Assignment 2: Teaching Quantum Computing with Virtual Reality

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***Abstract*—**Quantum Mechanics, by definition, belongs in a class of physics foreign to our known external world. How then should educators prepare themselves to impart the knowledge of Quantum Mechanics, Quantum Computing, and their applications onto fresh minted undergraduates, graduates, and professionals out in the field? Virtual Reality may be the only solution to allow us to explore a world where the laws of physics do not resemble our own, and we can explore phenomenon of an alternate universe.

1 RESERCH LOG

1.1 Background

The previous Assignment Research Log focused on developing an understanding of Quantum Computing as an educational topic. Grasping the foundational requirements needed for teaching Quantum Mechanics and Computing. As well as a broad survey of the student population being taught Quantum Computing and the ae disparity between the cohort groups. Considering that a deep understanding of Quantum Computing is not required, the age variance can differ wildly, from Middle School children through no-scientific adults and Software Engineering Professionals. The body of research explored in the previous assignment showed that Quantum Computing is available to the general masses, there is interest in the topic, and that the basics can be taught in such a way as to provide a fruitful baseline for students to continue their education in the topic.

For this Assignment, the methodology, teaching approach, and revolutionary teaching technology which may be required to best present the concepts of Quantum Computing are explored. Namely, Virtual and Augmented Reality is researched in the context of Quantum Computing in order to assert its viability as a teaching tool in bringing the other-worldly laws of Quantum Physics into our own reality. Furthermore, Virtual Reality may be the only viable tool that can allow students to conceptualize the laws of the Quantum World.

1.2 Papers

1) *Reference* – Wegener, M., McIntyre, T. J., McGrath, D., Savage, C. M., & Williamson, M. (2012). Developing a virtual physics world. Australasian Journal of Educational Technology, 28(3). Retrieved from https://ajet.org.au/index.php/AJET/article/view/847.
   Search – This paper was found through Google Scholar, searching for paper related to teaching Physics using Virtual Reality.
   Summary – The authors (Wegner et al., 2012) present a study of an iterative implementation of software for teaching first year physics students relativistic physics concepts. The main focus of the software was on students which are weaker in mathematics and require visual representation of advanced concepts in physics in order to fully expand their understanding of the phenomenon. The researchers used Virtual Reality as the main technology behind their Real Time Relativity simulations to facilitate better understanding of physics concepts.
   Takeaways – The main takeaway from this paper is the positive result that the Virtual Reality environment had on students. It is evident that those interested in the mathematical intricacies of Quantum Mechanics, may understand its intimate workings without VR technology. However, for all others, VR technology may allow an understanding and grasp of immensely powerful concepts and visualizations, while bypassing the complex mathematics which stand behind them.
2) *Reference* – Dede, C., Salzman, M., Loftin, R. B., & Ash, K. (1997). Using virtual reality technology to convey abstract scientific concepts. Learning the Sciences of the 21st Century: Research, Design, and Implementing Advanced Technology Learning Environments. Lawrence Erlbaum: Hillsdale, NJ. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.136.4289&rep=rep1&type=pdf.
   Search – This article was found on Google Scholar, searching for quantum algorithms.
   Summary – The authors (Dede et al., 1997) describe a suite of software packages for Virtual Reality simulations of physics phenomenon. More specifically, the virtual worlds MaxwellWorld, NewtonWorld and PaulingWorld allow a user to become a charged particle, a frame of reference and a molecule respectively. Additionally, the software packages allow a user to manipulate

the world around them from the perspective of the physical phenomenon that they are embodying.

Takeaways – The biggest takeaway from this study is the need, not only for the user to be immersed into the perspective of an abstract existence, but also to be capable of manipulating its own state and its environment. Controllers for Virtual Reality Headsets allow for a user to control their environment and explore its capabilities.

3) *Reference* – McGrath, D., Savage, C., Williamson, M., Wegener, M., & McIntyre, T. (2012, September). Teaching special relativity using virtual reality. In Proceedings of The Australian Conference on Science and Mathematics Education (formerly UniServe Science Conference). Retrieved from https://openjournals.library.sydney.edu.au/index.php/IISME/article/view/6244.

   Search – This source was found on Google Scholar for teaching Quantum Computing.

   Summary – The authors (McGrath et al., 2012), explored a specific example or Real Time Relativity software as in (Wegner et al., 2012) where students are taught Special Relativity through the VR environment. The researchers noted an increase in collaborative discussions among students, as well as a better fundamental understanding and conceptual grasp of concepts of Special Relativity. Additionally, the researchers noted the need for refined controls of the virtual world and as a major requirement by the users.

   Takeaways – As a well known teaching technique, when students collaborate to solve a problem, discuss a concept, or create a project their learning outcome increases. The Virtual Environment allows a student to set aside complex mathematical formulations and understanding and rather allow exploration and increase creativity with control of an unfamiliar world. This leads to further discussion and concept refinement with peers which ultimately allows for better understanding of the presented concepts.

4) *Reference* – McLellan, H. (1994). Virtual reality and multiple intelligences: Potentials for higher education. Journal of Computing in Higher Education, 5(2), 33-66. Retrieved from https://link.springer.com/article/10.1007/BF02948570.

   Search – This source was found on Google Scholar for teaching Quantum Computing.

   Summary – The author (McLellan, 1994) summarizes Howard Gardner's model of multiple intelligences (such as Spatial, Bodily-kinesthetic, Logical-mathematical, Musical, Linguistic, Interpersonal and Intrapersonal) and how Virtual Reality can facilitate an expansion of understanding and exploration of each one of those intelligences by ordinary people. Further questions are explored by the author as combining multi-sensory information becomes a challenge for Virtual Reality as navigation, taste, smell, and environmental control can all enhance a user's experience. Finally, the ethical implications of such a technology is also a topic that must be considered, but which makes the advancements of this technology also, so exciting.

Takeaways – The main takeaway from this study is the fact that Virtual Reality can reach much further than Audio/Visual immersion. Navigational control, the human senses currently untapped by Virtual reality, as well as targeted and ethically sound immersion of a user into a Virtual World can expand multiple intelligences of people who may not understand, nor need to grasp the complicated inner working of all the phenomenon they experience.

5) *Reference* – Hackathorn, J., Solomon, E. D., Blankmeyer, K. L., Tennial, R. E., & Garczynski, A. M. (2011). Learning by Doing: An Empirical Study of Active Teaching Techniques. Journal of Effective Teaching, 11(2), 40-54. Retrieved from https://eric.ed.gov/?id=EJ1092139.

Search – This source was found on Google Scholar for teaching Quantum Computing.

Summary – The authors (Hackathorn et al., 2011) explore the different teaching styles (lecture, demonstrations, discussions, and in-class activities) and their benefits, effectiveness, and their implications on classroom and material structuring. The conclusions drawn form the paper indicate that in-class activities provided the best scores and understanding of material of all teaching methods. Lectures and demonstrations were least effective, while discussions actually sought to confuse some students, rather than provide clarity, as even wrong conceptualization is circulated in a discussion, and can lead students off of the right path to understanding.

Takeaways – The main takeaway from this study, is that an in-class activity may not necessarily be the only teaching method but is a fundamental method in solidifying a correct understanding of a students conceptual understanding of a topic. In regard to learning complex Quantum Mechanics, activities such as VR exploration of the quantum world may provide a far better understanding of Quantum Mechanics than having a lecturer explain it, demonstrate its capabilities or facilitate a peer discussion on the subject.

6) *Reference* – Felder, R. M., & Silverman, L. K. (1988). Learning and teaching styles in engineering education. Engineering education, 78(7), 674-681. Retrieved from https://pdfs.semanticscholar.org/a100/c5a533d61342b9ce6024023608e7398f9a20.pdf.
Search – This source was found on Google Scholar for teaching Quantum Computing.
Summary – The authors (Felder & Silverman, 1988) paper on Learning Styles of Engineering students explore how various learner groups best absorb information of engineering concepts and material. The learners are categorized as Sensory/Intuitive, Visual/Auditory, Inductive/Deductive, Active/Reflective and Sequential/Global with each learner group corresponding to a best teaching style and content presentation which caters to their individual learning style. The paper goes on to explore the fact that most engineering student's learning styles do not correspond well to most educators' teaching style. Again, harking back to the fact that activities must play a role in an educational curriculum, whereas most engineering classes are focused on lecture style teaching, providing a poor outcome for student success and information retention.
Takeaways – The main takeaway from this study is the fact that, again, in-class activities solidify conceptual understanding of advanced topics. Quantum Computing, being an abstract topic, not easily presented with everyday metaphors. Thus, it is paramount that educators of Quantum Computing utilize activities which promote a deeper understanding of material and visualization of abstract phenomenon.

7) *Reference* – Felder, R. M., Woods, D. R., Stice, J. E., & Rugarcia, A. (2000). The future of engineering education II. Teaching methods that work. Chemical engineering education, 34(1), 26-39. Retrieved from http://ee.usc.edu/stochastic-nets/teaching-resources/documents/FelderTeachingMethodsThatWork.pdf.
Search – This source was found on Google Scholar for teaching Quantum Computing.
Summary – The authors (Felder et al., 2000) present a list of justifiable must-haves that an engineering educator should use to build their curriculum for a successful teaching of engineering principles. Clear objectives, fair and inductive course material and testing, as well as a reiterative call for Active and

cooperative learning make the list of guidelines to build a successful Engineering Course.

Takeaways – The main takeaway from this paper is that engineering principles cannot be presented a dry reading of a book written by Engineers, for Engineers. The course must be fair, contain active participation and cooperation, and maintain clear guidance where the end result of all the work that the students are putting in is going. For implementing Virtual Reality into a course curriculum, the program must fit well and support, if not promote, the values outlined in order to foster good understanding of concepts being taught.

8) *Reference* – Callaghan, V., Gardner, M., Horan, B., Scott, J., Shen, L., & Wang, M. (2008, August). A mixed reality teaching and learning environment. In International Conference on Hybrid Learning and Education (pp. 54-65). Springer, Berlin, Heidelberg. Retrieved from https://link.springer.com/content/pdf/10.1007%2F978-3-540-85170-7_5.pdf.

Search – This source was found on Google Search for teaching Quantum Computing.

Summary – The authors (Callaghan et al., 2008) study the effect of shared, collaborative virtual environments and avatar representation by 15,000 online students in a virtual learning space. The goal of the study is to determine whether such a virtual space is conducive to peer-to-peer collaborative learning and discussions which would generally be done in a per-to-person live setting. The results of the study were successful, showing increase in discussions and collaboration amongst students.

Takeaways – The main takeaway from this paper is that a Virtual Reality study environment must, not only provide an exploration into the concepts being taught, but also foster a learning environment where ideas can be shared, accessed and discussed openly in a rich, and diverse setting. Incidentally, Virtual Reality allows users to exist as avatars, in one place, while physically being located on other sides of the world. What can be more diverse than having students form different countries coming together to foster an understanding of complex concepts?

9) *Reference* – Loftin, R. B., Engleberg, M., & Benedetti, R. (1993, October). Applying virtual reality in education: A prototypical virtual physics laboratory. In Proceedings of 1993 IEEE Research Properties in Virtual Reality Symposium (pp. 67-74). IEEE. Retrieved from

https://ieeexplore.ieee.org/abstract/document/378261.

Search – This source was found on Google Search for teaching Quantum Computing.

Summary – The authors (Loftin et al., 1993) study a virtual physics laboratory which allows students to modify and explore a world where the coefficients of gravity, friction, and drag can all be manipulated. The goal of the study is to show that such exploratory laboratory activities can foster better retention, intellectual stimulation and motivation to learn about the subject matter. Guided by proposed experiments, the researches noted an increase in interest and motivation for the subject matter as well as a higher level of concept grasp and understanding, by using the virtual laboratory.

Takeaways – The main takeaway from this study is that even for classical physics concepts, such as gravity, the virtual environment can expand a student's understanding by facilitating control over variable which may not be permitted in the real world. Control, a common theme for Virtual Reality laboratories, allows the user to understand variables and coefficients beyond their mathematical representations. More so in Quantum Mechanics than in any other subject, being able to control the environment may allow a broader understanding of Quantum phenomenon than simply studying them from paper.

10) *Reference* – Mikropoulos, T. A., & Natsis, A. (2011). Educational virtual environments: A ten-year review of empirical research (1999–2009). Computers & Education, 56(3), 769-780. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S0360131510003052.

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Summary – The authors (Mikropoluos and Natsis, 2011) review a decade worth of research and studies on virtual learning environment. While the authors conclude that Educational Virtual Environments (EVEs) are widely used in multiple subjects, the retention rates of material has not been extensively studied. Furthermore, the best effect of an EVE was when the task of exploring an EVE was set within a well-structured, broader class material wit clear objectives, tasks and goals for the study material.

Takeaways – The main takeaway from this review is that EVEs best belong to augment a well-designed class curriculum. They are not meant to replace a curriculum altogether. EVEs provide the playground for understanding advanced phenomena as well as a collaborative space for multiple students to interact and share their ideas. However, all of this must be centered around a well organized set of objective and study material.

11) *Reference* – Brown, B. L. (2003). Teaching style vs. learning style. Myths and realities, 26(1). Retrieved from https://eric.ed.gov/?id=ED482329.
Search – This source was found on Georgia Tech Library Search for teaching Quantum Computing.
Summary – The author (Brown, 2003) explores the need to matching teaching and learning style and whether doing so is conducive to better learning outcomes. As matching of learning and teaching styles is determined to not be an effective requirement for proper subject matter comprehension and retention, the author (Brown, 2003) instead suggests focusing on the student to teacher relationship. The paper outlines the need tor Transmission, Development, Apprenticeship, Nurturing and Social Reform as necessary steps an educator must consider in order to match their teaching style to the students.
Takeaways – The main takeaway from this study is that teacher/student transmission of knowledge is a very complex relationship. This relationship can be further distanced with online learning, where students, alone, are forced into relationships with computer screens and walls of text. Conversely, Virtual Reality collaborative environments can provide the necessary environments to foster the relationships needed by students to create a nurturing learning environment.

12) *Reference* – Tsoulouhas, G., Georgiou, D., & Karakos, A. (2012). Adaptive content presentation in asynchronous learning environments. International Journal of Emerging Technologies in Learning (iJET), 7(2), 43-49. Retrieved from https://www.learntechlib.org/p/44998/.
Search – This source was found on Georgia Tech Library Search for teaching Quantum Computing.
Summary – The authors (Tsoulouhas et al., 2012) propose an architecture for a system which dynamically adapts to each students background, mood, knowledge level, and comprehension as a student moves through a set of study materials. The purpose of such a system is to maximize student satisfaction, curiosity, an effectiveness. Simulating the logical course flow of a Teching Assistant, the authors were able to demonstrate the effectiveness of their system.

Takeaways – The main takeaway from this paper is that advanced technology can allow personalized teaching plans which move a student through all material at a pace comfortable for the student, while maximizing success in the classroom. Especially in MOOC environments, where the content is presented, online, to hundreds of students, a smart agent which can tailor content presentation while keeping the student on track can be an invaluable asset to information retention.

13) *Reference* – Salas, J. A. A., Segundo, J., Álvarez, C., Arellano, J. C., & Pérez, A. A. (2014). Evaluation of the Use of Two Teaching Techniques in Engineering. International Journal of Engineering Pedagogy (iJEP), 4(3), 4-10. Retrieved from https://doaj.org/article/092f7ae6213341889980oa0623a14ba4.
Search – This source was found on Georgia Tech Library Search for teaching Quantum Computing.
Summary – The authors (Salas et al., 2014) Explore two techniques for teaching engineering concepts, namely Problem Based and cooperative Learning. Teachers are also presented with training on the two methods and observed in their lecture for further acceptance of new techniques. What is discovered is that courses long taught were slow to adapt, but across the board, adding new technique to a curriculum helped students with content retention.
Takeaways – The main takeaway from this study is that both Problem solving and Cooperative activities in the class help facilitate better concept retention. Although some educators may be slow to adapt their tried and true material to new techniques, in order to facilitate good student engagement, this may be necessary. Especially this is true for more advanced concepts such as Quantum Computing.

14) *Reference* – Bricken, W. (1990). Learning in Virtual Reality. Retrieved from https://eric.ed.gov/?id=ED359950.
Search – This source was found on Google Search for teaching Quantum Computing.
Summary – The author (Bricken, 1990) boldly asserts that Virtul Reality must be common place within two decades. His assertions stem form the fact that VR can teach lessons from the top down. From abstract experiences and interactions, students will then learn the math, rather than learning formulations and then building up the concepts. Barring a full understanding of implications of long-term use of VR, the author provide multiple

justifications for why VR must be the teaching technology of the future we are currently living.

Takeaways – The author asserts VR's dominance as a better platform for cooperative teaching of abstract concepts. The main takeaway from this paper is the fact the VR has potential not to simply augment the classroom experience, but to replace it with a virtual classroom and laboratory space which caters to the student's audio-visual senses. This methodology may prove to be a must stronger tool in an educator's arsenal than any other.

15) *Reference* – Shaari, A. S., Yusoff, N. M., Ghazali, I. M., Osman, R. H., & Dzahir, N. F. M. (2014). The relationship between lecturers' teaching style and students' academic engagement. Procedia-Social and Behavioral Sciences, 118, 10-20. Retrieved from https://www.sciencedirect.com/science/article/pii/S1877042814015328?via%3Dihub.

   Search – This source was found on Google Search for teaching Quantum Computing.

   Summary – The authors (Shaari et al., 2014) study the effect of teaching styles on student engagement. The authors assert that the facilitator teaching style and problem-solving teaching methods lead to positive student engagement. The results show a strong correlation between teaching styles of educators and student engagement in the study materials.

   Takeaways – The main takeaway from this paper is that content presentation and teaching style greatly determines the effectiveness that a study lesson will have on the student. Thus, specifically abstract concepts like Quantum Computing must be carefully structured in such a study lesson as to maximize student engagement and collaboration.

1.3 Synthesis

Quantum Mechanics and quantum Computing is an incredibly complex and fantastic area which will be encroaching into the mainstream technological stack in the coming years. Its power and use ability is far reaching and will revolutionize entire industries. As such, there is a desperate need to interest, teach, and familiarize people of all ages and walks of life in the basic concepts, theory and uses of the technology.

One of the best technological advancements in the past few decades was the advent of Virtual Reality. The technology allows a user to experience phenomenon, control their experience, collaborate with multiple users, and exist in a world that may not necessarily obey the same laws of nature that our reality does. More so, the technology provides and ideal playground for students of advanced concepts such as Quantum Mechanics to explore an otherwise inaccessible world from different perspectives. VR can provide the user the ability to modify variables, constants and coefficients without knowing or understanding the underlying mathematical principles. Furthermore, VR can allow worldwide cross collaboration of student on problems and conceptual discussions of topics, previously only discussed in an in-person classroom setting with a far narrowed set of diverse views.

Finally, the study materials needed in order to pull together a successful course on Quantum Mechanics, while utilizing VR must be well structured. The course must maintain active participation, problem solving, and student collaboration in a constant feedback loop with the educator to facilitate personal growth and understanding on complex concepts. VR technology should be implemented immerse a student in the world being covered by the educator while bypassing all the mathematical formulae which may be unnecessary to concept comprehension. Together, a well defined lesson plan which logical breaks for feedback loops, VR activities and group discussions may just allow the societal acceptance of Quantum Mechanics into mainstream with study materials geared for all students, from Middle School, through adult non-scientific professionals.

1.4 Reflection

In doing research, the most difficult aspect is keeping the objective of the research in plain sight. Each new paper brings opinions, information and ideas to the table which easily derail a focused search to other topics and discussions. Keeping a focused mind is crucial to exploring the literature on a specific topic.

The most difficult part of doing this research is in shifting gears from learner to researcher. Doing the reading and learning portion of this task is exhilarating as new information flow fills voids in understanding and answers previously unanswered questions. However, to tie everything back to one central question which needs answering is proving difficult. At certain points, the body of research resembles more of answers seeking a question, rather than a targeted search for an answer to an already existent question. Possibly, the goal of this research is to summarize and concatenate this body of knowledge into a coherent guide for creating such content. The true meaning to conducting and gathering this knowledge search is still elusive.

1.5 Planning

For the following assignment the task of defining a yet unexplored, unanswered, raw area of research or content will be the goal. Most research will focus on gaps in understanding or content which may be explored.

Most research summarized above is an exploration on what already exists; however none specifies on what is missing. This will be the main search of further exploration.

The idea of Virtual Reality for Advanced Concept Learning is an idea which seems to contain much hype and concept opinions without a large base in reality. To this day, widespread acceptance of Virtual Reality headsets has been mostly in the gaming industry. Considering the adaptation of VR for teaching has been discussed for decades, further research is required in determining why its adaptation has not been widespread yet. What technological roadblocks exist to facilitating full adaptation? Additionally, what is required by educators to transition to content creators, and how high is the bar to create, maintain, and manage VR content?

If the educational community is to adapt Virtual Reality into their coursework, creating the content should be as easy as designing their laboratory experiments., adaptive as their course materials, and bring to the table unique advantages not easily reproduced in a traditional class.

2 ACTIVITY

Online education and MOOCs were praised as having the potential to equalize access to education, but critics have suggested that they are having the opposite effect and are disproportionately used by already-affluent audiences. What is the truth about the relationship between online education and equity of access? Is it having an equalizing effect, or is it actually widening the gap in access to education?

In recent years, Massive Open Online Courses (MOOCs) have exploded in popularity. Professionals can earn certificates, interested parties can survey courses, subjects and study materials which previously were only available in traditional study institutions. Ideally, the bar to a high-quality education is significantly lowered as anyone with an internet connection can have access to world-class education. Furthermore, formal educational achievements such as Master of Science degrees such as Georgia Institute of Technology's Master of Science in Computer Science are now available to students across the globe for a financially reasonable price of $7000. However, such wide and easy accessibility possibly shuts out the underprivileged which do not meet the requirements of the majority of the student cohort.

MOOCs provide scalability and flexibility on the surface. However, the problems that plagued the underprivileged still exist and bar the access to good MOOC content the same as to a good education (Ichou, 2018). Necessities such as a good, stable internet connection, computer availability, English language proficiency and experience with computing concepts are all tools needed to successfully complete MOOC coursework. With a large part of the world still underdeveloped for internet connectivity, providing educational outreach to the underprivileged is as distant as ever.

Pursuing education, as a whole is an endeavor not easily undertaken by the underprivileged. Socioeconomic status, parental education, and personal motivations drive individuals to pursue further studies. As evident by the study of (Hansen et al., 2015) a fair placement of students in the HarvardX program would represent an equal distribution to that of the larger population. Largely, this would be a population of highly educated students with parents holding multiple degrees and high salaries (Hansen et al., 2015). As such, those whose previously barred from higher education and underprivileged would still find MOOC programs inaccessible or of low interest as there is no driving force behind participating nor the technology available to participate in such programs.

The solution therein lies with the policy and advocacy for MOOC programs to the underprivileged communities. Inequality as defined by (Czerniewicz, 2018) comprises of vital inequality, resource inequality and existential inequality. While Educational Technology has predominantly focused on the theory, development and implementation, not much attention has been paid to access and opportunity for the underprivileged to reach beyond their social standing. Educational Technology is not to blame for this disparity, but neither is it the solution to all the world's problems.

Educational Technology researchers, developers and consumers must then make an effort in order to broaden the opportunity for a wider socioeconomic population access to the content. Specifically, (Toyama, 2016) outlines that those individuals already promoting for equality should use technological advancements to gain further reach, those with the power to make a change should act accordingly to be an agent of that change, direct helping to those with socioeconomic disparities through funding, mentorship and networking and finally engaging in political change which can lighten the socioeconomic burden on the underprivileged.

As such, it is evident that MOOC developers and their institutions have ownership of not only the content they create, but the responsibility to provide outreach to individuals and facilitate communication, partnership and openness with underprivileged communities to advance education. As (Doyle, 2015) summarizes, the underprivileged population only stands to increase in socioeconomic inequality, if the only goal of MOOCs is to reduce costs to higher education.

In conclusion, Massive Open Online Courses have been hailed as a revolution to the education sector. Knowledge presented by the best lecturers in their fields widely available for the masses to absorb appears as the holy grail of producing the stepping stones for upward mobility to those in need. However, technological disparities, internet availability, socioeconomic pressures and family history keep the underprivileged from participating in the MOOC experience. It seems, in actuality, that MOOCs only succeeded in bringing down the cost of admission to those who already are privileged enough to attend the same lectures as before. In order for this fact to be proven false, MOOC educational institutions themselves must do more to reach out to the underprivileged communities. Through community outreach, mentorship, opportunity and creativity, it is possible to utilize the power of MOOCs to raise struggling communities out of poverty. However, politics must play a major role in reforming the socioeconomic pressures that exist on the underprivileged in order to allow enough breathing room to consider higher education as an option for that population.

3 REFERENCES

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2) Hansen, J. D., & Reich, J. (2015, March). Socioeconomic status and MOOC enrollment: enriching demographic information with external datasets. In Proceedings of the Fifth International Conference on Learning Analytics and Knowledge (pp. 59-63). Retrieved from https://dl.acm.org/doi/abs/10.1145/2723576.2723615.
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4) Toyama, K. (2016). The internet and inequality. Communications of the ACM, 59(4), 28-30. Retrieved from https://dl.acm.org/doi/fullHtml/10.1145/2892557.
5) Doyle, P. (2015). Massive open online courses. Will they create greater opportunity or inequality. American Journal of Educational Studies, 7(1), 43-64. Retrieved from http://toto.lib.unca.edu/MLA_theses/2013/DOYLE.pdf.