Journal of Universal Computer Science, vol. 24, no. 2 (2018), 129-148
submitted: 30/9/17, accepted: 3/11/17, appeared: 28/2/18

Effective Learning Content Offering in MOOCs with Virtual Reality – An Exploratory Study on Learner Experience

Supun Hewawalpita, Sachini Herath, Indika Perera, Dulani Meedeniya
(University of Moratuwa, Moratuwa, Sri Lanka
{supungs.10, sachini.h, indika, dulanim}@cse.mrt.ac.lk)

Abstract: Massive Open Online Courses (MOOCs) are becoming increasingly popular among academics and learners due to their extended utility beyond standard e-Learning course offerings. One of the unique features of MOOCs is that the participants follow the complete module on their own; A MOOC follower is often not constrained by typical factors that are considered necessary to participate in a blended or e-learning offering. The learning content type and the delivery of learning content can play an important role for MOOC success; importantly attractive learning content can help the self-paced MOOC learners to perform well in their learning process. We explored an improved MOOC setup with virtual reality (VR) support and the paper describes a comparative analysis on the efficacy of MOOC with virtual reality content delivery against standard video based MOOC learner support. The evaluations were carried out with groups of participants having different competency levels relevant to the course topic; one group had learnt the subject matter already whereas the other group was with zero prior knowledge. The results indicated statistically significant better performance from the students who have used VR with MOOC. The student feedback provided valuable insights into the way they perceived their learning interactions with positive responses promoting MOOC VR infusion. Research outcomes can help design effective learning content and interaction within MOOCs for the mainstream teaching and learner support needs.

Keywords: Virtual Reality, MOOCs, Learner Engagement, Learning Content Offering, Learner Experience, Immersive Technologies for learning
Categories: K.3.1, I.3.7, L.3

1 Introduction

Massive Open Online Courses (MOOCs) started to gain their popularity among ambitious, resourceful universities and research institutes mainly due to the technological flexibility of hosting successful MOOC instances. This initiative created a positive influence on millions of students who could not access to learning in those leading universities; with the open nature of MOOC courses accessible online through browsers made these courses so popular among a range of prospective students. In the current state there are several popular MOOC platforms available such as: Coursera, FutureLearn, edX, open2study, and NovoEd.

MOOCs associate with a set of teaching and learner support tools and methods, which are meaningfully applicable to a range of application scenarios. It is important to note that unlike e-Learning, MOOCs only offer a limited types of learning options. Among these learning activities following are widely available in almost all MOOC platforms. Forums, Videos and streaming content, Quizzes, and Hypertext based composed web pages [Gamage et al. 2015]. The main reason for this limited number of learning tool support is that they represent the most basic forms of learning interactions that can be universally applied across a range of courses and subject domains. However, some are in the view that the learning rigor is low and learning content and interactions do not effectively gain student learning [Bali 2014], while some researchers believe otherwise and endorse the pedagogical validity of MOOC learning activities and content [Glance et al. 2013].

While there are multiple success cases of MOOCs and their impact undoubtedly significant towards making MOOCs, a mainstream practice complementing the curricula, some of the critiques are of the view that MOOCs have yet to improve their learning offering to warrant as a formal educational methodology [Bali 2014]. The main challenge with MOOCs is the poor completion rate [Hew 2016] [Onah et al. 2014]; concerns are arising on the real value behind MOOCs and the consequences of it. It is mainly because there are higher dropouts in MOOC, which means only 7-13% of pass rate or sometimes less than that complete the courses [Jordon 2014]. This was observed across multiple MOOC studies and commonly attributed to the complete flexible learning arrangement where students often do not find an opportunity cost forgone of not engaging in a MOOC. Video based content delivery is the mainstream practice in MOOCs as the learning resources; however, there are many students who passively observe the video as pastime [Young 2013]. In this study we explore the possibility of active learner participation [Hew 2016] through virtual reality (VR) using problem-based, situated and creative learning types [Ibáñez et al. 2011] incorporation as an extension to the MOOC content offering. A VR content supported MOOC with these learning types can improve student learning experience. A MOOC course with VR support was designed and the student learning experience was evaluated against standard video based MOOC learning; Results and student feedback suggest positive outcome for learner experience through MOOCs with VR content. Thereby we can claim the fact that this research has successfully explored the research gap for infusing MOOCs with VR; however, evaluating VR as a generic technology was not part of our research focus.

The paper is arranged as follows: [Section 2] presents background and related work for the research; it also presents analyses carried out on a MOOC dataset received from CAROL, Stanford University. The results reassure the learner dropout and poor engagement challenges. [Section 3] presents the course details and the need for MOOC based course offering with VR. [Section 4] presents the experiments carried out with different conditions within the study. [Section 5] discusses the results, the statistical analysis of results, and the student feedback on their learning experience. Finally, [Section 6] concludes the paper with future research.

2 Background and Related Work

Technology enhanced learning (TEL) methods and practices have been found to be engaging and effective in a range of educational requirements. E-learning, blended learning and learning in immersive environments such as, OpenSim [Allison 2012] [Allison 2010] and Second Life [Esteves et al. 2011], are noteworthy TEL methods used as mainstream practices. With the recent view of facilitating for learning at large scale classrooms an improved TEL practice Massively Open Online Courses

(MOOCs) [Liyanagunawardena 2013] was introduced; MOOCs support extremely large numbers of student participations from geographically distributed locations with a range of demographic, socio-economical, and user traits.

2.1 Effective Student Learning in MOOCs – A Case Study

This section presents the preliminary study we have done through data analytics of a MOOC dataset; the purpose of this case study analysis was to investigate the typical student learning interaction behaviour in a MOOC and as such justifies the research cause of this study in exploring ways of student engagement through better ways of learning content offering. Student engagement in learning activities is a crucial requirement for effective student learning experience. In an e-learning environment, students are expected to engage with the learning content and learning environment as there is no other form of learning supported within. The same is valid with a MOOC based learning session; participants who actively engaged with the learning content provided do so with the motivation to engage in the learning session whereas the MOOC students who do not actively participate can be safely categorized as not engaged in the intended learning activities. [Hone and El Said 2016] identifies MOOC course content as a significant predictor of perceived effectiveness and active learner engagement within MOOCs.

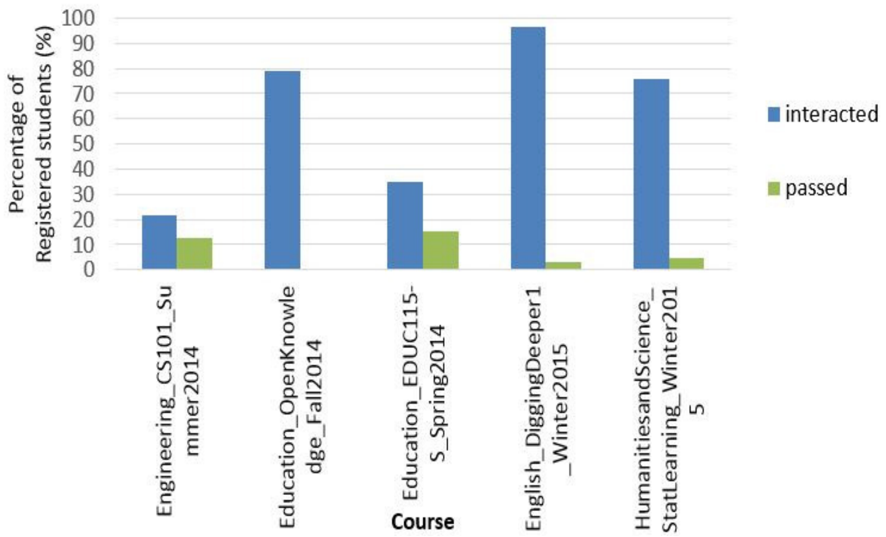

Figure 1: Rate of completion and interactions with MOOCs in the case study

To explore the typical nature of student interaction and engagement with learning in a MOOC setup an analysis was carried out as a case study using MOOC dataset obtained from Stanford University. The purpose of this data analysis was to examine how students engage in learning content, particularly, video; hence to justify the need for better learning content and interaction method. Anonymized data from five courses offered in Spring and Winter in 2014 were collected from Center for

Advanced Research Through Online Learning (CAROL) in Stanford University [CAROL 2017]. The dataset contains information on course content, forum interactions of the students and learning activities, video interactions and events triggered by individual students [Datastage 2017]. It can be observed that a significant fraction of students has not had any interaction after registering to the course. Among the students who have interacted with the course, the percentage of students who have successfully completed the course is always less than 50% [see Fig. 1]. Thus, even though the benefits of using MOOCs are high, the rate of achieving the targeted outcomes is in average 22% [Reich 2014].

To find the cause for the low rate of completion, hence poor course engagement, and weekly interactions of students in course Education_EDUC115-S_Spring2014 were analysed. Viewing lecture videos and completing assignments can be used to identify the predominant styles of engagement in MOOCs [Anderson et al. 2014]. The summary of relevant student activities in course, during the first six lessons is shown in [see Fig. 2]. Each lesson consists of a video lecture, a related quiz and optional lecture notes for further study.

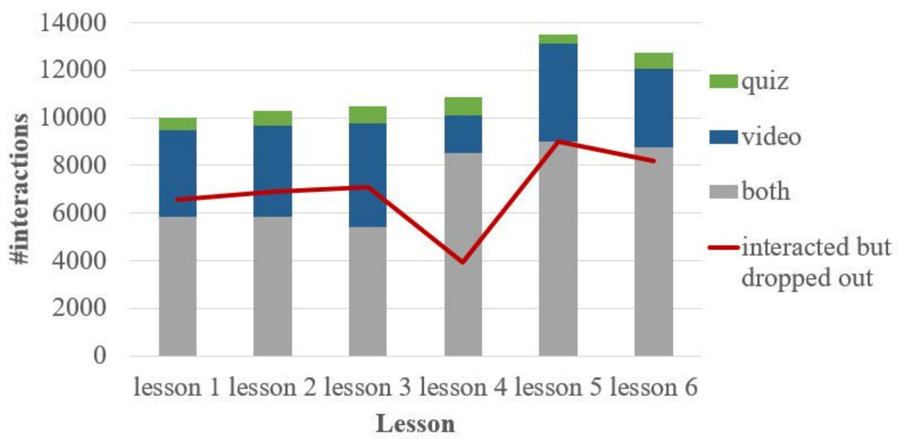

Figure 2: Weekly activity records of Education Spring 2014 course in the case study

Over 50% of students, who have tried the lesson, have completed both activities. Many students have started watching the video but did not complete its quiz. Most of these students are in-video dropouts; this can be used as a measure to compare relative differences in engagement across lessons [Kim et al. 2014]. Finally, a significant portion of students who participate in activities each week, did not engage in the activity to completion. According to [Coffrin et al. 2014], there are many students interacting with course videos, but do not complete the course; a consistent and declining trend of student engagement with learning content was reported.

[Lyndon and Loch 2014] suggest using right technologies for an effective MOOC learning; they reported video quality as a concern to be addressed for better content delivery and effective learning. As a solution, [Freitas et al. 2015] suggests that gamification and simulations gives a higher level of engagement, experimentation and creativity leading to increased course completion. Learner empowerment through better learning content and deliverables within MOOCs is an essential need for effective MOOC learning [Creelman et al. 2014]. This idea of learner empowerment is directly associated with adaptive learning [Clark 2013] as a possible approach to increase learner success rate and improve student engagement [Onah et al. 2014]. Student engagement in a MOOC can be improved if active learning is promoted [Hew 2016] with better learning content design and interaction than solely relying on video content delivery [Gamage et al. 2016]. Student performance is indicating the student engagement within a MOOC instance [Hew 2016]. Thus, in this research we have introduced VR technology as a means of elevating the level of interaction and considers its impact on student performance as an indicator for the success of MOOC offering through the students' effective learning experience.

2.2 Virtual Reality based Learning

Virtual Reality is a fast improving technology, which can be used to create innovative applications in many fields. Since its inception, the potential of VR technology for education has been identified and researched upon [Youngblut 1998]. The study identifies and evaluates multiple case studies on use VR technology in a traditional classroom setting. It is reported VR based content has a positive impact on student motivation and understanding of the content. However, the overhead of getting familiar with the navigational cues and physical discomforts reported when using VR technology for a longer period are some of its negative effects. It is interesting to note that majority of the positive impacts on learning were due to the level of interaction allowed in a VR world, rather than immersion.

Case studies by [Seymour et al. 2004] and [Nicholson et al. 2006] show that the use of virtual reality and 3D models in medical education results in a significant improvement of student performance. VR technologies are also used for motion training systems such as dancing [Chang et al. 2011] and martial arts [Chua et al. 2003]. Use of 3D virtual worlds for learning a new language were explored by [Ibáñez et al. 2011] and the case study shows that while the technology can be used to develop expected skills when learning a foreign language, there is a significant learning curve, which can be overcome by collaborative learning. [Huang et al. 2010] proposes five learning strategies for instructional designers of VR learning environments. Among these, situated learning, problem-based learning and creative learning were targeted when designing the lessons described in [Section 4].

[Diaz et al, 2014] have used remote laboratory platform Virtual Instrument Systems in Reality (VISIR) to conduct basic electronic practical on a MOOC. The paper presents the course structure, experimental setup and the preliminary results in detail. However, lack of a control group makes it difficult to attribute that the results are purely due on the introduction of VISIR technology. Similarly, most research work that are conducted on MOOCs uses Augmented Reality or Augmented Virtuality in Reality-Virtuality Continuum given by [Miligram et al. 1994], to deliver learning content. While there can be many unique approaches to incorporate simulation for engaged student learning, in this research, we explore the effect of using Virtual Reality (virtuality end of Milgram's continuum) for learning within MOOCs.

2.3 Previous Work

This section presents the previous research at University of Moratuwa aimed at developing effective technology enhanced learning methods, including MOOCs. Among these attempts, the most successful effort was using OpenSim based 3D multi-user virtual environment for supporting student learning [Fig. 3]. An especially designed virtual learning island within OpenSim installation was used in BSc Engineering degree programme Final Year course module CS4222 Software Process and Management [Perera et al. 2014]. Learning outcome was to use software process and lifecycle activities as well as developing student skills to participate in a software process model through exploration. OpenSim based virtual laboratory was a success and students reported positive feedback about their learning experience. However, certain technical and infrastructure challenges constrained this method from expanding. With the available server support we could only support just over 30 students on a given session, which is not sufficient for large classes that we usually have (100 - 130 students). The other main challenge was the off-campus access (remote access from home) to the server; the university IT policy did not welcome request to make custom ports being open. Because of these reasons, although we had a very positive experience from student learning point of view, this option of immersive learning was put on hold.

Figure 3: Left Inset – A student in avatar form explores Software Lifecycle Management training, Right Inset – students are engaged in a collaborative DevOps training activity as part of CS4222 laboratory session

Another attempt of student learning enhancement was tried with marker-based augmented reality; a generic framework was developed so that academics can upload relevant AR models for the course [Gunatunge 2014]. Initially the students showed keen interest with the AR model view but soon they demonstrated less interest. Our previous work on MOOCs is presented here as early attempts of this research group leading to this research. A review on quality aspects and effectiveness of a MOOC is presented in [Gamage et al. 2015]. An improved learner assessment framework on MOOCs through peer identification and aligned incentives is developed [Gamage et al. 2017]. A study evaluating the learner perspective on their MOOCs experience was conducted and the findings revealed that there are several key factors to be considered before deciding to offer a MOOC for effective learner satisfaction [Gamage et al. 2016] With these research experience of incorporating different virtual technologies with course teaching we identified MOOC arrangement with sufficient level of immersive or virtual reality support could be a useful method for supporting student learning. Importantly the ability to support large class sizes was a key factor that motivated us venturing into this research.

3 Enhancement for Learning Offering with MOOC and VR

Faculty of Engineering, University of Moratuwa (UoM), Sri Lanka offers a common first semester programme to its entire student batch with over 900 students. A 12 week long pre-academic term is offered to these students to get familiar with the learning environment. Since this pre-academic term allows semester long learning and skill development activities it was planned to let the students explore current popular trends in engineering to motivate them in their respective engineering specializations. Student are given the opportunity to follow a range of learning activities such as language skill development, computer programming, professional practice and mentoring, and research frontier topics in engineering. This extended pre-academic term brought in certain challenges to the academics and the faculty as only a limited set of resources could be assigned for the entire student group.

As part of the research frontier topics in engineering, we decided to offer introductory level course on bio-informatics. However, the challenge was letting all students participate in the online course in place of scheduled lab sessions. To address this challenge and to explore the possibility of introducing MOOC based learning activities we decided to setup an experimental MOOC environment with learning content relevant to this course module. The same course was selected for this research to study the effects of infusing MOOC with virtual reality content. Unfamiliarity of the subject to the students, course time frame and the ease of visualizing biological concepts in 3D graphics, made this course an ideal candidate for the study.

It is worth noting that although the given MOOC setup was immersed in a university environment with students of a regular degree program, the course being completely open and voluntary to participate in made it a close approximation of a typical MOOC. The resource constraint affected the study as none of the students owned their own personal VR device made us to follow this unique endeavour of setting up of MOOC with approximation; however, since the aim was to explore how VR supported MOOCs help student learning, even with this limitation, it can be stated that the MOOC setup in this study was sufficient enough to achieve the research objectives.

3.1 Course Outline and Delivery Plan

The expected learning outcomes for the course module Research Frontier in Engineering (RFE), instantiated into Bio-Informatics introduction, are as follows. There is a generic learning outcome for the module irrespective of the specialized topic and the rest come from the subject discipline.

By completing the RFE-Introduction to Bio Informatics module the students will be able to:

ILO1 – Explain the importance of research led engineering practices
ILO2 – Explain the fundamentals of cell biology
ILO3 – Explain the fundamentals of genetic coding
ILO4 – Apply computing models for managing biological information

The course outline specified for the *Introduction to Bioinformatics* course was as follow.

- Introduction to Bioinformatics
  - Cell biology
  - Genetic coding
  - Gene expression
- Applications of bioinformatics
  - Sequence Alignment
  - Phylogenetic

The course was designed for four weeks and the lesson plan for each week consisted of a lecture and one or more pre-designed learning activities. Content of each lesson [see Tab. 1] was selected to align with the intended learning outcomes of the course. The lesson for the 1st week was designed as an introduction to cell and its structure. The second lesson explained the concept of cell division and the different processes of mitosis and meiosis cell division. The third lesson covered genetic material, DNA, their structure and how they are made up of matching pairs of nucleotides. This lesson is advanced for the students hence special care was taken to include an interactive activity to aide them. Lesson 4 explains how information contained in DNA is decoded by the process of translation and transcription and how bio-informatics are applied to solve problem related to biological information.

3.2 The MOOC Environment

Among the existing MOOC platforms, Cousera and Edx are the most popular. None of the platforms currently supports VR content; hence our choice for this study was based on features available for videos and quizzes as given in [Manning 2017]. Edx offers scrollable and searchable captions for videos and a range of problem types for quizzes. Image mapped input problems was helpful to assess ability to visualize cell structures. In contrast, Cousera supports in-video quizzes and peer reviewed quizzes, but only supports multiple choice and fill-in-the-blank question types for in-video quizzes. Hence, we selected the free and open source MOOC platform, Open Edx [OpenEdx 2017] to host the experimental setup [Fig. 4].

Open Edx platform consists of a Content Management System (CMS) for course creators and Learning Management System (LMS) for students. The main features available for teachers and students are defined in the edx platform codebase. In addition, there are Independently Deployable Applications (IDAs) such that enhances the functionality offered by the platform. For the experiment, we used Edx Insights [Insights 2017] to get statistics regarding student interaction in the course. Decoupling tools and client layer, and the Persistence Systems layer from the core allow the platform to be used with a wide range of front-end and persistent technologies. The complex architecture and configurations make deploying an Open Edx instance non-trivial. Therefore, for the experimental setup, we used EduNext [Edunext 2017] which offers Platform as a Service (PaaS) hosting for Open Edx.

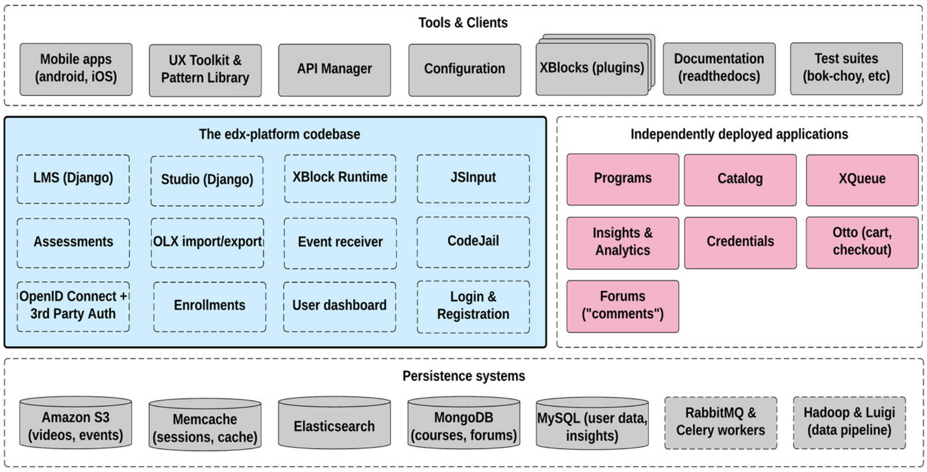

Figure 4: Open Edx Architecture [edX architecture, 2017]

The structure of the Introduction to Bioinformatics course was defined using sections, subsections and units containing multiple components of HTML content, problems and/or videos. The platform supported common problem types such as text input, dropdown and checkboxes, and advanced problem types such as image mapped input, which was used to create the quizzes for the course. The students could register to the MOOC and enrol to the courses to follow. Through the LMS the instructors can access grades and interaction logs for each student and each component.

The course structure is defined as lines of trees separating different section, adding a more immersive flavour and student-centred experience instead of forcing a sequential path as happens in the printed document.

3.3 Virtual Reality Simulation Setup

To study the effectiveness of delivering lesson content as virtual reality experiences, virtual simulations were developed using Unity 3D game engine [Unity 2017]. Unity 3D engine was specifically selected for this, so that the created environment could later be exported to multiple platforms. Oculus Rift [Oculus 2017] was used as the rendering VR headset during the experimental setup, paired with Leap Motion hand tracking device [Leap Motion 2017] for hand input. In actual usage, Oculus rift with touch sensors, Samsung Gear VR with touch control, or the experimental setup can be used if high end devices are available. Using the smartphone with a head mount as the rendering device along with hand tracking through the smartphone camera is a cheaper and widely accessible alternative.

4 Experiment Design for Evaluation

We deployed two courses on the Open Edx MOOC platform named *Introduction to Bioinformatics* as instructor-paced courses that runs for 4 weeks [see Fig. 5].

Although the two courses followed the same course structure [see Tab. 1], in one course, the activities designed for the first three weeks were delivered using virtual reality experiences instead of the traditional learning methods. In both courses, the lectures and activities in week 4 were delivered via traditional methods. As shown in Fig. 4, all the standard MOOC learning tools and communication methods available through the platform were incorporated in to the MOOC instance we created. However, since the focus of this research was to explore how VR content infusion with MOOC only the relevant student learning activities were used in the experiment and data collection. In particular, collaborative forms of learning and engagement in MOOCs such as Forums, Group Chat, etc were not considered as part of the study although such options were enabled in the course for student usage if they ever wanted to. The research did not cover collaboration (with VR or other means), due to resource limitation, which we highly recommend for a further study.

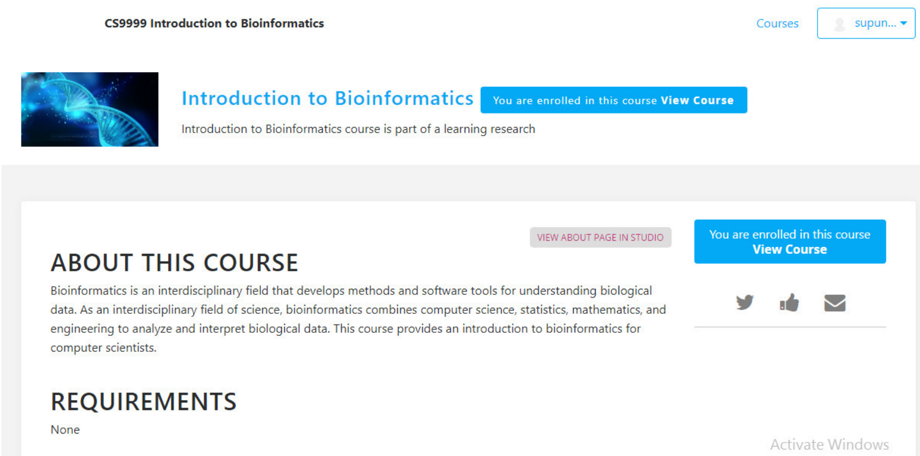

Figure 5: Home page of Introduction to Bioinformatics Course

After enrolling to the course, the students can follow the course by going through the components for each section. In a MOOC the students are free to choose the order of topics and even navigate back to the completed components, and the defined structure enforces an implicit ordering for their guidance [see Fig. 6].

The three virtual reality experiences designed for the course had different objectives and different levels of interactivity. Lecture for week 1 was developed as a guided tour to introduce parts of a eukaryotic cell [see Fig. 7a]. Throughout the tour parts of the cell and their functionalities were introduced with voice-overs and annotated text. This experience was interactive, and users could touch and move parts of the cell with their hands. Visualization for week 2 targets meiosis cell division. The VR experience is a controlled 3D animation with a minimum level of interaction. In contrast, in the interactive activity for week 3 users must construct a DNA sequence with nucleotides [see Fig. 7b]. The activity starts with a portion of a DNA sequence with base pairs with some nucleotides missing. Users were given a set of balls representing nucleotides and they had to complete the base pairs by placing matching nucleotides. A basic guide on base pair matching was shown as an aid and only the correct nucleotide could be placed at each of the blank space.

Week	**Topic**	**Unit**	**Component Type**
1	Introduction to cell	Lecture	Video / VR
		Quiz 1.1	Problem (Checkbox)
		Quiz 1.2	Problem (Image Mapped Input)
2	Cell Division	Hand-out	HTML
		Visualization	Video / VR
		Quiz 2.1	Problem (Checkbox)
		Quiz 2.2	Problem (Checkbox)
3	Base pairs	Hand-out	HTML
		Interactive activity	HTML / VR
		Quiz 3	Problem (Dropdown)
4	Gene translation and transcription	Lecture	Video
		Quiz 4	Problem (Checkbox)

Table 1: Structure of the Introduction to Bioinformatics MOOC course

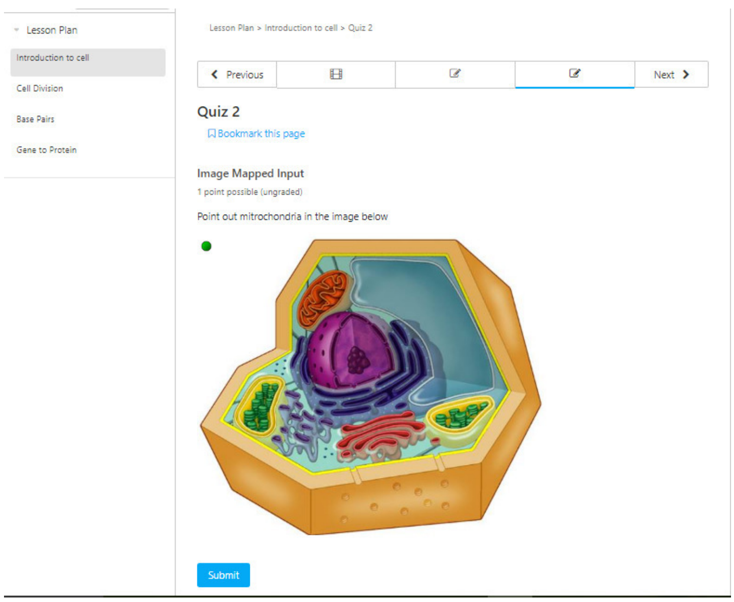

Figure 6: Student view of a quiz attempt in the MOOC course

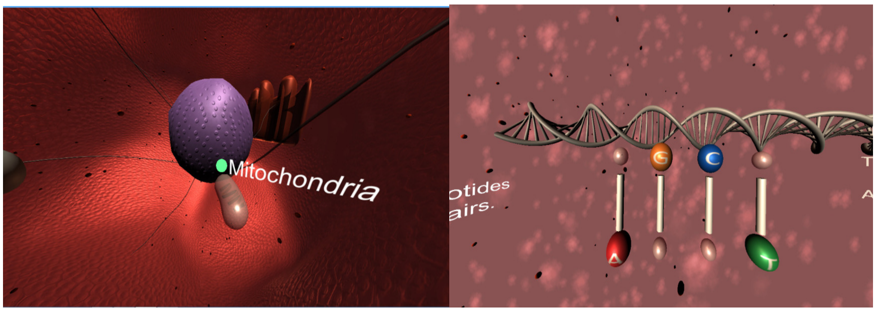

Figure 7: a) Lecture for Week 1- Introduction to cell and b) Interactive Activity 4 Week 3 – Base Pairs

In the other course, video content was available as lecture material and they were carefully designed to contain the same information as their VR experience counterparts. Lecture for week 1 was a rendered video of the eukaryotic cell tour VR experience with the same voice-overs. For week 2, lecture video consisted of a rendered video of the cell division VR experience. For week 3, an online activity was provided in which students had to match nucleotides to complete base pairs of DNA sequence. Thus, content wise both courses delivered the same information.

Figure 8: Student completing Interactive activity in week 3 using VR following creative and problem-based learning types

Two groups of students were used for testing the system: 42 first year undergraduates aged between 20 to 22 years and 42 final year undergraduates aged between 24 to 26 years who follow Bioinformatics course from Faculty of Engineering, UoM. The aim was to distinguish between how the learning experience varies among students who does and does not have prior knowledge on the subject taught depending on the method of content delivery. Two sample groups were randomly formed in each of the student groups and they were asked to follow one of the two MOOC courses used in the experiment. The test groups enrolled to the first course completed the relevant activities using the virtual reality setup discussed in section 3.3 [see Fig. 8]. The control groups enrolled in the second course and used the traditional learning content. Each of the four small groups consisted of 21 students from each batch. The activity grades and time spent on each activity was collected from the MOOC platform to compare effectiveness of learning and engagement.

5 Results and Analysis

[Fig. 9] shows the average grade for test group (VR) and control group (Video) from first year and final year batches. Since lesson 4 was delivered using the same content for control and test groups, comparing grades for Quiz 4, it can be established the performance of students in the control and test groups are similar within a batch.

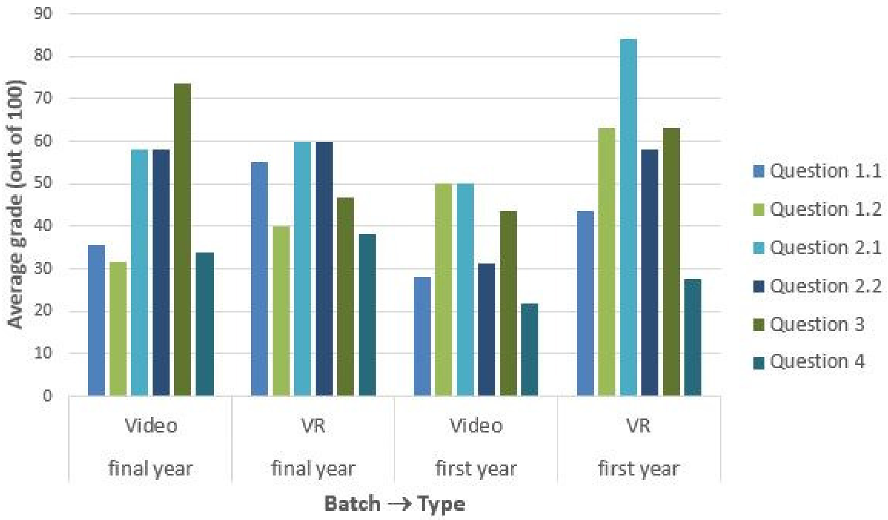

Figure 9: Average grade obtained for quizzes by the 4 student groups

By comparing lessons 1, 2 and 3, which were delivered using Virtual Reality and traditional content for test and control groups respectively, we were able measure the impact of the learning material used on the student performance. Final year undergraduates who are following a course on Bioinformatics shows better performance when using traditional learning content. In contrast, the first-year undergraduates have performed better when using virtual reality content.

The marks of the students were analysed using analysis of variance (ANOVA). The test group which had VR content showed significantly ($p<0.05$) better performance in quiz 1.1 with a mean value of 48.53% marks. In quiz 2.1 test group consisting of first year students without prior knowledge in Bioinformatics, manage to score a significantly ($p<0.05$) higher mean score of 84.21% compared to the mean score of 50% of their counterparts who accessed the traditional learning content. The same control group had scored 62.36% ($p<0.05$) in total for the first five quizzes significantly higher than that of the test group consisting of first year students. The last learning activity was a benchmark same lesson for both groups; the results confirmed no significant difference of quiz 4 marks between subject groups.

5.1 Student Feedback on Learning Experience

For a qualitative evaluation the students were asked to take part in an optional survey at the end. The first question was "Did you find the course content interesting?" [Fig. 10] summarises student responses categorized by the study year of the students and the type of MOOC they followed. The first-year students clearly express preference for VR content, while final year students display mixed reactions.

Next, the students were asked to rate the likelihood of them following VR based and video based MOOC courses voluntarily. [Fig. 11] shows the percentage responses of students categorized by the year of study. The final year students show a higher motivation to follow MOOC courses than first year students irrespective of the content type. It is interesting to note that tendency of first year students to follow VR based courses and video based courses are identical. Since this contradicts with previous findings, we further analysed the preferences of first year students. [Fig. 12] shows the percentage responses of students in following video and VR based MOOC courses, categorized by the year of study and the type of MOOC they used. It can be observed that the students who initially followed a VR based MOOC are more likely to try another MOOC course irrespective of the content type. Even the students who have initially used video content show a greater preference for VR based MOOCs.

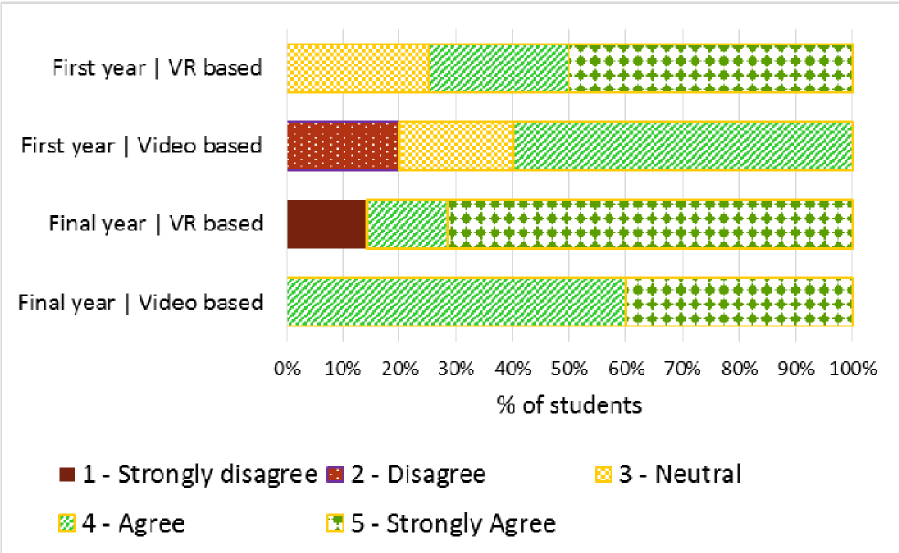

Figure 10: Rating on the interestingness of MOOC course content

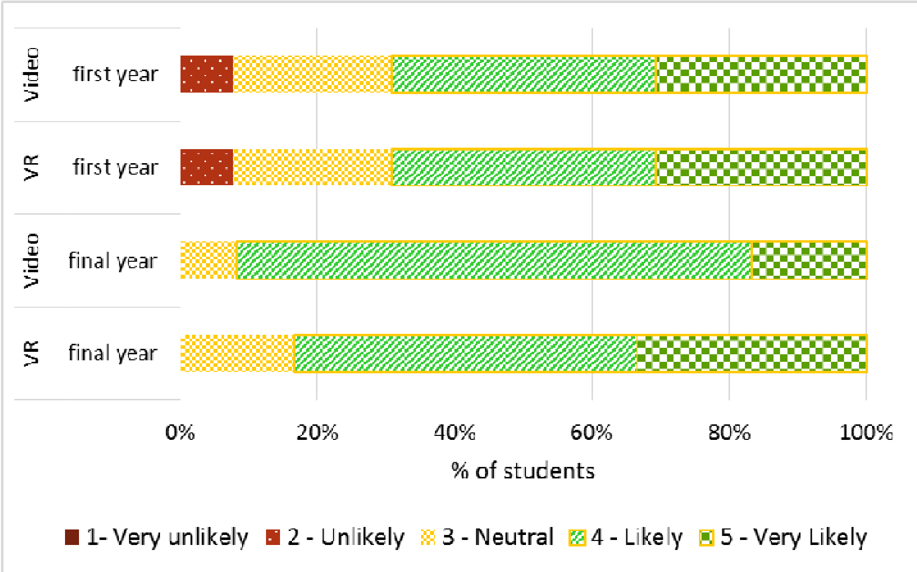

Figure 11: Likelihood of students following VR/ video based MOOCs

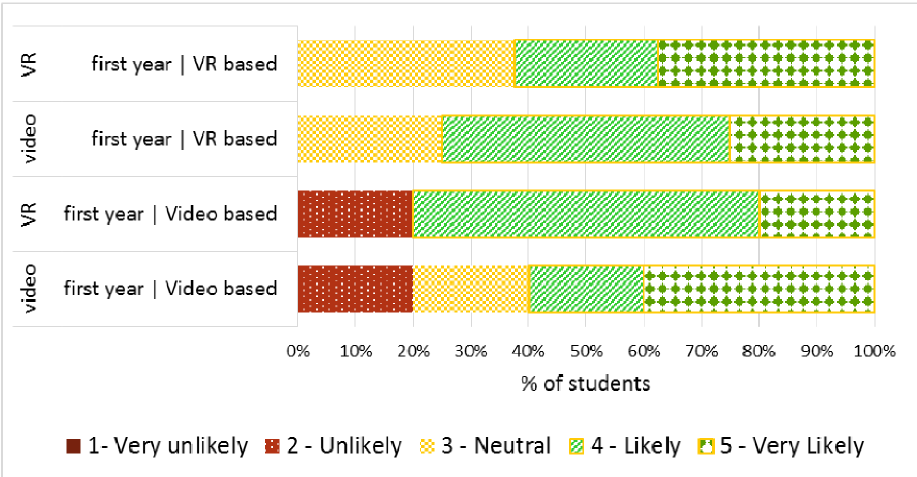

Figure 12: Likelihood of first year students following VR/ video based MOOCs given the type of course they followed.

To analyse the comments made by students, we stemmed the key words of comments and ran the Apriori algorithm [Agrawal et al. 1993]. Taking into consideration that the comments were written by students in a non-native language, a low minimum support of 10% was selected. Some of the interesting association rules discovered, and their confidence is given in [*see* Tab. 2]. (The term virtual reality had

50% support and always appeared together. Thus, it was converted to the single term VR during pre-processing)

Association Rule	Support (%)	Confidence (%)
good, content → VR	10	100
audio → VR, content, focus	10	100
first, time → VR	10	100
video → lesson	14	100
understand → VR	14	75
focus → VR	10	66
text → video	10	66
learn → interesting	28	50

Table 2: Interesting association rules extracted from student comments

To identify the sentiment associated with the association rules, we explored the comments in which the identified word groups appear. {Good, content, VR} has a positive sentiment in all cases.

"VR based content is easy to memorize. It is good if we can have such resources in more complex subject material too."

{Audio, VR, content, focus} had a negative sentiment associated as the immersion in VR has prevented the focus on audio recording.

"Virtual Reality based learning is fun and the content is great, but it seems that focus to the audio is lost sometimes."

{video, text} indicates that non-native English speakers depends heavily on the subtitles and textual instruction in videos to capture the learning content.

"Add more textual contents to the videos. Sometimes it's hard to grab the theories with one iteration."

{VR, first, time} indicates that while most users were excited to try VR for the first time, they had difficulty concentrating on the overall experience of the environment.

"In the virtual reality videos, as it was the first time we experienced such thing, we couldn't concentrate on the recording played about the lesson"

Due to the small sample size, we are unable to present the sentiments with acceptable accuracy. However, the results present interesting phenomena regarding learning content that can be used for further investigation.

6 Conclusions

Literature suggested poor engagement in the MOOC activities as a main challenge. Using Stanford University MOOC data (offered by CAROL) we could experience the gravity of this challenge, a considerable level of poor student engagement with course content was observed. Thereby this research explored the use of virtual reality as a viable mean of learning content delivery medium in MOOC to improve student interaction with the course and their learning experience.

It was hypothesised that the immersive experience from VR could be used to increase student engagement and course attraction than static forms of content such as video lectures. The student performance at each learning activity within the experiment MOOC and VR setup indicated VR simulations improves the student learning within MOOCs. Another interesting observation was the student who had no prior knowledge on the subject matter gained higher levels learning success through virtual reality simulation supported MOOC compared to the students who had already followed a related course previously. This is an important finding, which need further research, as often MOOC participants do not have prior knowledge on the subject matter, hence incorporation virtual reality simulation as part of the learning content can substantially improve their learning experience and success rate at the MOOC. Student feedback indicated few essential factors to address. Focus on audio and ability to access subtitles/textual support while using VR learning content were highlighted as important factors; further research on these with suitable technology incorporation is needed before using VR for mainstream MOOC content delivery.

The study has its own limitations as well: In this research we have used students of the university, who may not ideally represent typical MOOC crowd. However, the course being completely open to all students and they can either enrol or not purely as per their choice made them a reasonable approximation of MOOC participation. Due to the resource constraints of the research it was challenging to collect data from a large group of participants; the statistical analysis was carried out with required power and confidence levels to address this issue. It is recommended to conduct further studies with large group of participants from actual MOOC for a better research output. Another study on how different course topics respond to VR supported simulation can be worthy to explore. In this study only VR based situated learning, problem-based learning and creative learning were used. It is suggested to study further on role playing and collaborative learning types of VR with MOOC setups. It is important to note that due to the limitations prevailed within the research the VR exercises designed in the study and the course used are relatively small, the findings cannot be generalized; further study is recommended to address these limitations.

While the tools and methods used in this experiment can be expensive for certain users, it is a completely effective concept even with basic forms of virtual reality tools such as Google Cardboard with a smart phone. If an attractive technology such as virtual reality can bring in some form of enthusiasm to the course activities, as we have observed in this study, there is a considerable opportunity to MOOC designers and academics to overcome the challenge of student participation thereby improving the student learning experience. We believe that this study can help academics and researchers for offering better leaner experience in MOOC.

Acknowledgements

The research is partly funded by the Senate Research Grants of UoM. We thank Stanford University for MOOC data set for initial analysis; we thank the UoM student participants.

References

[Agrawal et al. 1993] Agrawal, R., Mannila, H., Srikant, R., Toivonen, H., Verkamo, A. I.: "Fast Discovery of Association Rules"; Advances in Knowledge Discovery and Data Mining, 12, 1 (1993), 307-328.

[Allison 2010] Allison, C., Sturgeon, T., Miller, A., Perera, G. I. U. S., Nicoll, J. R. N.: "Educationally Enhanced Virtual Worlds"; Proc. Frontiers in Education (FIE2010), IEEE Publication (2010), T4F-1.

[Allison 2012] Allison, C., Campbell, A., Davies, C. J., Dow, L., Kennedy, S., McCaffery, J. P., Miller, A. H. D., Oliver, I. A., Perera, G. I. U. S.: "Growing the Use of Virtual Worlds in Education: an OpenSim Perspective"; Proc. of 2nd European Immersive Education Summit eIED (2012), 1-13.

[Anderson et al. 2014] Anderson, A., Huttenlocher, D., Kleinberg, J., Leskovec, J.: "Engaging with Massive Online Courses"; Proc. of 23rd ICWWW2014, ACM Publication (2014), 687-698.

[Bali 2014] Bali, M.: "MOOC Pedagogy: Gleaning Good Practice from Existing MOOCs"; Journal of Online Teaching and Learning, 10, 1 (2014), 44–57.

[CAROL 2017] Center for Advanced Research through Online Learning. https://iriss.stanford.edu/carol. 2017 [cited 2017 September]

[Chang et al. 2011] Chan, J. C. P., Leung, H., Tang, J. K. T., Komura, T.: "A Virtual Reality Dance Training System Using Motion Capture Technology"; IEEE Transactions on Learning Technologies, 4, 2 (2011), 187-195.

[Chua et al. 2003] Chua, P. T., et al.: "Training for Physical Tasks in Virtual Environments: Tai Chi"; Proc. IEEE Virtual Reality 2003, IEEE Publication, (2003), 87-94.

[Clark 2013] Clark, D.: "Adaptive MOOCs"; CogBooks Adaptive Learning, (2013).

[Coffrin et al. 2014] Coffrin, C., Corrin, L., de Barba, P., Kennedy, G.: "Visualizing patterns of student engagement and performance in MOOCs"; Proc. 4th Learning Analytics and Knowledge 2014, ACM publication (2014), 83-92.

[Creelman et al. 2014] Creelman, A., Ehlers, U., Ossinnilsson, E.: "Perspectives on MOOC quality - An account of the EFQUEL MOOC Quality Project"; International Journal for Innovation and Quality in Learning, 2, 3 (2014), 78-87.

[Datastage 2017] Carol Learner Data Documentation: http://datastage.stanford.edu/. 2017 [cited 2017 September].

[Diaz et al, 2014] Diaz, G., Loro, F. G., Castro, M., Tawfik, M., Sancristobal, E., Monteso, S.: "Remote Electronics Lab within a MOOC: Design and Preliminary Results"; Proc. 2nd Experiment@ 2013 (exp. at'13), IEEE Publication (2014), 89-93.

[Edunext 2017] eduNEXT, Open edX Platform as a Service: https://www.edunext.co/. 2017 [cited 2017 September].

[edX architecture 2017] Open edX Architecture, Open edX Developer's Guide documentation: http://edx.readthedocs.io/projects/edx-developer-guide/en/latest/architecture.html. 2017 [cited 2017 September].

[Esteves et al. 2011] Esteves, M., Fonseca, B., Morgado, L., Martins P.: "Improving Teaching and Learning of Computer Programming through the Use of the Second Life Virtual World"; British Journal of Educational Technology, 42, 4 (2011), 624-637.

[Freitas et al. 2015] de Freitas, S. I., Morgan, J., Gibson, D.: "Will MOOCs Transform learning and teaching in higher education? Engagement and course retention in online learning provision"; British Journal of Educational Technology, 46, 3 (2015), 455-471.

[Gamage et al. 2015] Gamage, D., Fernando, S., Perera, I.: "Quality of MOOCs: A Review of Literature on Effectiveness and Quality Aspects."; Proc. 8th Ubi-Media Computing 2015 (8^{th} UMEDIA), IEEE Publication, (2015), 224-229.

[Gamage et al. 2016] Gamage, D., Fernando, S., Perera, I.: "To MOOC or Not to MOOC, That Is the Problem: A Learner's Perspective"; Revolutionizing Modern Education through Meaningful E-Learning Implementation, IGI Global, (2016), 131-148.

[Gamage et al. 2017] Gamage D., Whiting M. E., Rajapakshe T., Thilakarathne H., Perera I., Fernando, S.: "Improving Assessment on MOOCs Through Peer Identification and Aligned Incentives"; Proc. 4th ACM Conference on Learning@ Scale, ACM Publication, (2017), 315-318.

[Glance et al. 2013] Glance, D. G., Forsey, M., Riley, M.: "The Pedagogical Foundations of Massive Open Online Courses"; First Monday, 18, 5 (2013).

[Gunatunge 2014] Gunatunge, E. M. P., Hewagama, H. Y. M., Hewawalpita, S. G. S., Perera, I., Udara, Y. B. N.: "AugLAC—Generic Framework for Augmented Location Aware Commerce"; Proc. 7^{th} ICIAfS 2014, IEEE publication, (2014), 1-5.

[Hew 2016] Hew, K. F., "Promoting Engagement in Online Courses: What Strategies Can We Learn from Three Highly Rated MOOCS"; British Journal of Education Technology, 47, 2 (2016), 320-341.

[Hone and El Said 2016] Hone, K. S., El Said, G. R.: "Exploring the Factors Affecting MOOC Retention: A Survey Study"; Computers & Education, 98 (2016), 157-168.

[Huang et al. 2010] Huang, H. M., Rauch, U., Liaw, S. S.: "Investigating Learners' Attitudes Toward Virtual Reality Learning Environments: Based on a Constructivist Approach"; Computers & Education, 55, 3 (2010), 1171-1182.

[Ibáñez et al. 2011] Ibáñez, M. B., Rueda, J. J. G., Galán, S., Maroto, D., Morillo, D., Kloos, C.D.: "Design and Implementation of a 3D Multi-User Virtual World for Language Learning"; Educational Technology & Society, 14, 4 (2011), 2-10.

[Insights 2017] edX Insights: https://insights.edx.org/. 2017 [cited 2017 September].

[Jordon 2014] Jordan, K.: "Initial Trends in Enrolment and Completion of Massive Open Online Courses"; The Int. Rev. of Research in Open and Distributed Learning, 15, 1 (2014).

[Kim et al. 2014] Kim, J., Guo, P. J., Seaton, D. T., Mitros, P., Gajos, K. Z., Miller, R. C.: "Understanding In-video Dropouts and Interaction Peaks in Online Lecture Videos"; Proc. 1st ACM conference on Learning@ scale 2014, ACM Publication, (2014), 31-40.

[Leap Motion 2017] Leap Motion: https://www.leapmotion.com/, 2017 [cited 2017 September].

[Liyanagunawardena 2013] Liyanagunawardena, T. R., Adams, A. A., Williams, S. A.: "MOOCs: A Systematic Study of the Published Literature 2008-2012"; The International Review of Research in Open and Distance Learning, 14, 3 (2013), 202-227.

[Lyndon and Loch 2014] Lyndon, W., Loch, B.: "Academics' Perceptions on the Quality of MOOCs: An Empirical Study"; International Journal for Innovation and Quality in Learning, 2, 3 (2014), 53-63.

[Manning 2017] Manning, J.: "Comparing MOOC Platform Features"; Stanford | Teaching Commons; https://teachingcommons.stanford.edu/teaching-talk/comparing-mooc-platform-features [cited 2017 November].

[Miligram et al. 1994] Milgram, P., Takemura, H., Utsumi, A., Kishino, F.: "Augmented Reality: A Class of Displays on the Reality-Virtuality Continuum."; Telemanipulator and Telepresence Technologies, 2351, (1995), 282-293.

[Nicholson et al. 2006] Nicholson, D. T., Chalk, C., Funnell, W. R. J., Daniel, S. J.: "Can Virtual Reality Improve Anatomy Education? A Randomised Controlled Study of a Computer-Generated Three-Dimensional Anatomical Ear Model"; Medical Education, 40, 11 (2006), 1081-1087.

[Oculus 2017] Oculus, V. R.: "Oculus rift."; http://www.oculusvr.com/rift. 2017 [cited 2017 November].

[Onah et al. 2014] Onah, D. F. O., Sinclair, J., Boyatt, R.: "Dropout Rates of Massive Open Online Courses: Behavioural Patterns"; Proc. of EDULEARN14, (2014), 5825-5834.

[OpenEdx 2017] Open edX Portal, Open Source MOOC Platform; https://open.edx.org/. 2017 [cited 2017 September].

[Perera et al. 2014] Perera, G. I. U. S., Meedeniya, D., Allison, C., Miller, A.: "User Support for Managed Immersive Education: An Evaluation of In-World Training for OpenSim"; Journal of Universal Computer Science, 20, 12 (2014), 1690-1707.

[Reich 2014] Reich, J.: "MOOC Completion and Retention in the Context of Student Intent"; EDUCAUSE Review Online (2014).

[Seymour et al. 2004] Seymour, N. E.: "VR to OR: A Review of the Evidence that Virtual Reality Simulation Improves Operating Room Performance"; World Journal of Surgery 32, 2 (2008), 182-188.

[Unity 2017] Unity - Game Engine: https://unity3d.com/. 2017 [cited 2017 September].

[Young 2013] Young, J. R.: "What Professors Can Learn from ‘Hard Core’ MOOC Students"; Chronicle of Higher Education, 59, 37 (2013).

[Youngblut 1998] Youngblut, C.: "Educational Uses of Virtual Reality Technology"; (No. IDA-D-2128), Institute for Defense Analyses Alexndria VA, (1994).