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Effectiveness of using an Immersive and Interactive Virtual Reality Learning Environment to Empower Students in Strengthening Empathy and Mastery Learning

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Abstract: In this paper we present the significance of immersive virtual reality learning environment by a conducted research which emphasizes experience in learning. The case study presents the analysis and comparison of the results in students' empathy and mastery learning between using a 360° video of a modern history topic – the World War II Kokoda campaign, against an immersive and interactive virtual world learning environment (Kokoda VR). Kokoda VR was developed to have an accurate recreation of places and events. By using photogrammetry of real locations and artefacts, in combination with animated characters, Kokoda VR places the students in the centre of the action. While each of the design techniques are not new to the development Virtual Reality Learning Environments (VRLEs), the combination and then application, created an immersive experience where students not only witness the event but also relive the experience. Participants in this study are high school and university students, who were divided into groups to use the 360° video and immersive virtual world application. Surveys and post-tests were conducted to identify how significant the enhancement is in the learners' empathy, mastery learning and their relationship. Results show that using immersive and interactive virtual reality learning environment have significant improvement in empathy and mastery learning. The study also shows that there is a positive association between empathy and mastery learning but the results does not show sufficient evidence of a strong relationship.

Keywords: immersive virtual reality learning environment, empathy, mastery learning, photogrammetry

1. Introduction

The capacity of Virtual Reality (VR) to provide meaningful enrichments for educational purposes is gaining significant interests and the possibilities for immersive learning using VR are endless and evolving. Although virtual reality has existed for decades now in different forms, the high cost of using this technology inhibits it from being used in education. With the emergence of affordable head mounted displays (Southgate & Smith, 2017) and the push for development of application for the classrooms by some of the major technology companies, such as Google (Google for Education, 2019) and Facebook's Oculus Education pilot program (Oculus VR, 2018), it is now making it possible to use immersive VRLEs in the classrooms. However, there is still a gap between claims for the usefulness of VR in academic learning and scientific research testing these claims.

The goal of the present study is twofold. The first part is to compare the instructional effectiveness of immersive VRLE in increasing empathy and mastery learning, compared to a 360° video. Empathy and mastery learning are two of the important salient features of VR applied in education (Abadia, Calvert & Tauseef, 2018). This research question has important practical implications concerning whether it is worthwhile to use immersive VRLEs in classrooms because

developing them is resource intensive compared to 360° videos. The second part is to analyze the relationship of increased empathy to student's mastery learning. For the purpose of this study, empathy is defined as "sensitivity to, and understanding of, the mental states of others" (Smith, 2006); and mastery learning, which was introduced by Bloom (Bloom, 1968), maintains that students must achieve a level of mastery (e.g., 80% score on a test) in pre-requisite knowledge before moving forward to learn subsequent information.

Several researches have shown that empathy assist students in having better academic achievement (Decety & Ickes, 2011; Bonner & Aspy, 1984; Mangione, Discepolo, Tore, Tore, Cozzarelli and Corona ,2013) and immersive VRs are effective tools in increasing empathy from its users (Shin, 2018; Shin & Biocca, 2017). The significance of this objective is to determine how the level of empathy is positively correlated to students' engagement in the learning environment that leads to mastery learning in the immersive VRLEs.

To serve this purpose, we created a VR experience for teaching history called Kokoda VR. Kokoda VR was designed and developed as a 40-minute educational experience to immerse Australian high school students in a significant moment in modern Australian history. By blending archival information such as photos, film and diary entries with virtual re-enactments, Kokoda VR provides the most complete portrait of a specific time and place. Using Kokoda VR and 360° videos, the research is conducted, and the results are analyzed and presented for the said above stated goal.

The paper is organized as follows: section 2 reviews previous work on VRLE's that afforded increase in empathy and learning. Section 3 discusses the development of Kokoda VR. Section 4 presents study design while section 5 discusses the results and analysis respectively. The paper is concluded in section 6 outlining the future work.

2. Related Literature

This section presents relevant studies of VRLEs that measures empathy and learning; and literatures that looks at the benefits of increased empathy to learning.

2.1 Empathy in VRLE

Empathy is an important instructional element that can increase students' interests (Rehan Dar, 2016. Preceding studies have demonstrated that VR can increase the empathic response felt by users, when compared to the same experience viewed in 2-dimensional presentation (Kandaurova and Lee, 2018; Schutte and Stilinović,. 2017; Shin and Biocca,2017). However, these studies were not tested on a VRLE with an immersive narrative set in a realistic 3D environment. This paper presents the role of a VRLE with a linear narrative has on user empathy in an immersive learning environment.

2.2 Learning in VRLE

The following studies show that virtual reality has great potential in improving learning outcomes for education across different fields. Mastery learning were measured by studies in VR applications in the areas of space education (Bhargava et al, 2018), aviation (Chittaro and Buttussi, 2015), medical education (Bruno, Ongaro &Fraser, 2007), and construction (Lucas, 2018). These studies used pre and post-tests to measure learning. Butt, Kardong-Edgren, & Ellertson (2018), who also applied VR in clinical education, used a different approach to measure mastery learning by asking participants to answer two questions regarding the topic of the study. Kuronen-Stewart et al (2015) also applied the use of VR in clinical education. Their study used quantitative questionnaires to measure perceived effectiveness in learning and similarity to real-life setting. Experimental results by Alhalabi (2016) showed higher performance of the students in leaning the engineering education using immersive VR as a result of more engagement in the learning environment. The study (Akbulut, A., Catal, C., & Yildiz, B., 2018) particularly in computer engineering course using VR evidenced more successful student results compared to traditional teaching approaches.

2.3 Empathy and Learning

There is evidence from neuroscience, psychology and other educational research of the strong relationship of empathy in learning (Brennan, Daily, and Kaman, 2018; Cooper, 2011; Mangione, Discepolo, Tore, Tore, Cozzarelli, and Corona,2013), academic performance and increase in both critical and creative thinking skills (Bonner and Aspy, 1984). There is no current study that looks at the relationship between empathy and learning when using VRLEs. In this study, the effect of immersive VRLEs in influencing higher empathy in the participants is compared if it results to better mastery learning.

3. The Development of Kokoda VR

Kokoda VR is a VRLE designed to immerse students in a significant moment in modern Australian history. Thousands of World War Two soldiers died on the Kokoda track in really hard conditions. The VR experience contextualizes and visualizes the Kokoda campaign, the intense conditions and the sacrifices made by many. Located in the jungle mountains of Papua New Guinea, it's hard to get to Kokoda and impossible to go back in time, but through VR, students can still attain a meaningful experience.

To fit in with the Australian curriculum and be a useful teaching resource, Kokoda VR needed to be historically accurate. However, the full experience needed to be condensed to be to a one class time of 40 minutes. Therefore, only key moments in the campaign could be described and linked together in a series of 12 scenarios, or chapters. Each chapter had to describe a significant historical moment, be engaging for the student and elicit a feeling of empathy for the soldiers. In addition, for Kokoda VR to act as a virtual field trip, high levels of realism and accuracy were required (see examples in Figure 1). This motivated the use of photogrammetry capture in the dense jungle and mountains of Papua New Guinea. Photogrammetry is the science of eliciting information about physical objects and environment by making measurements from photographic images. In this research, the focus was on the use of stereophotogrammetry which involves the estimation of 3D coordinates of an object by comparing multiple photographic images taken from different positions (Foster and Halbstein, 2014).

For each location, an area of approximately 10 meters in diameter was captured. A 360° photograph was taken from the central point of each location.

Figure 1. A sample screenshot from Kokoda VR (Calvert, Abadia & Tauseef, 2019)

In addition to the location, photogrammetry capture of museum artefacts from the Kokoda campaign was also performed. These included soldier uniforms, weapons and equipment from both sides in the conflict.

The models created from the photogrammetry capture were turned into a virtual set, approximately 10 meters in diameter, that the user can explore and where the key pieces of action take place. 360° photographs taken at each location were used to show the distant environment. To hide the seam between the photogrammetry stage and the 360-photograph, custom made 3D models and terrain

created using a variety of model building and photogrammetry techniques were added to the scene (see Figure 2).

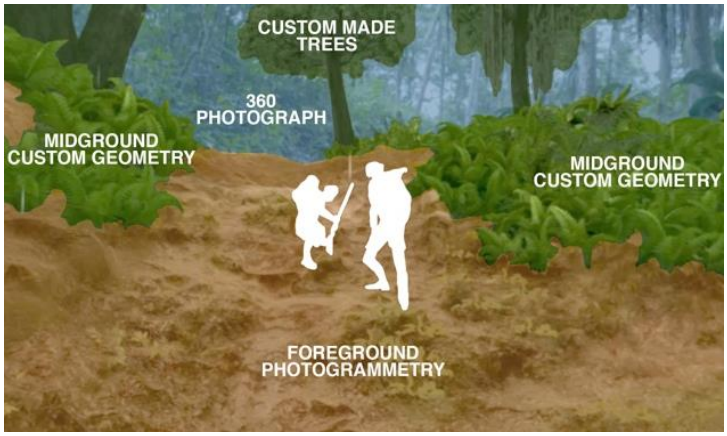

Figure 2. Screenshot from Kokoda VR with overlays showing how the scenes were constructed with a mixture of photogrammetry models and custom-made models (Calvert, Abadia & Tauseef, 2019)

To further fill out each scene, more than 40 real museum artefacts from World War Two captured from location or museums were placed in the scene. These photogrammetry locations and artefacts, motion graphics, voice over recording, location audio, musical score and character animation were combined to produce an immersive and interactive VR.

Integral to the story of Kokoda was the sense of hardship experienced by the Papuans, Australian and Japanese soldiers. Table 1. provides examples of how scenarios were designed in the Kokoda VR experience, with the goal of having the user feel empathy for the soldiers.

Table 1.
Example of Scenarios Designed to Elicit Empathy

Real scenario from the Kokoda campaign	Affordance based design manifestation	Desired empathic condition/response
It rained for most of the Kokoda campaign	Simulated rain falling around the user, with matched spatial audio	Environmental conditions were unpleasant for the soldiers
The Kokoda track is very steep	Place the user midway up a steep incline and search for a branch to use as a walking stick	The track was physically demanding
When vital supplies were dropped in from the air, they smashed on the ground	User sees planes approaching and releasing supplies, then see and hear (in 3D audio) the supplies smash on the ground	Soldiers already in harsh conditions weren't adequately supported
Soldiers often had to dig their own protective trenches, at night and without adequate equipment	User must shine a flashlight around a dark jungle environment to find an empty food tin to dig with	Soldiers had minimal equipment and often had to work in dark and harsh conditions

4. Study Design

The major participants in the study included high school and university students. The participants consist of high school students who will be studying the Kokoda history. For high school, two schools were chosen to participate, one public school and another private to cover different socio-economic background (analysis of this is not presented in this paper). For each school, one class was chosen by the

history teachers to use the Kokoda VR (experimental group) while the other group was chosen to use the 360° video (control group).

The study approach for high school students were replicated to university students. Two universities participated, one from Australia and another university from India. This is to identify if the empathy results are different from students who have no background knowledge of the historical content (students from India) compared to Australia university students with knowledge about Kokoda. This helps the study understand if the use VR increases the feeling of empathy regardless of their knowledge of the story presented.

All participants are self-selected. Students under 18 need permission from their parents. The parents and participants were informed about the study and they can voluntarily choose to participate or not. There was a total of 96 students who participated in the study (42 high school students and 54 university students).

4.1 Data Collection

All participants were asked to complete the student demographics survey before participating in the experiment. The experiment was conducted on the week before the Kokoda topic is introduced to high school students. All high school students who participated understand what the Kokoda campaign is about but have not yet have lessons about the details of this historical events. For university students, Australian participants have knowledge of the historical background while participants in India has none.

The students during the text were asked to have a 40-minute Kokoda VR or 360° video experience. Immediately after using Kokoda VR or 360° videos, participants completed a post-questionnaire which asked five questions relating to empathy (see Table 2 for an example survey question about empathy. The participants had to respond using a scale from 1 to 5. Two days after the students have completed the activity, the participants were asked to complete the online test to determine mastery learning.

Table 2

Sample Empathy Survey Question

Q1: I felt sad while seeing what the soldiers went through at that time
Q2: When the soldiers spoke about the conditions on the track, I could empathise with their struggle
Q3: I could understand the difficulties faced by both the Australian and Japanese soldiers.
Q4: I have a better understanding of the sacrifices made by soldiers on both sides of the conflict
Q5: Being a soldier in the Kokoda campaign would have been an exciting experience (scores to this question were reversed, to give an indication on student's willingness be a soldier in Kokoda)

Included in the data collection but not presented in this paper is the gathering of additional feedback form the students. Students were asked by their teachers to talk about their experience. They were also asked to take a quiz a month after the experiment to test and identify if there is an association between empathy and long-term recall; and if VRLEs are effective tools for long-term recall.

5. Results and Analysis

In all high schools in Australia, the Kokoda campaign is part of the history curriculum. In the data collection, high school students who participated have been given an overview of the Kokoda campaign before they participated in the experiment. The university participants, on the other hand, are a mixture of students who learned about the Kokoda campaign and those who have not heard of the Kokoda campaign. Before the experiment, the university students were only given a brief overview of what the Kokoda campaign is all about. The results and analysis of the experiment for empathy, mastery learning, and their correlation are presented below.

5.1 Empathy

Overall, there is a significant increase in empathy felt by participants in the VR version over 360°video (Figure 4). Participants in the Kokoda VR experienced 85% empathy (4.2 out 5 scale) while 360° participants experienced 76% empathy (3.8 out 5 scale). Figure 4 also shows that for both Kokoda VR and 360° groups of participants, university participants have higher empathy (mean =4.27) than those who are in high school (mean =3.81). The standard deviation is 0.2308 (calculated considering the mean empathy (360°video and Kokoda VR) of high school and university participants with reference to all participants mean empathy).

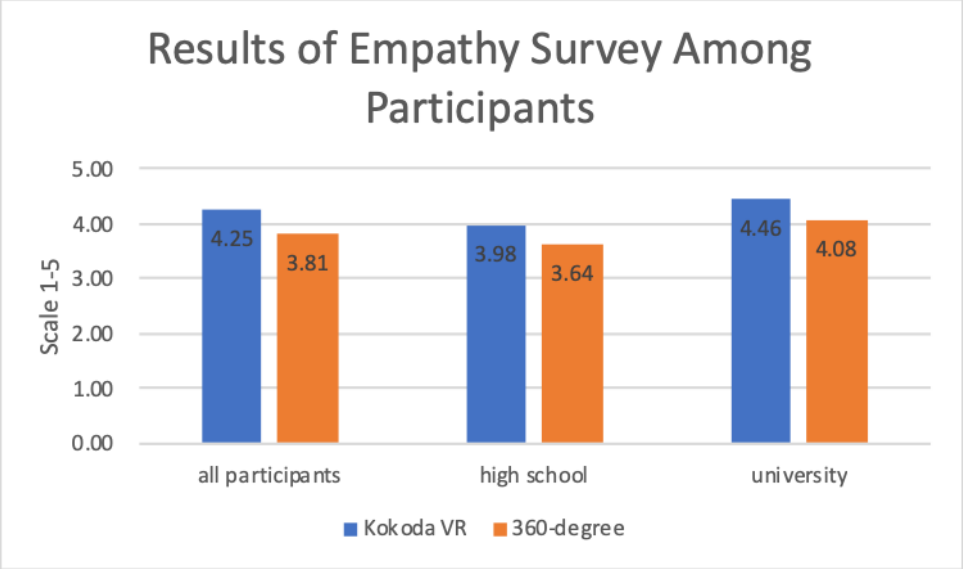

Figure 4. Graph showing the result of the empathy survey among participants.

However, our study shows that empathy is increased in VR over 360° video, but only when the specific scenario has been effective in the application of the technological affordances of 6-DOF head-tracking VR. Table 3 shows the responses to the empathy questions.

Table 3

Mean, Standard Deviation and t-Test scores for the empathy questions

Question	Kokoda VR		360° video		t-Test
	Mean	SD	Mean	SD	
Q1	4.43	0.75	4.05	0.93	0.1457
Q2	4.29	0.71	4.15	0.93	0.0080
Q3	4.55	0.59	4.26	0.90	0.0019
Q4	4.55	0.54	4.36	0.82	0.0004
Q5	3.16	1.46	2.87	1.06	0.1194

For questions 3 and 4, responses from the VR group are clustered more around ‘agree’ and ‘strongly agree’ compared to the 360° video group. The responses to questions 1 and 2 are evenly spread across both conditions. The responses to question 5 have a low empathy for both Kokoda VR and 360° groups.

When users hear soldiers speak of their discomfort in the jungle (Q2), or better understanding of the sacrifices made by soldiers on both sides of the conflict (Q3), there is no statistically significant increase in empathy in VR over 360° video. It is our view that the user can see the harsh conditions and arduous events the soldiers speak about in both conditions, 360° video and VR, but the user is not

experiencing the harsh conditions for themselves. Therefore, the full benefits of the immersive environment in VR are not being utilized.

The study also compared the empathy results of university participants who have learned the Kokoda campaign history in high school to those who have not heard of the Kokoda campaign until the introduction before the experiment. Results (see Table 4) show that participants with no background knowledge of Kokoda felt 7% more empathy using Kokoda VR compared to 360° video. This means these participants are more engaged in the immersive virtual learning environment that increased empathy. The same case with participants of Kokoda with background, having an empathy 5% higher than 360° video participants. In both cases, there is an increased empathy using Kokoda VR. Considering that if participants do not have background of Kokoda, they are not biased in their engagement. So, we can give weightage to the results of participants having no Kokoda background. With this we can conclude that using Kokoda VR has a higher level of empathic experience.

Table 4

Comparison of Level of Empathy Between University Participants – Background Knowledge vs No Background Knowledge

	Kokoda VR	360-degree
No Kokoda Background Knowledge	88%	81%
With Kokoda Background Knowledge	90%	85%

5.2 Mastery Learning

Table 5 summarizes the result of the tests given to the participants to measure mastery learning. Test scores show that VR participants in the study performed better than 360° video with an overall score of 85% compared to a 79% for 360° video participants. The high school participants performed better than university participants. The test results for high school participants have a 10% difference between VR and 360° video test results. VR participants' mean test score is 94% compared to 84% for 360° video participants.

Table 5

Test Results of All Participants (Score out of 10)

	All Participants (n=96)		High School (n=51)		University (n=45)	
	Mean (%)	SD	Mean (%)	SD	Mean (%)	SD
Kokoda VR	85	0.94	94	0.74	80	0.85
360° video	79	1.7	84	1.7	74	1.7

The study also looked at test results of university participants with background knowledge compared to those without. Results (see Figure 5) show that participants with no background knowledge of Kokoda showed 0.47 points (4.7%) higher test scores using Kokoda VR compared to 360°. This means participants in the study have shown that using VRLEs can assist in mastery of the concepts. The same case with participants of Kokoda VR with background which showed increased test results of 0.6 points (6%) compared to the 360° video participants with background. In both cases there is an increased test results using Kokoda VR. With this we can conclude that using Kokoda VR there is a higher level of learning experience.

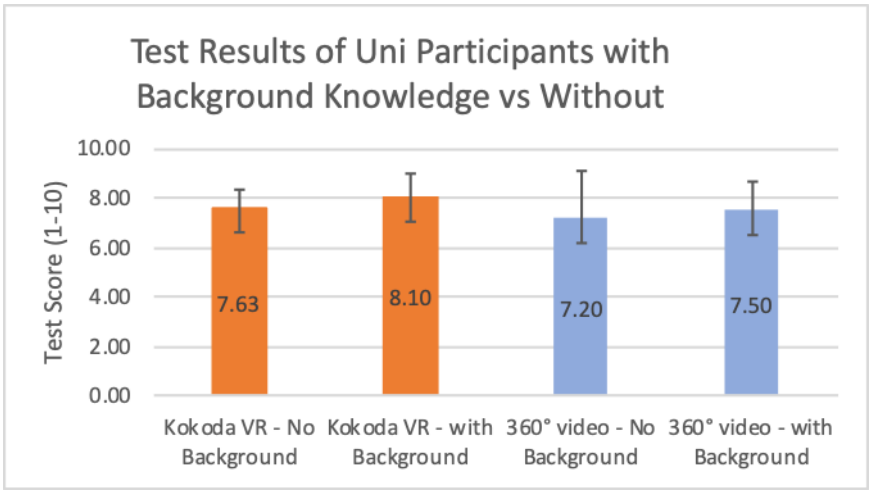

Figure 5. Graph Showing the Comparison of Test Results Between University Participants – Background Knowledge vs No Background Knowledge

5.3 Relationship between Empathy and Mastery Learning

The relationship between empathy and mastery learning in using VRLE is compared by using the empathy and test scores of participants. For both high school and university participants, high empathy scores also showed some high-test scores. The following graphs show the association between empathy and mastery learning in VR for participants (Figure 6) and 360° video participants (Figure 7).

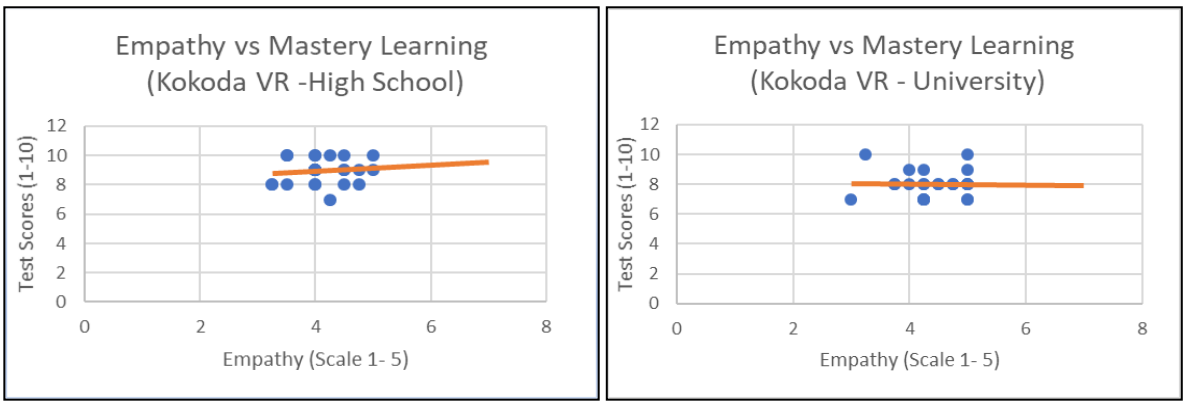

Figure 6. *Association between Empathy and Learning for Kokoda VR participants.*

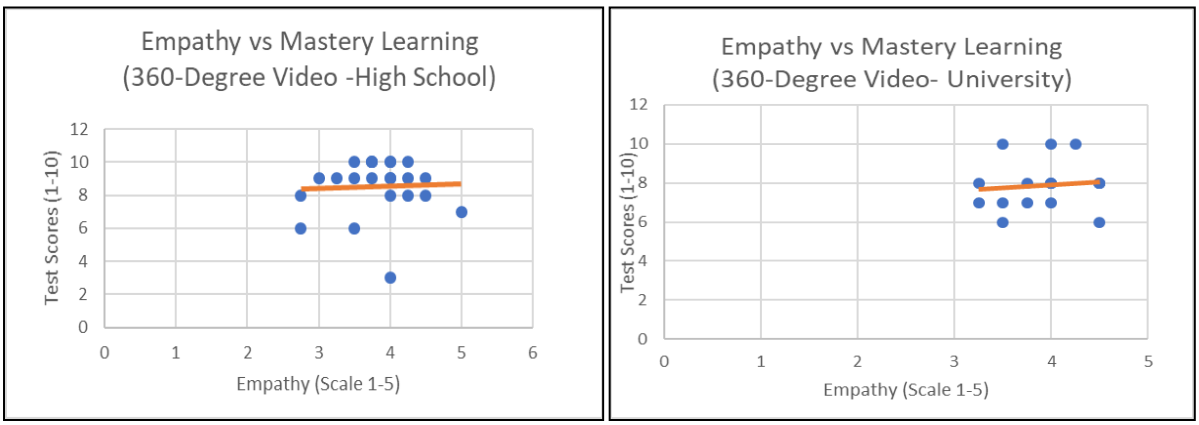

Figure 7. *Association between Empathy and Learning for 360° video participants.*

The coefficient of determination for Kokoda VR high school participants is 0.0144 while 0.0016 for 360° video participants. For university participants the coefficient of determination for Kokoda VR is 0.0004 while 0.0103 for 360° video participants. Although all showed positive association the relationship is weak, which is not sufficient to conclude that a high empathy leads to better mastery learning.

6. Conclusion and Recommendations

This study has shown how the use of an immersive VR has potential in improving the student empathy and mastery learning. Further studies are needed to identify relationships of other salient features of VRLEs (e.g., engagement, perception, immersion, motivation) to student learning, and find if there are causalities in these relationships. The results of the study show that students who use the Kokoda VR have higher empathy and mastery learning compared to those who use the 360° video. Although there is a positive association between empathy and mastery learning, the coefficient determination is low which is not enough to say that the two salient features have a strong relationship. The limitation of the study presented in this paper is that it did not include the effect of long-term recall and use of focus group to evaluate student's empathy. Although it was not included in the paper, a focus group where students were asked by their history teachers to talk about their experience were included in the study design. Students were also asked to take a quiz a month after the experiment to test the long-term recall. That will be reported in future presentations.

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