforts spent could be in vain. For example, in a social event, such as a protest in downtown Los Angeles, there are too many uncertainties and anything could happen. Can the movie producer accurately predict what will happen, where and when, in order to shoot the demanded 360° videos? On the other hand, organizations like DeVry University frequently require employees to participate in video-based training programs. It could be feasible for DeVry's corporate training department to manage a Hollywood-style of moving production and produce 360° videos that are suitable for the training.

IX. Barrier and Issues of Technological Implementation

In this section, the authors will describe six critical factors and how they impose barriers and cause issues: (a) cost, (b) time, (c) technology, (d) quality, (e) result, and (f) content.

VR has not yet earned the recognition of being a standard instructional tool, the authors found it difficult to obtain financial support from administrators to fund the experiments. The lack of success stories and proven records also makes it difficult to justify the funding. DeVry University is one of the leaders in the education of technology, its campuses already have at least one computer lab for students of its technical programs to work with, particularly gaming and graphics design students. With a minor modification, computers in the "Media Lab" were able to provide reasonably good VR experiences to students. However, the authors had to pay for the "low-end" PC out their own pockets. For instructors who wish to experiment with 360° videos, one possible way to recover the cost of investment is through tax credits. The Internal Revenue Service (IRS) publishes specific requirements for educators to deduct educational items. An article provided by the Intuit.com website [9] suggests educators consult with a Certified Public Accountant (CPA) for eligibility to deduct an allowed amount of educational expenses of computer equipment and software when filing a tax return. On the other hand, the cost of a Google Expeditions Kit for 30 students is US$9,999 or US$333 per student, which is still not a justifiable cost with lack of evidence that Google's VR field trips could improve student learning outcomes.

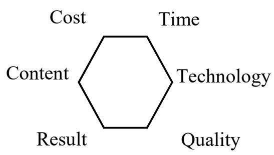

Fig. 4 The six critical factors

Instructors are solely responsible for managing class time. In an accelerated class that lasts for only eight weeks or shorter, instructors may not have the luxury to spare class time to have students watch 360° videos one by one. The authors chose to: (a) leave at least one set of equipment in an open lab, with the permission of lab administrators, (b) require students to go to the lab to watch the designated videos prior to the due date, and (c) prepare either PowerPoint slides or written reports or both using their first-person perspectives to describe their findings, results, and/or recommendations.

Using 360° video as a supplemental instructional material is probably still in its early infancy; therefore, there are currently limited sources to turn to for implementing best practices or classroom standards, although both Pearson & Houghton Mifflin Harcourt have recently announced their initiatives to bring VR-embedded content to educators.

Unlike any matured products, VR equipment suppliers are competing to define the commercial standard; therefore, investing in equipment is risky in: (a) total cost of ownership, (b) issues of compatibility, and (c) accelerated rate of technology obsoleteness. For example, while Oculus' equipment specification is still in use, academia might have to adapt Microsoft's new specification for Windows 10 VR headsets, giving the consideration that Windows OS is the dominant PC OS in academia. The following lists Microsoft's minimum specifications [6] for the readers' reference.

1. CPU: Intel Mobile Core i5 (e.g. 7200U) Dual-Core with Hyperthreading equivalent
2. GPU: Intel® HD Graphics 620 (GT2) or better, preferably DX12 (DirectX 12) API Capable GPU
3. RAM: 8GB Dual Channel (required for integrated Graphics
4. HDMI: HDMI 1.4 with 2880×1440 @ 60 Hz or HDMI 2.0, or DP 1.3+ with 2880×1440 @ 90 Hz
5. HDD:100GB+ SSD (Preferred) / HDD
6. USB: USB 3.0 Type-A or USB 3.1 Type-C Port with DisplayPort Alternate Mode
7. Bluetooth: Bluetooth 4.0 for accessories

360° VR quality is predictably hard to control due to: (a) hardware incompatibility, (b) software complexity, (c) CPU and operating system platforms, and (d) fast changing requirements according to current industrial competition. It is necessary to note that VR Technology developers are working on smell and taste and have made a remarkable progress [12]; therefore, shortening the gap between the production result of VR content and the viewers' expectations is probably a frustrating burden to the instructors who adapt VR as an instructional tool.

Genre of currently available 360° videos is limited, especially those with suitable content to be used to teach technology courses at college level. By the way, instructors wishing to integrate 360° video with their curriculums can visit the Google Expeditions site at https://edu.google.com/expeditions/ for supports.

It is necessary to address the "presbyopia symptom". Presbyopia is a vision condition where the lens of the eye loses its ability to accurately focus on a focal point. In other words, it happens when a person's eye lens can no longer accommodate well enough to provide a clear view. Presbyopia typically happens when a person turns 40 years of age or older. With presbyopia, viewers often feel fuzzy and dizzy for a short period of time after watching 360° videos.

X. Recommendations

Even when VR products are sold on the market at a reasonable price, the VR-based education industry is still in its infancy. The authors rate most of the available educational VR content as "immature" due to their poor availability, compatibility, and reusability. Currently, most VR contents are for entrainments, advertisements, propagandas, and news. They might meet the requirements for an individual classroom meeting, but may not function appropriately in most college classrooms. At the current stage, the authors only recommend college instructors to adapt 360° videos as supplementary instructional content and s a medium to allow for a panoramic view of an event or incident, and to use them only when the resources are available at an affordable price or for free. It is still be too early to be using available 360° videos as a substitute for instructional content.

The authors also suggest college instructors use 360° video as an approach to minimize the possible influence of the instructor's personal perspectives on students when engaging students to exercise their critical thinking skills in making first-person judgments.

Unlike AR, VR headsets restrict users to an individual experience [4]; therefore, using VR as instructional content for group-based learning activities is not recommended.

XI. Conclusion

Recent advances in VR have created a whole new way to bring students together with interactive learning opportunities, and the technology is on its way to becoming an effective, engaging, low-cost instructional solution for a wide range of subjects and grade levels. When being used as a supplementary instructional tool to facilitate students to exercise their analytical and critical thinking skills with first-person perspectives, 360° video is found to be effective and efficient. Although it will take a while before VR becomes ubiquitous in classrooms across the US, the authors advocates that college instructors of all subjects should begin investigating: (a) how the currently available 360° videos could enhance their teaching in certain topical areas, (b) the true cost of implementing 360° videos at their institution, and (c) the feasibility of integrating 360° videos with the curriculum.

XII. Author's Note

Despite the fact that this paper was solely written by the listed author, Professor Pedro Manrique, who had made a significant contribution to this research, was supposed to be the co-author. Yet, he chose to leave his teaching post for another career opportunity prior to the preparation of this paper. Therefore, the listed author wants to give him the credit he deserves, and as such, this paper was written using "the authors" as if it were written by two contributors.

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