

Cyber-innovation in the STEM classroom

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ABSTRACT: This paper presents the formative evaluation of an ongoing NSF-sponsored research project in classroom innovation using augmented reality (AR) to enhance STEM education. It will also discuss the relevance of AR in engineering and architecture research in understanding complex data sets in sustainability. Exposing students to advances in digital modeling, data visualization and performative software is preparing them for new pathways for decision-making in the AEC professions. Recent research shows that Technology Mediated Learning Environments (interacting with computer-based tools) can enhance learning. Augmented Reality (AR) or the ability to augment the real world environment with computer-generated information is bringing a new dimension to learning and designing using multiple data streams. The project objectives were to 1) explore opportunities and obstacles presented by AR in the classroom, 2) look at the impact of various strategies to integrate AR, and 3) contribute to research on how people learn using technology-mediated environments by developing a better understanding of the various attributes of these technologies.

KEYWORDS: cyberlearning, STEM education, virtual and augmented reality, sustainability

INTRODUCTION

Introducing new tools into a familiar environment is always a challenge. Introducing new teaching tools involves working with two distinct groups, instructors and students. Students lack familiarity with any previous models of the teaching environment as the course and the course material are assumed new. General learning theory assumes the critical issue for learners is they actively seek to integrate new knowledge with knowledge already in their cognitive structure (Novak: YEAR). However, introducing cyberlearning tools including augmented reality, mixed reality or any digital device creating an immersive virtual experience is a challenge for both teachers and learners. Recent research shows that Technology Mediated Learning Environments (interacting with computer-based tools) can enhance learning. Augmented Reality (AR) –the ability to augment the real-world environment with computer-generated information, experienced by multiple users in real time– is bringing a new dimension to learning (Kamarainen 2013) Integrating AR with other simulation technologies has the promise of leading the next generation of computer-based learning environments.

Our initial research questions were (1) how would engaging with digital tools impact students' problem-solving skills and collaborative learning interactions, (2) how would interaction with the project change students' understanding of building science principles in their respective disciplines, (3) would using AR enhance the ability of students to successfully transfer the principles they have learned to new situations and (4) what impact could the project approach have on student motivation for further collaborative learning, remain relevant and continue to inform our next steps.

Over the past two years, the University of Arkansas collaborated with Florida International University and Missouri State University on an NSF-Improving Undergraduate STEM Education (IUSE) grant "Collaborative Research: Strategies for Learning: Augmented Reality and Collaborative Problem-Solving for Building Sciences" (NSF #1504898). This project developed a new teaching and learning environment using integrated Building Information Modeling (BIM) with augmented reality (AR) in order to provide three-dimensional, interactive, annotated models of buildings for visual learning. In order to quantify and qualify the influence of AR on student learning, interdisciplinary courses were leveraged between architecture, mechanical, and civil engineering. The faculty collaborated to teach a joint course offered as an elective in all three disciplines on advanced topics in sustainability. The teaching staff believed this was an area with adequate duplication in all three disciplines for meaningful content to be created for a shared course.

This collaboration not only provided a platform for investigating AR in the classroom, but also exposed students to known professional domain affiliations in industry between architecture and engineering. In general, the strength of the architecture discipline is design and performance visualization while engineering focuses on design and performance analysis. Often professional students do not encounter real-world situations in the Architecture, Engineering and Construction (AEC) disciplines until they are in the professional world. Introducing the opportunity for collaboration in a shared setting to them in academia better prepares them to be leaders in their respective fields and advances student success by promoting innovation in teaching and learning in a multi-disciplinary classroom environment (Messadi 2017).

1.0 METHODOLOGY

The multidisciplinary collaboration at the University of Arkansas (UA) was pursued through three coordinated courses and group projects. The other participating schools, Florida International University (FIU) and Missouri State (MS), followed a similar structure. During the spring of 2016, the UA “Control Group” classes participated in the project. These included undergraduate level courses with students from: 1) Architecture (ARCH 303V Advanced Topics in Sustainability taught by Dr. Tahar Messadi, 2) Civil Engineering (CVEG 4863 Sustainability in Civil Engineering, taught by Dr. Andrew Braham) and 3) Mechanical Engineering (MEEG4473 Indoor Environmental Design, taught by Dr. Darin Nutter). The content of courses, testing and implementation process in the “Control Group” at UA, followed a similar path to FIU’s Control Group. These courses ran autonomously but included interdisciplinary lectures by the participating faculty, combined with in-class presentations of student research. In addition, guest speakers provided additional insights into the topics examined in class. The courses comprised from 45 students working in teams of 5-6 students with each discipline represented on the team.

In the Fall 2016 semester the three groups of students tested traditional learning tools to understand sustainable concepts in building envelopes, heating and ventilation systems, and structural elements of the an addition to Vol Walker Hall on the UA campus. In Fall 2017 three instructors, one from each respective department continued the grant study by co-teaching a combined course introducing augmented or mixed reality into the student learning process. This was the “Experimental Group.”

The UA team used the HoloLens™ a head-mounted display (HMD) with a holographic computer that creates a blended environment where the user can view reality while also “seeing” overlaid holographic data. This allows the user to interact with digital content as part of the real world. Fig. 1 is an example of the way we employed AR (technically also refereed to as ‘mixed reality’)¹ using the HoloLens to identify heating and ventilation (bright yellow), fire suppression (red), and support elements (dark yellow) in Vol Walker Hall. By overlaying these images on reality, students were able to “see” the different components of the building while standing in the building space. Based on our experimental data our formative evaluation informed



Figure 1: Simulated view using HoloLens showing projection of digital information on top of actual physical space.
Source: (Author 2017)

refinements in the approach to the development of content for the HoloLens. Students indicated they became overwhelmed trying to work through too large an area in a building while managing quantitative

analysis for three systems; we therefore focused on a single classroom area, a large studio, on the thread flow of the building.

For the content development of the digital information in the HoloLens the team collaborated with the UA TESSERACT Lab using previously generated BIM information from Vol Walker Hall. We anticipate continuing this affiliation moving forward. The summative evaluation of the IUSE-project uses pre- and post-surveys, video of collaborative student interaction and testing to compare control and experimental groups from the 2016 to 2017 semesters to measure the influence of AR on learning.

The FIU team using a similar protocol managed the cyberlearning components employing a different approach to augmented reality, AR-Skope and VR-Skope. The device used was a mobile tablet with software designed to give students just-in-time data and knowledge for building systems related to a specific campus building. Students were expected to go to the building and use the handheld device in situ while they discussing solutions to the problem sets given throughout the semester. Preliminary results of from the control and experimental group for the FIU team are given in this paper. A brief overview of their AR approach is given here and further steps are discussed in the conclusion.

The FIU team included Shahin Vassigh (FIU PI), Ali Mostafavi, Deborah Davis and Albert Elias. Three courses were identified in architecture, construction management and mechanical engineering. Rather than teach a unified course with students registered for the same class, students registered for unique courses, but worked together on three projects. The semester work was divided into three-five week units organized around the 3 units of: 1) Building Siting and Foundation, 2) Building Envelope and Mechanical Systems, and 3) Construction and Post-Occupancy Evaluation (Vassigh 2015). In cases that the content was not a part of the traditional course, it was added with an additional guest lecture, video recordings, or posted materials online. The course structure for the Experimental Group courses was almost identical to the Control Group course work, with the expectation that the Experimental Group of students had access to the project instruments. The Fall 2016 semester did not include AR and was designated the Control Group. The Spring 2017 semester included the AR-Skope software used on a mobile tablet device and was designated the Experimental Group.

2.0 RESULTS

As with our prior work, a formative evaluation and assessment continued centered around observing and understanding the interaction, collaboration and group approaches used when completing the Technical Reports, with a particular focus on improvements across our two experimental groups from Fall 2016 and Spring 2017. A key component of our formative evaluation was on providing just-in-time, constructive and informative feedback to the groups regarding their collaborative efforts, comments on their questions with respect to the Technical Report, as well as timely process-based evaluations. An important aspect involved communicating and enabling subsequent process changes to help improve group interactions and collaborative learning. The following preliminary results are based on responses from the Control and Experimental groups given on a pre- and post- Attitude Survey Questionnaire, Table 1.

Table 1: Survey given to students during the first week of classes and again in the last week of the semester. Source: (Lee 2017)

Question	N	Pre-Attitude		Post-Attitude	
		Mean	SD	Mean	SD
When I work together with others, I achieve more than when I work alone.	264	3.67	1.04	3.12	1.44
I willingly participate in cooperative learning activities.	264	4.09	0.91	3.54	1.44
When I work with other students I achieve more than when I work alone.	264	3.60	1.07	3.06	1.45
Cooperative learning can improve my attitude towards work.	264	3.95	0.91	3.42	1.41
Cooperative learning helps me to socialize more.	264	4.14	0.94	3.62	1.43
Cooperative learning enhances good working relationships among students.	264	4.11	0.88	3.52	1.40
Cooperative learning enhances class participation.	264	4.00	0.93	3.38	1.44
Creativity is facilitated in the group setting.	264	3.89	0.89	3.36	1.44
Group activities make the learning experience easier.	264	3.77	1.03	3.14	1.43
I learn to work with students who are different from me.	264	3.95	0.90	3.59	1.36
I enjoy the material more when I work with other students.	264	3.43	1.01	2.89	1.32
My work is better organized when I am in a group.	264	3.11	1.12	2.77	1.41
I prefer that my teachers use more group activities / assignments.	264	3.34	1.13	2.77	1.48

2.1 Pre-/Post-Attitude Survey on Collaborative Learning

A mixed model repeated measures ANOVA was conducted to compare the effect of Group (*Control Group*, *Experimental Group 1* and *Experimental Group 2*) and Major (*Architecture*, *Construction Management and Mechanical Engineering*) (IVs) on Test (Pre-/Posttest course learning and content knowledge) (DV). A main effect of Group was found, $F(2,256) = 7.24$ $p < .01$, $\eta^2_{\text{partial}} = .054$ as well as a significant interaction between Group and Test, $F(2,256) = 10.33$ $p < .01$, $\eta^2_{\text{partial}} = .075$. Follow up ANOVAs found a significant difference between Groups for the Posttest, $F(2,262) = 3.35$ $p = .04$, $\eta^2_{\text{partial}} = .025$, but not the Pretest. Post hoc tests using the Bonferroni correction revealed a significant difference between the *Control Group* ($M = 4.29$, $SD = .23$) and *Experimental Group 2* ($M = 5.15$, $SD = .18$) Posttests ($p = .03$) (See Figure 2). There was no significant difference between the Posttest of *Experimental Group 2* and the other two groups.

Pretest scores for all three groups were statistically the same, students in *Experimental Group 2* who employed the use of AR performed significantly better on the Posttests than students in the *Control Group*, who did not use any digital tools. This indicates that the use of our digital tools, AR positively impacts and increases on student learning and content knowledge of building science principles. This is important for two reasons. First, it provides evidence that interactive digital VR technologies can improve learning across domains that often need to work together on the same projects, such as Architecture, Construction Management and Mechanical Engineering. Second, the successful implementation of our AR application demonstrates that these technologies can further provide additional content that otherwise might be more difficult and time consuming to provide without this type of tool.

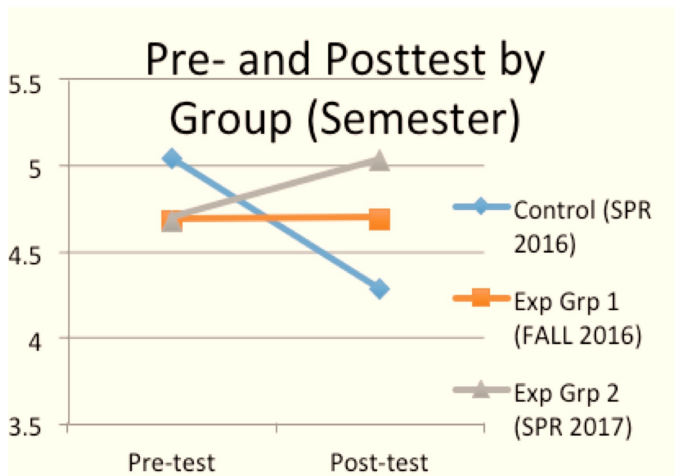


Figure 2: Content Knowledge Pre- and Posttest Scores by Group (Control Group, Experimental Group 1, Experimental Group 2) over actual physical space. Source: (Lee 2017)

Students in all three groups were also administered Pre- and Post-Attitude Surveys on their views of collaborative learning. Although engagement in collaborative learning was a focus of the formative assessment process, we were also interested in investigating whether use of the technologies in combination with formative collaborative learning approaches would impact student attitudes towards and motivation for engaging in further collaborative learning. This is of particular interest in this project as it involved students from three different domains where, some would argue, collaboration would be more difficult as a result of the need for collaboration across these divergent domains.

For all three groups, Pre-Attitude surveys were administered at the beginning of the semester, prior to the commencement of any group work. Post-Attitude surveys were administered at the end of the semester, once all group projects were completed. The survey consisted of 13 questions using a 5-point Likert scale, where responses ranged from Strongly Disagree to Strongly Agree. An overall score was calculated for each participant by converting the response for each question to an integer ranging from 1-5, and adding together the individual scores from each question.²

Overall, results indicate that students in all three groups indicated a decrease in their attitude towards collaborative learning from the Pre-Attitude ($M = 48.57$, $SD = 0.66$) to Post-Attitude ($M = 40.24$, $SD = 1.08$) surveys. As can be seen in Table 1, this pattern is consistent across each of the questions of the survey. This finding is not surprising given the cross-domain nature of our study, but it also does not tell the whole story.

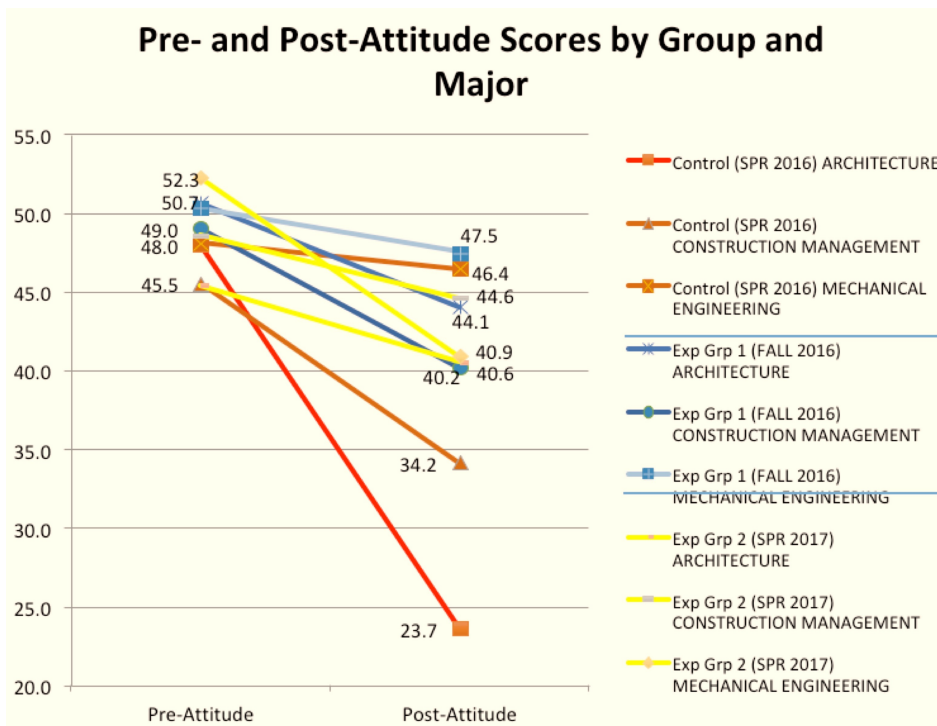


Figure 3: Collaborative Learning Attitude Pre- and Posttest Scores by Group (Control Group, Experimental Group 1, Experimental Group 2) and Major (Architecture, Construction Management and Mechanical Engineering). Source: (Davis 2017)

To better understand the formative influences on participants' attitudes, the significant interactions discussed above found should be explored more closely. Follow up ANOVAs found significant differences for the Posttest between Groups, $F(2,255) = 5.71$, $p = .004$, $\eta^2_{\text{partial}} = .043$, and Major, $F(2,255) = 6.05$, $p = .003$, $\eta^2_{\text{partial}} = .045$, and a significant interaction between Group and Major, $F(4,255) = 5.02$, $p = .001$, $\eta^2_{\text{partial}} = .073$. There were no significant differences found for the Pretest. Post hoc tests using the Least Significant Difference revealed difference between the Control Group ($M = 34.77$, $SD = 2.21$) and both Experimental Group 1 ($M = 43.91$, $SD = 1.66$) Posttests ($p = .01$) and Experimental Group 2 ($M = 42.03$, $SD = 1.70$) Posttests ($p = .011$). A significant difference for Posttests was found between the Mechanical Engineering Majors ($M = 44.95$, $SD = 1.60$) and both Architecture Majors ($M = 36.10$, $SD = 2.10$) ($p = .001$) and Construction Management Majors ($M = 39.66$, $SD = 1.89$) ($p = .03$) (See Figure 3). No significant difference was found between Architecture and Construction Management Majors. As can be seen in Figure 3, Architecture and Construction Management Majors in our Control Group had the steepest decreases in their attitudes toward collaborative learning (Lee 2015). As this was our first semester implementing collaborative learning, our formative assessments and improvements in subsequent semesters does appear to have had a mitigating impact on attitudes towards collaborative learning in subsequent semesters. Thus, although in *Experimental Group 1* and *Experimental Group 2* a decrease from Pre- to Post-Collaborative Learning Attitudes is present, the decrease is not nearly as marked as with the *Control Group*.

CONCLUSIONS

Based on our statistical analysis of preliminary results we are hopeful, but cautious about the value of cyberlearning in the STEM classroom. Results are not consistent and may reflect cultural differences across the majors participating in the study or other factors including the impact of the initial learning process with the technology, the ease of use of the AR technology offered in the FIU experimental group, or the overall organization of the course requiring students meet additional time outside of class to complete the collaborative assignments. There are various factors potentially impacting the attitudes of students in the project. The UA faculty completed the Experimental Group course in Fall 2017 and will be able to compare their results to the FIU study. We anticipate some variation in outcomes due to the differences in technology.

Designing learning models is a dynamic interaction between instructors, subject matter, and students. Adding cyberlearning tools, in our case a digital tablet giving students just-in-time access to critical data or knowledge, complicates the evaluation of results twofold. However, based on a faculty de-brief and

indicators of productivity for the university such as publications and reports, there are several collateral benefits worth mentioning. First, faculty developed curriculum across departmental boundaries. This was significant for developing new courses, especially elective courses as second; giving students in the AEC disciplines the opportunity to work together during their university experience prior to their professional life is an important strategy for educating professionals able to navigate complex real-world problems. Third, differences in discipline approaches to similar problems helped faculty in the respective disciplines identify areas of improvement for courses specific to their disciplinary curriculum. For example, engineering students had more difficulty reading plans, elevations and sections whereas architecture students were not familiar with useful software for building performance analysis. And finally, faculty productivity was affected as the study supported numerous publications, proceedings, and grant applications disseminating findings over a wider array of journals and publications. Faculty published in journals typically outside of their sphere of influence as results pertained to students and classes in multiple disciplines.

It is our intention to continue to pursue this line of questioning regarding the value of cyberlearning in the STEM classroom. Our initial research questions collaborative learning and technology integration in the classroom remain relevant and continue to inform our next steps.

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ENDNOTES

¹ Mixed reality is a general term used to indicate the use of a (typically) digital device creating a virtual or simulated representation of either 2-d or 3-d information. Augmented reality indicated the user is aware of both a real-world condition and a virtual one at the same time. For example, a museum visitor using headphones while viewing an exhibit is augmenting their experience, hence it is an augmented reality.

² A mixed model repeated measures ANOVA was conducted to compare the effect of Group (*Control Group*, *Experimental Group 1* and *Experimental Group 2*) and Major (Architecture, Construction Management and Mechanical Engineering) (IVs) on Test (Pre-/Post-Collaborative Learning Attitude Score) (DV). Main effects of Test, $F(1,255) = 61.24$ $p < .01$, $\eta^2_{\text{partial}} = .194$, Group, $F(2,255) = 5.43$ $p = .005$, $\eta^2_{\text{partial}} = .041$, and Major, $F(2,255) = 5.79$ $p = .003$, $\eta^2_{\text{partial}} = .043$, were found. Significant interactions were found between Test and Major, $F(2,255) = 3.24$ $p = .04$, $\eta^2_{\text{partial}} = .023$, and Test, Major and Semester, $F(4,255) = 6.43$ $p < .001$, $\eta^2_{\text{partial}} = .092$, along with Semester and Major, $F(4,255) = 2.53$ $p = .04$, $\eta^2_{\text{partial}} = .038$.