A Review of the Virtual Reality Applications in Education and Training

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***Abstract*—Virtual reality technologies for supporting teaching and learning have been an academic research topic for decades. In the last five years, major progress have been made and the virtual reality technology is getting closer to being implemented in education. This paper presents an overview of the uses of virtual reality in education, specifically on the Oculus Rift platform. The purpose of this study is to explore the current use of virtual reality to support teaching and learning. The results of the study show what is the distribution of curriculum content in virtual reality applications and what are the best users' rated educational virtual reality applications.**

Keywords— virtual reality, oculus rift, educational applications, evaluation

I. Introduction

Virtual reality or VR is an artificial set of images and sounds, produced by a computer to create a simulated environment that incorporates auditory, visual, haptic, and other types of sensory feedback. This technology can be used to create environment similar to the real world or fantastical that is not possible experience in conventional physical reality. Virtual reality is broadly applicable and has been applied to many different areas of education including technology training, medicine, natural sciences, history or architecture. The advantage of VR over conventional methods of description is that the student is given the opportunity to experience subject matter that would be difficult if not impossible to illustrate or describe with conventional methods. Virtual reality can more precisely demonstrate features or processes. It allows an extreme close-up examination of an object. Observing the model of an object from different perspectives shows areas, which have not been seen before. For example, a virtual reality model of a neighbourhood gives the residents a unique point of view on the links between objects, structures or public areas.

Although Virtual Reality has come to the public's attention since the 1980s, it is only the last decade that the VR headsets have seen such an increase in sales. New hardware has entered the consumer market providing affordable pricing models but also completely new technologies are being designed and developed [1]. The beginnings of modern-day virtual reality can be traced back to 2012 when a Kickstarter project named Oculus Rift was introduced with the purpose of providing an affordable high-quality Head-Mounted Display (HMD) to the public. The preproduction phase of the Oculus Rift included various models to give developers a chance to develop applications before official launch to the consumers. The latest version Oculus Rift S has a LCD display, 2560×1440 resolution per eye, a 80 Hz refresh rate, tracking and positional capabilities. The device also features a 110-degree field of view and integrated headphones with 3D audio effect. There is an application store (Oculus Store), that allows only applications that run easily on the recommended hardware. The store is available through various options: from desktop application, via the website or the VR-based application called Oculus Home. Users can rate VR applications (called VR experiences) for their comfort (such as causing motion sickness or jump scares). However, it is completely optional for developers and they do not have to use Oculus Store to distribute their applications. According to the set of data from Steam hardware & software survey from December 2018, market share shows the Oculus Rift is leading with 46.45% of users over the HTC Vive's with 40.82%.

The goal of this study is to explore the use of virtual reality to support teaching and learning. The two following research questions were addressed in this study:

What is the distribution of curriculum content in virtual reality applications on the Oculus Rift platform?

What are the best users' rated educational virtual reality applications?

II. Related Work

Several studies have been conducted on the applications and usefulness of virtual reality in education and training. McLellan [2] provides wide-ranging review of the related literature to the research and use of virtual reality for education and training. Duncan, Miller and Jiang [3] described benefits that virtual worlds can have in teaching and learning, as they can provide a laboratory for collaborative work, socialization and entertainment. However, they emphasized that the use of virtual worlds for education should not disadvantage particular social, minority or disabled groups.

Gilbert [4] described how students commonly find science subjects to be abstract, requiring a depth of understanding and visualization skills. Visualization technologies such as virtual reality can be used to address the problem of misconception and help students understand better.

Embedding virtual reality into higher education curriculum increases the engagement of students and contributes to their motivation to learn. Alho Barata, Filho, and Alves Nunes [5] developed software for virtual reality where students interact with it by visualizing a transformer installed in a substation and performing operation and maintenance procedures in a virtual environment. There is an authoring module where it is possible to create virtual operating procedures and maintenance in an electric power substation. Also an execution module, in which user can eventually perform the operating and maintenance procedures in a virtual environment.

Examples of incorporating virtual reality content in science and engineering education include energy engineering [6], process engineering [7], mining [9], training drone pilots [10], virtual operator station for mobile robots [11].

III. Research Method

Oculus provides distribution of the virtual reality applications through the Oculus Store (named Rift Experiences). The application is submitted for a review to guarantee it meets the technical and content standards. Once the application passes this review, it will show up in the Oculus Store in one of the following categories: *Apps* (utility applications), *Games* (from first-person perspective players interact with content where they can either win or lose), *Entertainment* (interactive narrative-driven experiences), *Early Access* (applications which are in active development). Besides categories, applications are sorted by genres. There are 35 different genres such as Productivity, Sports, Racing, Action or Educational.

Screening and assessment of applications for study inclusion were guided by a systematic review process and restricted to the Oculus Store. The store was inventoried during a single week in January 2019, resulting in the identification of 1255 total applications. Applications meeting the following inclusion criteria were retained for analysis: (a) educational genre (b) available to the public for download.

Two study authors (PS and MB) used the information provided in the applications' titles, genre, descriptions, and available screenshots to identify those apps meeting the above inclusion criteria. Most of these applications were games or other multimedia content. An ultimate sample of 171 applications met inclusion criteria and was submitted to content analysis.

IV. Results

A coding instrument was developed to identify educational virtual reality applications in the following categories: curriculum content, language, price, size, rating by stars and number of voters. Table 1 presents characteristics of the sampled applications.

Each application was classified by *Curriculum content*. Within this classification 21 areas were identified: the majority of the applications were classified as Space (N = 26, 15.2%), Nature (N = 25, 12.3%), History (N = 19, 11.1%) or Medicine (N = 19, 11.1%). Because the authors of this study come from the engineering field, the particular interest was also focused to applications from engineering area. There were only six applications from Engineering genre (N = 6, 3.5%).

Another classification was by *Language* in which an application communicated with the user. The majority of the applications used English as a communication language (N = 171, 100%), other languages included French (N = 11, 6.4%), Chinese (N = 8, 4.7%) or Japanese (N = 6, 3.5%). Altogether 16 languages were identified. A group of applications was able to communicate with more than one language (N = 20, 11.7%).

Classification by *Price* reveals the majority as free applications (N= 98, 57.3%), the most expensive applications in the price range $20.00 – $22.99 (N = 5, 2.9%) are minor.

The majority of applications in the sample had *Size* in the range 2.00 – 2.99 GB (N = 74, 43.3%), then 3.00 – 3.99 GB (N = 41, 24.0%).

TABLE I. CHARACTERISTICS OF SAMPLED APPLICATIONS ON THE OCULUS STORE (N = 171)

Characteristics	***N***	***%***
Curriculum content		
Architecture	10	5.8
Art	12	7.0
Ecology	1	0.6
Engineering	6	3.5
Food	1	0.6
Game	15	8.8
History	19	11.1
Chemistry	2	1.2
Literature	1	0.6
Math	3	1.8
Medicine	19	11.1
Multiple	3	1.8
Music	6	3.5
Nature	21	12.3
Physics	1	0.6
Psychology	4	2.3
Safety	3	1.8
Sociology	2	1.2
Space	26	15.2
Tool	8	4.7
Travel	8	4.7
Language		
Arabic	2	1.2
Danish	1	0.6
Dutch	1	0.6
English	171	100.0
French	11	6.4
German	5	2.9
Hebrew	1	0.6
Chinese	8	4.7
Italian	5	2.9
Japanese	6	3.5
Korean	4	2.3
Norwegian	2	1.2
Portuguese	3	1.8
Russian	4	2.3
Spanish	5	2.9
Swedish	2	1.2
Price ($)		
Free	98	57.3
0.99 – 4.99	29	17.0
5.00 – 9.99	29	17.0
10.00 – 19.99	10	5.8
20.00 – 29.99	5	2.9
Size (GB)		
2.00 – 2.99	74	43,3
3.00 – 3.99	41	24,0
4.00 – 4.99	16	9,4
5.00 – 5.99	13	7,6
6.00 – 6.99	12	7,0
7.00 – 7.99	6	3,5
9.00 – 9.99	1	0,6
10.00 – 19.99	6	3,5
20.00 – 29.99	2	1,2

The Oculus Store is using 5-stars users' rating system to evaluate each application. This methodology provides easily understandable metric without difficulty because users are in general ready to vote by clicking a star rating. Star ratings create standardization and can reduce individual preference. If there is an adequate amount of ratings, it is possible to sort results. The issue is, that numerous ratings are expected to make this system work. The quality of star ratings is influenced by the average number of stars and also by the number of reviews.

The Oculus Store provides sorting of applications by alphabetical order, popularity, comfort rating, release date, price and user rating. However, sorting by user rating count overall star rating and does not count a number of reviews. Therefore on the top of the list are applications with the 5-star rating but only one user review. The solution for this is the application of Bayesian average to estimate and rank preferences by 5-star rating. A Bayesian average is a method for evaluating the mean of a population consistent with Bayesian interpretation. As opposed to evaluating the mean entirely from the available data set, other existing information related to that data set may also be consolidated into the calculation in order to minimize the impact of large deviations, or to assert a default value when the data set is small [12].

$$rating = \frac{C \times m + \sum reviews}{C + N} \qquad (1)$$

m represents a prior for the average of stars

C represents our confidence in the prior

N the number of reviews

We have collected data about average user's star rating and a number of reviews for each educational virtual reality application from a sample of 171 applications. We have excluded applications which curriculum content was identified as *Games*. The minimum number of reviews was set to 5. On the basis of the data, we have calculated Bayesian average and list the top 10 educational virtual reality applications based on users' rating (Table II).

TABLE II. TOP 10 EDUCATIONAL VIRTUAL REALITY APPLICATIONS BASED ON USERS' RATING ON THE OCULUS STORE

	Application	Curriculum content	Users' star rating	Number of ratings	Bayesian average
1	1943 Berlin Blitz	History	5	286	4.97
2	Wrench: Engine Building Demo	Engineering	5	143	4.93
3	Vinyl Reality	Music	5	16	4.52
4	Wonderful You	Medicine	4.5	118	4.44
5	Hold The World	Nature	4.5	45	4.35
6	Hoover Dam: IndustrialVR	Engineering	4.5	33	4.30
7	Apollo 11 VR HD	Space	4.5	17	4.16
8	eXPerience· Colorblindness	Medicine	4.5	11	4.03
9	NeuroExplorer	Medicine	5	5	4.00
10	Mars Is A Real Place	Space	4.5	10	4.00

V. DISCUSSION AND FUTURE DIRECTIONS

The virtual reality technology is often connected with an entertainment experience and could be considered as an expansion of the gaming industry. According to a survey conducted by Greenlight VR [13], personal interest for education outweighs the request for gaming content — 63.9% compared to 61.0%. Based on the data, we can conclude that there is possible demand for educational virtual reality experiences.

People use digital devices in every aspect of their daily lives and are often looking for techniques to make knowledge transfer comfortable, faster and more effective. Learning with the virtual reality technology seems to be the expected next step for the evolution of education.

There are no expectations to change traditional teaching methodology in the classroom, but VR is going to empower teachers to improve their students learning graph with fun and immersive experience. Babich [14] suggests several ways higher education institutions can benefit from utilizing virtual reality:

- **Visual learning** - VR is helpful for a group of visual learners. For example, presenting mechanisms in 3D environment is enormously useful in understanding how such a technology works.
- **Feeling of presence** – Rather than reading about the topic in textbooks, students are able wear a virtual reality headset and be virtually transferred to the location.
- **A virtual laboratory** - Science labs allow students to investigate scientific phenomenon and see inside how world around us works based on practical know-how. However, they are high-priced and almost impossible to scale. Instead of visiting a physical one, a virtual laboratory can be simulated. Students get proactive experience in realistic environments and engage in exciting exercises relevant to real-world experiences. Virtual reality provide good learning opportunities and ability to scale.
- **Learning by doing** - Learning outside the classroom helps students to acquire practical skills rather than reading instructions. Students are stimulated in the virtual reality environment to find out things for themselves and have a chance to learn by doing things.
- **Emotional reaction** – Students can recollect various details through the emotional reactions and increase their interest in the virtual reality environment.

On the basis of our data from best users' rated educational virtual reality applications, we have found two examples from engineering area which show how to incorporate virtual reality content in science and engineering education.

Application *Wrench: Engine Building Demo* is detailed race car mechanic simulator [15]. The task for the users is to work through assembling an inline four-cylinder engine. This virtual laboratory simulate a physical one and it is extremely helpful in understanding and showing in 3D from which components is the cylinder engine being assembled.

Application *Hoover Dam: IndustrialVR* combines a documentary-style approach with visuals of the dam and powerhouse [16]. Users will learn how the turbine works, what happens inside towers or how the generator functions. Through visual learning, students are capable to wear a virtual reality headset and be virtually transferred to the location.

Limitations

Our study has some limitations:

- Our search was performed in Oculus Store (Rift Experiences), which is the primary distribution channel for the Oculus Rift applications and did not cover other store Steam (store.steampowered.com) or individual developers. However, with Oculus Store being the main distribution channel, we can expect that the numbers of applications being distributed through other channels are rather marginal.
- There was no analysis on mobile virtual reality applications from Google Play store for the smartphone or standalone VR headsets.

VI. CONCLUSION

Virtual reality offers both challenges and opportunities for the educational sector. VR technologies can be used as an educational and training tool with the advantages of being fully controllable, practical and out of danger. With the progress in 3D visualisation technologies, an increasing range of teaching and training material can be utilised in virtual reality environments.

This study is an overview of VR applications for educational and training purposes on the Oculus Rift platform. The results of the study show that the distribution of curriculum content in virtual reality applications is dominated by areas from space, nature, history and medicine. The majority of the applications used English as a communication language, more than half of sampled applications are available as free without paying any fees.

We have collected data about average user’s star rating and a number of reviews for each educational application. We have calculated Bayesian average from the data and list the top 10 educational virtual reality applications based on users’ rating.

For further research, it would be interesting to see qualitative feedback of its users (teachers and students).

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