Enhancing Learning of System Modelling through 360^0 Virtual Reality Video and 3D Printing

Juan-Carlos Muñoz
School of Engineering and Technology
CQUniversity
Australia

Michael Cowling
School of Engineering and Technology
CQUniversity
Australia

James Birt
Faculty of Society and Design
Bond University
Australia

New technologies like 360^0 virtual reality videos and 3D printing are creating philosophical shifts in approaches to teaching and learning in the classroom. However, most studies isolate new technology rather than study the benefits of using them in combination. Multiple representations support a variety of learning activities especially when students are learning new concepts or complex ideas. This study explores the blending of a 360^0 video-case study with 3D-printed haptic manipulations to enhance learning of ICT systems analysis and design. We hypothesize that the blending of both the virtual and physical can lead to improved learning motivation, engagement and enhance learning outcomes. The study follows a design-based research (DBR) methodology with this paper representing the second loop of the DBR approach focusing on both the usability and learning outcomes from a sample of 24 participants from an Australian University. The results of the study show positive impact on the measure of navigability and communication when compared to a traditional lesson leading to improved engagement and motivation among the learners.

Keywords: system modelling, ICT education, 360^0 video, 3D printing, design-based research.

Background

Innovative new technologies such as virtual reality (VR) and 3D printing are not just altering the field of education for students, they are shaking up the role of educators and creating philosophical shifts in approaches to teaching and learning (Becker et al., 2018). There is growing interest in 3D immersion and VR applications, especially 360^0 VR videos where students can dive themselves into an immersive playback experience (Hosseini & Swaminathan, 2016). The use of visualization such as VR has provided an opportunity to present essential learning content for students using multiple visual representations. For example, when a written narrative fails to communicate a concept or a given problem, a visual representation can potentially remedy the problem and facilitate understanding (Sankey, Birch, & Gardiner, 2012).

Likewise, there is an increased growth in the use of 3D printing within education afforded by the accessibility of printers and the benefits such as creativity and manipulation (Buehler, Kane, & Hurst, 2014). 3D printing has been utilized to support learning in a range of educational and training contexts. The human sense of touch is a dynamic, informative, and convenient perceptual system to connect and construct meaningful understanding (Lederman, Klatzky, Morgan, & Hamilton, 2002). Interactive and hands-on learning environments are considered as promising strategies for providing instructional content that allows the learner to engage actively in the learning process (Jones, Minogue, Tretter, Negishi, & Taylor, 2006). However, most studies explore each of these innovative technologies in isolation. Multiple representations support a variety of learning activities and unique benefits when students are learning new concepts or complex ideas (Ainsworth, 2006).

For example, studies involving multiple mixed media visualizations have been used by paramedics to train lifesaving skills (Birt, Moore & Cowling, 2017) and within architectural design-based education to assist with spatial learning (Birt & Cowling, 2018). The use of technology and haptic representations can provide an array of visual information and feedback. In addition, the importance of using a framework as a sequence of learning activities has a significant role in ICT system modelling (Muñoz-Carpio, Cowling, & Birt, 2018). Visual literacy skills are important elements in education and their development is one of the main goals of technology education (Verner & Merksamer, 2015). An essential question that arises from this study is how 360^0 visualization and 3D-printed tools can be used as a connecting part to improve learning motivation, engagement and advance students' learning outcomes.

Methodology

The aim of this research is to investigate the learning engagement and motivation using a 360^0 video and enhanced learning modelling when adding 3D-printed components in a System Analysis and Design (SAD) context. The research intervention adopts the design-based research (DBR) hybrid approach proposed by (Muñoz-Carpio, Cowling, & Birt, 2018) when investigating learning performance and engagement in SAD. This methodology, '4C' (derived in the first DBR loop), that show an iterative process (see Figure 1), proposes a set of connected activities established with the purpose to enable requirements understanding, solutions and incremental modelling development. This method guides students with pathway support to build a model by following four steps (Conceptualization, Connection, Construction and Consolidation)
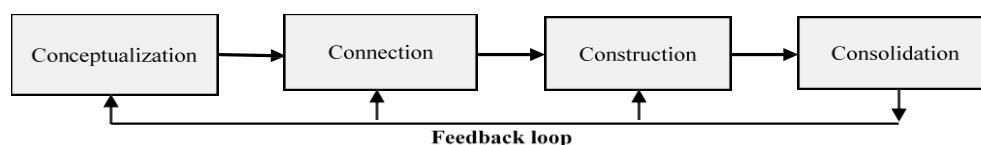

Figure 1: 4C Framework adapted from (Muñoz-Carpio, Cowling, & Birt, 2018

In the second loop, twenty-four, *(n=24)* first-year student participants currently enrolled in an information technology program were recruited as volunteers from an Australian University who enrolled in a SAD unit. Ethics clearance was granted for this study before running the experiment. All participants received a short lecture PowerPoint slide highlighting the 4C framework that provided a visual overview of the process to model their system as shown in Figure 2. A demonstration of the experiment with the tools and a usability assessment survey was also outlined.

Figure 2: Visual overview of modelling mapped to 4C framework

Learning Intervention

The second loop of the DBR experiment represents virtual and tactile elements to enhance students learning of system modelling. This follows loop one usability testing, that provided feedback for evaluation and solution implementation following the DBR methodology. All participants were imparted system modelling theory highlighting the process of constructing a system model. The students participating have a technological line competency in using unified modelling language (UML) before starting the experiment. All participants were assigned a code to be used in the test for results traceability and informed of the experiment in line with ethics. Prior to the intervention, students were administered a pre-test exam to determine level of knowledge about use cases and UML syntax to define a baseline competency.

The participants were assigned to one of the two conditions (experimental and control). Twelve participants, *(n=12)* were randomly allocated to work under a control group condition (CG) and twelve, *(n=12)* under the experimental group condition (EG). All students were provided their assignment stimulus with a scenario involving library management and booking systems, but the method of delivery was different for each group.

The CG participants were given a standard printed case study, paper and pen to create a 'use case' model. Learners in this group were assigned with the same case study as the EG but as a narrative written case. CG students were required to identify users and use cases to make connections and construct a present a system model. On the other hand, the EG was given a box containing 3D-printed components (syntax), a set of instructions and a Google cardboard type with a smart phone ready to be used for the 360^0 video to be watched. The use of a virtual scenario provides an ocular explanation of a system environment in a real-world setting and the addition of tactile 3D-printed syntax address opportunities to represent a system that can be manipulated and visualized.

The conceptualization step in the EG, allowed students to immerse themselves into a virtual case study 'library management and booking system' to experience the scenario and conceptualize the elements of the problem domain. The aim of virtual immersion is for learners to extract symbolic information from the real-world scenario rather than reading a narrative and to promote analysis motivation and visual engagement. In the second step - connection students identified actors and activities in a checklist fashion using 3D components that represent actors and activities that presents the syntax for system modelling UML. This activity can be presented as puzzle-like pieces as part of the preparation of the intervention. In the third step - construction, the initial construction of the structure of the models is represented using UML for modelling using puzzle pieces that do and do not join. This phase provides a conceptual understanding of connection and process of construction meaningful understanding reflected in a system model. Connections have made between actors and use cases form the basis of the entire system's use case model. The final phase - consolidation follows the construction phase where students have connections made between actors and use cases representing an entire and informative system. This phase assisted the learner with model abstraction from the real-world scenario and support learning with a visual and tactile learning method.

Results

We investigated the impact of presenting a case study using a 360^0 video, supported by using physical 3D- printed tools to assemble a system model. A paired *t-test* was run to determine whether there were statistically significant usability aspects. These results help determine what are the most important pedagogical advantages of using visual enabled multimodal learning for system modelling, specifically focused on learning use case modelling. The authors understand the low power of the sample size, but this is in keeping with early stage usability testing. Table 1 presents the results of paired sample *t-test* for the two conditions performed for the CG and EG of the usability measure. Each measure was ranked on a Likert scale from 0 to 5 with 0 representing not relevant and 5 representing very relevant. Results of the usability test were analyzed using SPSS v25. Table 1 display the results of the paired statistics.

Table 1: Usability Test - Paired Samples Statistics CG vs EG

Assessment measure	Mean	Std Dev	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper	t	p- value	
Accessibility	0.867	0.834	0.215	0.405	1.328	4.026	0.001#	
Learnability	0.467	1.246	0.322	-0.223	1.157	1.451	0.169	
Efficiency	0.267	1.486	0.384	-0.557	1.090	0.695	0.499	
Satisfaction	0.267	1.100	0.284	-0.342	0.876	0.939	0.364	
Memorability	0.600	1.298	0.335	-0.119	1.319	1.790	0.095	significance at 0.05 =*
Error Free	0.933	1.280	0.330	0.225	1.642	2.824	0.014*	
Manipulability	1.000	1.512	0.390	0.163	1.837	2.562	0.023*	
Navigability	1.200	1.373	0.355	0.440	1.960	3.384	0.004*	
Visibility	1.000	1.363	0.352	0.245	1.755	2.842	0.013*	significance at 0.01=#
Real-world	0.733	1.534	0.396	-0.116	1.583	1.852	0.085	
Communication	0.600	0.910	0.235	0.096	1.104	2.553	0.023*	
Creativity	0.933	1.163	0.300	0.289	1.577	3.108	0.008*	
Engaging	0.867	1.187	0.307	0.209	1.524	2.827	0.013*	
Motivating	0.867	1.457	0.376	0.060	1.674	2.303	0.037*	

The paired sample is used to determine whether the mean difference between two sets of observations is zero and measure the performance of the students' sample before and after completing the intervention. Two competing hypotheses are measured under the paired *t-test* sample, the null hypotheses (H_0 = the intervention has no positive effect on the assessment measure) and the alternative hypotheses (H_1 = the intervention has a positive effect on the assessment measure). The null hypothesis (H_0) assumes that the mean difference is equal to zero and therefore confirming the hypothesis. Alternative hypothesis assumes that the mean difference between the paired samples is not equal to zero. In our case results are not zero, confirming H_1 hypothesis. Significance of the results is determined by the p-values.

Table 1 shows the usability measures outcomes of the significant and non-significant results of the user-centered interaction. The results of the use of a 360^0 video as an educational tool fundamentally helps increasing students'

motivation and engagement. This preliminary result of the usability test as hypothesized show that the intervention has a positive effect on engagement and motivation. These results suggest that the use of a spherical 360^0 video is also significant for the intervention on accessibility, error-free, manipulability, navigability, viability and communication as it provides an added layer of facilitated interaction for individuals and between students. These results show statistically significant on the <0.050 alpha. Positive results on the accessibility (significant on the <0.010 alpha) can be associated to the ocular 360^0 interaction and consequently students' navigability and visibility that leads to engagement to the task and motivation providing a foundation for learnability when incorporating 3D printed components.

Table 2 presents the results of the plot from eight questions related to SAD domain asked to the participants. The table display the median, quartiles (Q1=lower and Q2=upper) of a data set results showing the values. Questions asked referred to use cases standards, notations and concepts. In the pre-test, the comparative groups, under the experimental conditions, the results have slightly different distributions of the results in the mean, 2.91 and 3.88 respectively. In the post-test, under EG, the results are higher (mean = 6.33) compared to the CG (mean=5.166).

Table 2: Pre and Post testing performed on two groups showing outliers

Data Summary									
Groups		N	Min	Q1	Median	Q2	Max	Mean	SD
Pre- Test	CG	12	1	2.75	3	3	5	2.9167	0.9962
	EG	12	2	3	4	5	5	3.8333	1.1934
Post- Test	CG	12	3	4.75	5	6	7	5.1667	1.1934
	EG	12	4	5.75	7	7	8	6.3333	1.1547

Table 3 presents the data results after removing atypical data value(s) that are notably different from the rest of the data (outliers) to reduce the impact of variance of the results (max 8 points). One student has been removed from the CG and two from the EG condition. The results of the pretest under both conditions shows a median value of 3 and median results of the post-test 5 and 6.5 for the CG and EG respectively. The comparative results indicate that learning in the post-test has increased compared to the pretest.

Table 3: Pre and Post testing performed on two groups with outliers removed

Data Summary									
Groups		N	Min	Q1	Median	Q2	Max	Mean	SD
Pre- Test	CG	11	0	2	3	3	4	2.5	1.0871
	EG	10	0	2	3	4.25	5	3	1.7581
Post- Test	CG	11	0	4	5	5.25	7	4.6667	1.8749
	EG	10	0	4.75	6.5	7	8	5.3333	2.708

Discussion

In this intervention we outlined the use of a VR 360^0 video case study demonstrating an alternative approach providing an educational learning experience when modelling systems. Table 1 presents the results of the paired samples *t-test* of the usability test measures (Control vs Experimental). As hypothesized, the results of alternative hypothesis H_1 confirms that the intervention has a positive effect on the assessment measure. The statistical significance is determined from the p-value, demonstrating that engagement (0.013) and motivation (0.037) are statistically significant on the <0.050 alpha. Usability results were also significant for the intervention on accessibility, error free, manipulability, navigability, visibility, communication, creativity. The nature of using haptic 3D syntax has helped students with learning outcomes in the experimental conditions post-test as indicated in Table 2 of the learning outcomes results.

The role of physical manipulation reinforces accessibility when solving problems, active collaboration and interaction which encourages communication and creativity. The nature of using 360^0 video using google cardboard with a smart phone assists students with the manipulability, memorability, navigability and communication as it provides an added layer of facilitated interaction between teams. Positive results on the accessibility and real-world measures can be associated to the visual 360^0 interaction and consequently students' satisfaction that encourages engagement and motivation and provides a groundwork for learnability.

The use of 3D-printed syntax in the learning activity can provide a haptic ability to connect the classified data elements and characterize them to the visual information captured from the 360^0 video as part of the learning activities. Table 2 presents pre-test and post-test outcomes using box and whisker results performed on two groups showing outliers. Three students have been outlaid from the total sample n=24 as they shown a high variance. Table 3 shows the results of the testing performed on two groups with outliers removed to reduce abnormal distance from the other data results in the experimental condition. As hypothesized, the incorporation of 3D-printed objects in the experimental condition enhances and reinforces learning outcomes. This result indicates that students reinforce learnability in the experimental condition. Students undertaking the experimental method score slightly higher (mean = 3) than those undertaking the traditional teaching method (mean =2.5) in the pre-test. However, the variance is minimal and can be due to the variability of students' learning competences. The findings suggest the importance of integrated interactive instructional 360^0 video into the learning activities combined with 3D-printed syntax can enhance manipulability, navigability, visibility and communication to improve motivation and learning engagement. The experimental condition is best for the consolidation stage, motivation and engagement. A limitation of the intervention is limited by the sample size (n = 24) in which the experiment was performed but compatible for usability testing. The use of a sample of students with foundational knowledge of system modelling is preferred rather than having a large number of students with no foundational knowledge. The effects of quantitative data shows quality results for discussion that can be significant when applying the intervention across a range of different areas of study.

Conclusion and future work

The use of 360^0 video enhanced by 3D-printed syntax can be used in ICT system analysis and design to enhance motivation, engagement and learning. 3D-printed components can assist students to manipulate, navigate and communicate their system models. These characteristics in partnership can boost integration and participation of learning system modelling. This level of engagement can suppress fear of failure and create learning accessibility and create positive association with learning. We are currently working on adaptive use of the 360^0 video including the use of Oculus go and Oculus quest to extend sphere towards a higher representation of the case study using simultaneous users.

References

Ainsworth, S. (2006). DeFT: A conceptual framework for considering learning with multiple representations. *Learning and instruction, 16*(3), 183-198. doi:10.1016/j.learninstruc.2006.03.001.

Becker, S. A., Brown, M., Dahlstrom, E., Davis, A., DePaul, K., Diaz, V., & Pomerantz, J. (2018). NMC horizon report: 2018 higher education edition. *Louisville, CO: EDUCAUSE.*

Birt, J., & Cowling, M. (2018). Assessing mobile mixed reality affordances as a comparative visualization pedagogy for design communication. *Research in Learning Technology, 26*. doi:10.25304/rlt.v26.2128.

Birt, J., Moore, E., & Cowling, M. (2017). Improving paramedic distance education through mobile mixed reality simulation. *Australasian Journal of Educational Technology, 33*(6), 69-83. doi:10.14742/ajet.3596.

Buehler, E., Kane, S. K., & Hurst, A. (2014). *ABC and 3D: opportunities and obstacles to 3D printing in special education environments.* Paper presented at the Proceedings of the 16th international ACM SIGACCESS conference on Computers & accessibility. doi:10.1145/2661334.2661365.

Hosseini, M., & Swaminathan, V. (2016). *Adaptive 360 VR video streaming: Divide and conquer.* Paper presented at the 2016 IEEE International Symposium on Multimedia (ISM). doi:10.1109/ISM.2016.0028.

Jones, M. G., Minogue, J., Tretter, T. R., Negishi, A., & Taylor, R. (2006). Haptic augmentation of science instruction: Does touch matter? *Science Education, 90*(1), 111-123. doi:10.1002/sce.20086.

Lederman, S. J., Klatzky, R. L., Morgan, T., & Hamilton, C. (2002). *Integrating multimodal information about surface texture via a probe: relative contributions of haptic and touch-produced sound sources.* Paper presented at the Haptic Interfaces for Virtual Environment and Teleoperator Systems, 2002. HAPTICS 2002. doi:10.1109/HAPTIC.2002.998946.

Munoz, J. C., Cowling, M. A., & Birt, J. R. (2018). Framework to Enhance Teaching and Learning in System Analysis and Unified Modelling Language. In M. J. W. Lee, S. Nikolic, G. K. W. Wong, J. Shen, M. Ros, L. C. U. Lei, & N. Venkatarayalu (Eds.), *Proceedings of 2018 IEEE International Conference on Teaching, Assessment, and Learning for Engineering, TALE 2018* (pp. 91-98). IEEE Computer Society. doi:10.1109/TALE.2018.8615284.

Sankey, M., Birch, D., & Gardiner, M. (2012). The impact of multiple representations of content using multimedia on learning outcomes across learning styles and modal preferences. *International Journal of Education and Development using ICT, 7*(3), 18-35.

Verner, I., & Merksamer, A. (2015). Digital design and 3D printing in technology teacher education. *Procedia CIRP, 36*, 182-186. doi:10.1016/j.procir.2015.08.041.