2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
Paper ID #37713

Augmented Botswanan Learning Experience

Dr. Cameron Denson, North Carolina State University at Raleigh

Cameron Denson is an associate professor of Technology and Engineering Design Education (TDE) in the Dept. of Science, Technology, Engineering and Mathematics (STEM) Education at N.C. State University.

Niloufar Bayati, North Carolina State University at Raleigh

AUGMENTED BOTSWANA LEARNING EXPERIENCE

(Work in Progress)

Abstract

The Augmented Botswana Learning Experience (ABLE) is an international collaboration between two STEM institutions that engages engineering students in solving real-world problems using a problem-based learning approach and service-based learning pedagogy. The ABLE project aims to create a collaborative learning environment for engineering students in Botswana and the US by utilizing augmented reality and Onshape technologies to develop their visualization and 3D modeling skills. The project provides an eight-week co-curricular program focusing on problem-based learning approaches to address authentic real-world problems, particularly in Botswana. To accomplish the ABLE project's goals, six high-performing students from an introductory engineering graphics course in the US will serve as consultants for design teams in Botswana. The emphasis is on creating an immersive experience that utilizes mixed reality for the students using AR technology, enabling them to participate in activities that involve decision-making, object design, basic assembly and the mentality of "modify and re-define". The ABLE project represents an innovative approach to engineering education that leverages technology and cross-cultural collaboration to prepare students for real-world problem-solving, using 3D Modeling along with AR technology. Deliverables for the project include a 3-D model of the original device, 3-D model of modified model utilizing AR technology, 3-D printed examples of final products and a 2-page write up detailing the modifications and describing its presumed increased functionality.

Introduction

In 2016 a meeting was convened that included the respective presidents of the *US National Academy of Engineering*, *Royal Academy of Engineering* and the *Chinese Academy of Engineering*. In what came to be known as the Global Grand Challenges Summit, it was here that academy representatives asserted that 21st century challenges facing the global community could only be met through innovative education, research and engineering solutions. This declaration helped spur a shift in engineering education as many academic programs began organizing content around the Grand Challenges and pivoting from a competitive, lecture-based course of study to a more hands-on, collaborative problem-solving approach (Mote, Dowling, & Zhou, 2016). With a new focus on more problem-based approaches to teaching engineering concepts practitioners seized upon growing opportunities to engage students in experiential learning experiences where they could *learn by doing* (Appiah-Kubi & Brion, 2019). For the global community there were implications as well. While the recent global pandemic helped to demonstrate the unique challenges globalization presents, it also highlighted the growing possibility of intercontinental collaborations where students could hone their problem-solving abilities while solving authentic real-world problems (Beddoes, Jesiek, & Borrego, 2010; Mote, Dowling, & Zhou, 2016).

While this paradigm shift provides opportunities for students to collaborate across border lines there is still much to be learned about how to best support students in these global settings. This includes determining the most effective pedagogical practices, instructional strategies and identifying educational technologies that would best suit learning in these environments. This *Work in Progress* paper seeks to examine the potential of using augmented reality (AR technology) in support of a co-curricular, problem-based learning experience that seeks to introduce engineering and technology students to authentic real world-problems. The use of AR technology in this project will be used to help provide students with an immersive learning environment to enhance their learning experiences (Wu, Lee, Chang & Liang, 2013). This paper will first provide a brief literature review on problem-based learning in engineering education, the use of AR as a teaching tool and finally conclude with a description of the *ABLE* project and future work yet to be completed.

Problem-based learning

The literature supports active-learning approaches grounded in problem-based learning to inculcate students with critical thinking skills and problem-solving ability (Finelli et al., 2012). First introduced as a formal practice by medical educators, problem-based learning can best be described as collaborative group work whereby students are tasked with solving complex real-world problems under the direction of an instructor (Allen, Donham, & Bernhardt, 2011). Traditionally engineering education at the tertiary level has relied on a didactic approach to teaching and learning characterized by instructor-centered approaches to instruction yet, studies have shown that engineering students learn more from problem-based learning when compared to traditional lecture styles of instruction (Yadav, 2011). For engineering courses, project-based learning and problem-based learning activities also help support the development of robust and professional skills generally sought out by industry (Beddoes, Jesiek, & Boreggo, 2010).

Interestingly, a problem-based approach to learning is still seeking traction amongst students themselves. While empirical data suggests that students perform better when actively learning content in a problem-based setting, students themselves perceive lecture-based approaches to teaching as more effective, (El-adaway, Pierrakos, Truax, 2014; Yadav et al., 2011). Nonetheless, investigators for the *ABLE* project are encouraged to use this approach to learning having found that students are more motivated, show more interest and achieve at a higher level when learning within this setting (Munawaroh & Setyani, 2022).

Service-Learning

Service learning or service-based learning is seen as a pedagogical tool that supports problem-based learning by actively addressing identified needs of a community (El-adaway, Pierrakos, Truax, 2014). In the context of addressing authentic real-world problems of global communities, service-based learning pedagogy is an appropriate practice. This transformational and integrative approach to problem-based learning is unique in that it is characterized by a reciprocal relationship where both parties benefit from the activities (Furco, 1996). Furthermore, this learning pedagogy is integral in helping engineering students develop sophisticated beliefs about engineering while increasing their interest in the field (El-adaway, Pierrakos, Truax, 2014). It is the hope that framing activities in this manner will help students work towards providing solutions that are not only sustainable but consider the cultural and societal impacts of introducing technological solutions for different cultures.

Co-Curricular Learning

Another characteristic of the *ABLE* project is the co-curricular learning experience. Co-curricular experiences can be defined as learning experiences outside of the classroom that help meet meaningful learning outcomes (Suskie, 2015). As an example of a co-curricular experience, this project will utilize collaborative learning whereby students will apply content learned in the classroom (3-D modeling) to help solve real-world problems. Research has shown that students are more motivated to learn course content when provided with an authentic real-world context that allows for the application of skills learned in the classroom (Yadav et al., 2011). There are other benefits to this kind of learning experience for engineering students beyond the technical skills that students will develop. Critical thinking skills and ethics development are areas that are supported by co-curricular learning environments (Finelli et al., 2012). The co-curricular learning experience is a defining characteristic of the *ABLE* project and seen as a vital component of this intercontinental learning collaborative.

Augmented Reality

As an instructional tool augmented reality has offered some promise in engineering design settings. Augmented reality (AR) provides engineering and technology education with new and innovative opportunities to engage learners in immersive experiences that are holistic and realistic (Wu, Lee, Chang & Liang, 2013). Augmented reality can be described as 3-D modeled objects superimposed or composited into a real, physical environment. This is distinguished from virtual reality where users are immersed into a synthetic world completely (Azuma, 1997). To support the collaborative learning experience investigators felt that the use of AR technology would be most appropriate.

In a systematic review of literature on the use of AR technology in the classroom, Garzón (2021) concluded that collaborative learning experiences ruled as the context most benefiting from an AR intervention. It was also proffered that the use of problem-based learning served as the ideal environment for an AR intervention (Garzón, 2021). As a part of this project students will develop and hone their 3-D modeling skills. Recent studies have touted the potential of AR to develop 3-D modeling skills and improve spatial ability amongst engineering students (Egresitz, 2022; Guntur, Setyaningrum, & Retnawati, 2021). In considering the skills that students will develop as a part of the *ABLE* project and our intended collaborative learning environment, investigators felt that AR technology was the most appropriate educational technology to support student learning.

Project Description

This project will introduce an AR intervention through a problem-based, service-based learning experience for engineering and technology students in Botswana and the US. Using the short-course materials, students in Botswana will complete the eight-week course guided by a problem-based learning activity wherein students will work to solve an authentic real-world problem local to their community. As a part of the learning experience students in Botswana will also develop 3-D modeling skills and their spatial ability while designing a solution to a real-world problem; students in the US will develop skills in the area of engineering ethics, creativity and problem-solving as they will serve as “consultants'' for student teams in Botswana (Finelli et al., 2012; Guntur, Setyaningrum, & Retnawati, 2021).

The ABLE short program offers civil engineering students in Botswana an opportunity to develop their visualization and 3D modeling skills using OnShape software and AR media. This program will create a collaborative learning environment between students at a U.S. university with advanced 3-D modeling skills and civil engineering students in Botswana. The ABLE project will create a collaborative learning environment by matching undergraduate students from a US university with advanced 3-D modeling skills, with civil engineering students in Botswana, who will work together to address a real-world problem impacting Botswana. The program is designed to assist students in developing and refining their ability to use this universal technical language within the context of the concurrent engineering design process as well as gain an understanding of how computer-aided design (CAD) is used to create and design technological solutions to authentic real-world problems. Emphasis will be placed on Augmented Reality media that will help create an immersive experience for the international students along with collaborative learning between STEM institutes. Students will participate in activities that involve decision-making at a fundamental level, the design objects, basic assembly and the new mentality of “modify and re-define ''rather than “delete and re-create”.

To accomplish the goals of the ABLE project instructors in the US will first identify six high performing students in an introductory engineering graphics course who will serve as “consultants” for design teams in Botswana. The student design teams in Botswana will consist of three (3) to four (4) member teams who will work to solve an authentic real-world problem native to their local community. The student teams in Botswana will work with their instructor to identify existing technology that they would like to modify for the purpose of improving its performance. Over an eight (8) week period student teams will meet weekly with their team consultants who will offer suggestions for improving the modification of their technological device. Using the web-based 3-D modeling software Onshape, student teams in Botswana will engage in flipped classroom pedagogy as they learn 3-D modeling skills using pre-recorded instructional videos. To enhance the learning experience of all participants, and to create an immersive learning experience, students will use AR technology applications to depict their 3-D modeled solutions in a physical space.

For the purposes of the *ABLE* project the minimum AR technology required of students includes a camera, display, and processor. Based on consultation with AR specialists investigators for this project have chosen to work with smartphone-based AR technology that utilizes a pass-through camera-enabled mixed-reality for the user. This technology will allow for the overlay of 3-D model objects in the smartphone's camera thus creating a blend of the physical and virtual world (Keating et al., 2011). Here, while viewing the physical objects that students will seek to improve and modify they will be afforded the opportunity to view, interact, and manipulate the 3-D image they have modeled. Working in unison the camera will assist in capturing the real-world physical objects that students will work to modify. This image will then be processed by the processor which has the task of adding virtual objects to the real-world video captured by the camera. This newly created image will then be displayed using either a smartphone or laptop screen (Guntur, Setyaningrum, & Retnawati, 2021). Researchers for the *ABLE* project have experimented with the 3DBear for use as the potential processing software. 3DBear currently boasts an education option that allows for the free use of its software in a limited capacity. However, after further consultation it has been recommended that investigators for the project use Sketchfab for our 3-D viewing purposes. Sketchfab runs on legacy computing and utilizes a plethora of rendered 3-D modeling files thus improving the chances for adoption for student participants.

Work-to-Date

Investigators for the *ABLE* project traveled to Botswana in the summer of 2022 to present a Memorandum of Understanding (MOU) between the respective universities. Within this MOU, it outlined the responsibilities of each institution. This MOU was reviewed and approved by the legal team of the university in the US and subsequently was reviewed and signed-off by the corresponding university in Botswana. It is under this agreement university professors in the US are seeking to secure additional funding to further develop the co-curricular activities, fund site visits, provide training for student consultants and secure 3-D modeling materials for the co-curricular learning experience. Researchers have also identified the problem-based activity, 3-D modeling software and corresponding courses that will participate in this project. Investigators for the project have developed a truncated 8-week short course and syllabus to guide this problem-based learning experience.

Future Work

To achieve the stated goals of the *ABLE* project there are several components yet to be addressed. First, the corresponding professor in the US will need to identify an appropriate classroom in the US to facilitate the co-curricular learning experience and additionally select the six (6) high achieving students to serve as project team consultants. Furthermore, representatives from Botswana will seek to identify one co-operating instructor from Botswana and their corresponding course to allow for implementation of the eight (8) week course enhancement. Instructors in the US and Botswana will work together collaboratively to identify existing technological tools that can be modified as a part of the *ABLE* project. During their visit to Botswana, investigators for the project identified potential problem-solving activities that included a service-learning component. This included improving the design of a community water tank as shown in Figure 1 or an antiquated milk line that was no longer working as shown in Figure 2.

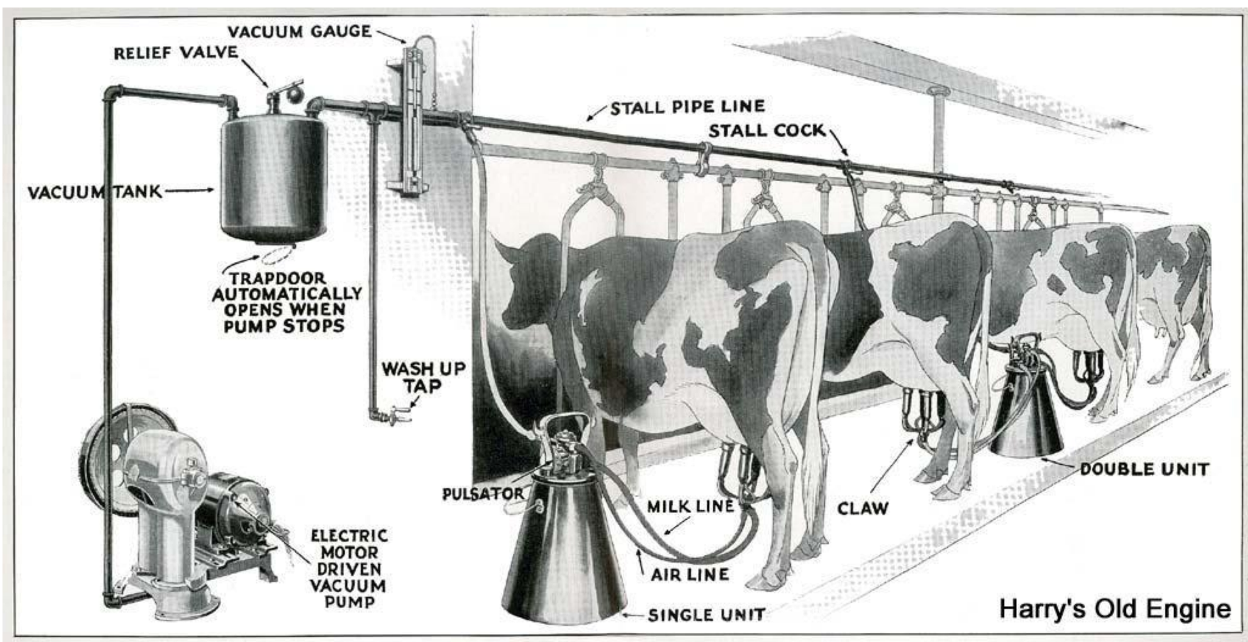
Conclusion

While ambitious, there are many challenges to providing this collaborative learning experiences for students in the US and Botswana. First, investigators must determine the appropriateness of educational technology used in support of co-curricular learning experiences. While research suggests that use of AR technology within a problem-based learning activity can provide students with a learning environment that is authentic and immersive (El-adaway, Pierrakos, Truax, 2014; Finelli et al., 2012; Garzón, 2021; Suskie, 2015), questions remain around access, compatibility and licensing of both the AR technology and the 3-D modeling software to be used. Additionally, there are logistical challenges that need to be addressed including but not limited to working in different time zones, agreeing upon suitable outcomes for both parties, determining the sustainability of potential solutions, and ascertaining cultural differences that may impact the learning experience.

Research has shown that students are more motivated to learn engineering concepts when introduced in compelling real-world contexts (Coyle, Jamieson, & Oaks, 2006). It is under this premise that investigators for the *ABLE* project endeavored to produce a service-learning project that would bring together students from different continents to solve an authentic real-world problem. As with most things of a complex nature there are many problems that we may not foresee. In doing our best to avoid these issues, diligent planning and research-based solutions will be utilized to provide students with an environment that is conducive to collaborative learning. While the development of 3-D modeling skills and spatial ability are integral to this project it is important to keep in mind that at the heart of the *ABLE* project is the development of a collaborative learning experience that can potentially help us address challenges we face as a global community.

Figure 1
Community Water Tank

Figure 2
Automated Milk Line



REFERENCES

Allen, D. E., Donham, R. S., & Bernhardt, S. A. (2011). Problem-based learning. *New directions for teaching and learning*, *2011*(128), 21-29.

Álvarez-Marín, A., & Velázquez-Iturbide, J. Á. (2021). Augmented reality and engineering education: A systematic review. *IEEE Transactions on Learning Technologies*, *14*(6), 817-831.

Appiah-Kubi, P., & Brion, C. (2019). Effects of Service Projects on the Perceived Skills of Engineering Technology Students. *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship*, *14*(1), 21-31.

Azuma, R. T. (1997). A survey of augmented reality. *Presence: teleoperators & virtual environments*, *6*(4), 355-385.

Coyle, E. J., Jamieson, L. H., & Oakes, W. C. (2006). 2005 Bernard M. Gordon Prize lecture*: Integrating Engineering Education and community service: Themes for the future of engineering education. *Journal of engineering education*, *95*(1), 7-11.

Beddoes, K. D., Jesiek, B. K., & Borrego, M. (2010). Identifying opportunities for collaborations in international engineering education research on problem-and project-based learning. *Interdisciplinary journal of problem-based learning*, *4*(2), 3.

Egresitz, J. (2022). Science fiction no longer: augmented reality and the technology engineering education classroom. *Technology and Engineering Teacher*, *81*(5), 16-21.

El-adaway, I., Pierrakos, O., & Truax, D. (2015). Sustainable construction education using problem-based learning and service learning pedagogies. *Journal of Professional Issues in Engineering Education and Practice*, *141*(1), 05014002.

Finelli, C. J., Holsapple, M. A., Ra, E., Bielby, R. M., Burt, B. A., Carpenter, D. D., ... & Sutkus, J. A. (2012). An assessment of engineering students' curricular and co-curricular experiences and their ethical development. *Journal of Engineering Education*, *101*(3), 469-494.

Furco, A. (1996). Service-learning: A balanced approach to experiential education.

Garzón, J. (2021). An overview of twenty-five years of augmented reality in education. *Multimodal Technologies and Interaction*, *5*(7), 37.

Guntur, M. I. S., Setyaningrum, W., & Retnawati, H. (2020, July). Can augmented reality improve problem-solving and spatial skill? In *Journal of Physics: Conference Series* (Vol. 1581, No. 1, p. 012063). IOP Publishing.

Keating, G., Guest, D., Konertz, A., Padovani, N., Villa, A. (2011). Designing the AR Experience: Tools and Tips for Mobile Augmented Reality UX Design. In: Marcus, A. (eds) Design, User Experience, and Usability. Theory, Methods, Tools and Practice. DUXU 2011. Lecture Notes in Computer Science, vol 6770. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-21708-1_16

Lemons, G., Carberry, A., Swan, C., & Jarvin, L. (2011). The effects of service-based learning on metacognitive strategies during an engineering design task. *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship*, *6*(2), 1-18.

Majeed, Z. H., & Ali, H. A. (2020). A review of augmented reality in educational applications. *International Journal of Advanced Technology and Engineering Exploration*, *7*(62), 20-27.

Mote, C.D., Dowling, D.A. & Zhou, J. (2016). "The power of an idea: the international impacts of the grand challenges for engineering." *Engineering* 2, no. 1 (2016): 4-7.

Munawaroh, M., & Setyani, N. S. (2022). The Effect of Problem Based Learning Model, Learning Ways and Motivation on the Entrepreneurial Attitude. *AL-ISHLAH: Jurnal Pendidikan*, *14*(3), 4023-4030.

Suskie, L. (2015). Introduction to measuring co-curricular learning. *New Directions for Institutional Research*, *2014*(164), 5-13.

Wu, H. K., Lee, S. W. Y., Chang, H. Y., & Liang, J. C. (2013). Current status, opportunities and challenges of augmented reality in education. *Computers & education*, *62*, 41-49.

Yadav, A., Subedi, D., Lundeberg, M. A., & Bunting, C. F. (2011). Problem-based learning: Influence on students' learning in an electrical engineering course. *Journal of Engineering Education*, *100*(2), 253-280.