2016

Using gamification and mixed reality visualization to improve conceptual understanding in ICT system analysis and design

Juan Carlos Muñoz
Central Queensland University

Michael A. Cowling
Central Queensland University

James Birt
Bond University, james_birt@bond.edu.au

ASCILITE SHAPING THE FUTURE OF TERTIARY EDUCATION
Show Me The Learning
Adelaide, Nov 27-30, 2016

Using Gamification and Mixed Reality Visualization to Improve Conceptual Understanding in ICT System Analysis and Design

Juan Carlos Muñoz
School of Engineering and Technology
Central Queensland University

Michael A Cowling
School of Engineering and Technology
Central Queensland University

James Birt
Faculty of Society & Design
Bond University

This paper presents a research design and intervention that investigates how the use of mixed reality visualization and gamification can be applied to an ICT systems analysis and design course. The research focuses on a learning approach of an ICT modelling and design framework based on visual augmentation of traditional course content and class delivery. Assessment of the learning impact in regards to learners, system components and their interaction in system scenarios will be performed. Allowing learners to explore and discover information in the form of a gamified *scavenger hunt* that supports scaffolding learning chunks, aims to assist them towards a conceptual understanding of the solution. Educators can incorporate selected representations of key learning artefacts and resources in an augmented capacity using a variety of media such as 2d images, videos, graphics, simulations, and 3d models applied into the design process and promote active learning in the classroom.

Keywords: mixed reality, gamification, visualization, modelling and design, systems analysis

Introduction

In this fast changing digital economy, there has been an increase in the dependency on Information Systems (IS) and technology requirements across organizations (Adams et al., 2016) .With the increasing compliance between business strategies and Information Communication and Technology (ICT) design, system modelling is becoming a very relevant skill to learn (Furian et al., 2014). However, learners face increasing difficulties in conceptualizing (Moreno and Mayer, 2007) and understanding abstract concepts particularly in System Analysis and Design (SAD) (Wu et al., 2013).

Learners are challenged to conceptualize without a real world reference model, or specific visualizations of the system under investigation. This can lead to learning disconnection and therefore disengagement (Barjis et al., 2012; Fayoumi and Loucopoulos, 2016). Gamification is one potential solution to improve students' motivation and engagement in the chunking and scaffolding of information necessary to build complex systems models and to involve them into an active learning process (Dominguez et al., 2013; Hamari, Koivisto and Sarsa, 2014; Kim, 2015; Starks, 2014).

Simulations and game-based learning approaches are gaining popularity when analyzing and designing complex systems (Barjis et al., 2012). According to Prensky, Aldrich and Gibson (2007), there is an integration between innovation and technology, leading to the increasing use of visualizations (Martin et al., 2011), mixed reality (Adams et al., 2016) and game-like learning environments (Barjis et al., 2012) in higher education. These environments can be ubiquitous across desktop, web or mobile applications (Dominguez et al., 2015).

In conjunction, gamification has started to change the way training, assessment and motivation is done in business, marketing, management and sustainability initiatives (Dicheva et al., 2015), but its increasing usage and application in education and engineering is still a terrain to explore. Robson et al. (2015) acknowledges that gamification can change participants' behaviors as reinforcement and emotions are key drivers of human behaviors, which links well with education motivation and learning through visualization.

The use of visualization through multi-dimensional graphics and simulation could provide an opportunity to present key learning content for students using multiple representations (Martin et al., 2011; Wang et al., 2013; Wei et al., 2015). Augmented visualization and gamification may help to create new teaching dimensions that can increase students' motivation, attention, confidence and satisfaction and stimulate a deeper understanding of complex problems and content learning (Fayoumi and Loucopoulos, 2016; Wei et al., 2015; Wu et al., 2013).
In particular, a visual representation, images or simulations could overlay solutions, complement content and facilitate understanding when a written narrative fails to communicate a concept or a given problem (Sankey, Birch and Gardiner, 2011; Starks, 2014). Therefore, the use of mixed reality and gamification in SAD curricula has the potential to link conceptual and practical activities.

According to Siau and Loo (2006), Unified Modeling Language (UML) is the standard modeling language for object-oriented modeling, learning UML becomes essential for the majority of novice designers, as well as some proficient analysts. An essential question that arises from this research is how augmented visualization and gaming can be used as a bridge to advance students from the use of traditional UML language to comprehensively address the dynamics of a system design and improve students' conceptual understanding of modelling.

Background

According to Satzinger, Jacson and Burd (2015, p. 5) *System Analysis and Design is an iterative process where analysts build models to represent the real world using Unified Modelling Language*. Traditional delivery methods of systems modelling using UML rely on paper and pencil or abstract design tools such as MS Visio, Smartdraw or Conceptdraw diagram software (Brandt, 2013). This approach to modelling can be difficult for novice learners to understand because the concepts need to be understood first as no feedback is provided when using traditional modelling tools (Schenk, Vitalari and Davis, 1998).

Research shows that learners do not process the entire conceptual modelling of information. Instead, they focus on specific areas and components of the model and connect their understanding by integrating pieces and portions of the model (Gemino and Wand, 2005). As a result, learners are becoming disengaged, as they find it hard to understand the connection between the concepts and model components without a visual learning aid (Estapa and Nadolny, 2015; Wei et al., 2015). Therefore, scaffolding (Starks, 2014) theoretical systems models, particularly around the complexities of SAD can assist learners understand concepts. This enables them to gain conceptual understanding of design rational and how components and connections develop (Fayoumi & Loucopoulos, 2016; Sedrakyan, Snoeck & Poelmans, 2014).

The use of visualization and game-like learning environments increase social contact and collaboration and include motivational elements such as curiosity, challenge and healthy competition between students (Dicheva et al., 2015; Dominguez et al., 2013; Robson et al., 2015). Adding a gamified layer to a core activity rather than a full activity game allows learners to connect key concepts and their representations and therefore to increase user experience and engagement (Hamari, Koivisto and Sarsa, 2014).

In addition, learning environments may include more than one instructional approach. For example, a mixed reality environment can be designed in a game situation, adapting location-based learning (Wu et al., 2013). Through mobile devices learners can access important information as they arrive at pertinent locations; for example, students could discover a campus or school or information in the form of a *scavenger hunt* (Kim, 2015). Geolocation used in dispersed population could be advantageous as students could capture data or contribute to the creation of information and make them available to others (Sharples, 2013).

The use of novel educational technologies and approaches such as visualization and gamification opens up opportunities for researchers to investigate and design enhanced, interactive and more dynamic curriculum for learners. AR improves SAD courses in several ways, for example students' motivation increases when they can enjoy the process of learning and therefore course comprehension is improved. By incorporating immersion, navigation and interaction using AR, confidence, relevance and attention can be improved. Additionally, by integrating multiple sources of information while learning, AR can reduce the cognitive workload of learners (Neumann and Majoros, 1998) and allow them to focus on a particular component of the system. The cycle of building and modelling using AR can be an educational experience in itself compared to a traditional approach because it allows students to receive feedback enabling them to connect the real and the virtual scenario. The challenge in a SAD course is for learners to integrate concepts to be used by mixing technology and learning styles (Wei et al., 2015).

According to Mayer (2005) multimodal learning environments deliver instructional materials in many sensory styles. Accordingly, students that participate in a multimodal learning approach outclass learners who learn using traditional learning methods. These sets of tools are considered supportive for teaching delivery. In some situations student's learning success are determined by their ability to visualize and manipulate multidimensional materials using technology skills to thrive in the digital economies (Sankey, Birch and Gardiner, 2011).

Therefore, this research proposes an intervention for enhancing learners' understanding of SAD through augmenting traditional course content and delivery. The use of visualization, mixed reality, and gaming activities will be used to enhance learner understanding, involvement and motivation. The context for this study is a traditional face-to-face delivered undergraduate ICT SAD course at an Australian University using multiple classes. Mixed reality intervention and gamification is expected to improve Systems comprehension, conceptual understanding and engagement of students undertaking the course when compared to traditional classroom approaches of static UML. The research questions are as follows: RQ1: Does gamification and simulations allow students to visually learn about components of the system and their interaction? RQ2: Can students learning of modelling and design be improved by incorporating gamification and mixed reality learning environments into teaching practices? RQ3: Does the use of gamification in teaching enhance students' conceptual understanding compared to a traditional UML approach?

Research Design and Methods

An action research methodology will be used to capture data to answer the research questions. The research questions seek to assist in the development of a framework and to identify the attributes of future interventions. The natural cyclical setting of action research involves four dynamic steps: planning, action, observation and reflection that allow researchers to critically reflect on their actions and provide a structure for practice and improvements (Kemmis and Mc Taggart, 2005). The reflective nature of action research and its attention to practical outcomes is suitable when innovation and evaluation in teaching and learning is applied (Hodgson, Benson and Brack, 2013).

Experiment Design

Participants for this research will be 50 students enrolled in an undergraduate ICT System Analysis and Design course at an Australian University. Action research will be conducted using a multilayered visualization and will be implemented into three standard tutorial classes. All students will have access to the visualization intervention as per ethics requirements to collect data from students. The research design will incorporate tools, technology and methodologies to promote learning communication, creativity and motivation.

The approach for the experiment is to divide students into two groups A and B; taking one group out of the classroom and having this group discover learning chunks by using location based activities that feature some elements of game playing to create a systems model. Students will need to interact with their campus or community of learning, find information in a scavenger mode, and complete certain steps to connect their findings. Students will be using a mobile or tablet with a custom mixed reality application developed in Unity 3D with the Vuforia AR plug-in. As students move throughout the campus, fiduciary markers will be encountered to access chunks of game-related information that are found using the geolocation method.

The other group of students will be using the traditional approach using paper and pencil and MS Visio tool to complete UML exercises. For this purpose, students will work on different levels of the exercises and all students under experimental conditions will have access to the intervention and technology by rotating students. Student learning outcomes in the experimental conditions will be compared with the traditional approach using SPSS. The goal is to provide research data on those completing the exercise in the traditional way with those completing the intervention after implementation. Qualitative data will be analysed using NVivo to identify significant themes presented in students' survey feedback.

The requirements of the system that are examined will define the parts of the system that have to be analysed and modelled. In this case the stakeholders (researchers and tutors) will outline criteria and propose pragmatic limitations of the model. Instructions given related to the visualization intervention and model constructions will assist students to comprehend conceptual understanding of the model rationale. In particular, components of the key aspects of the problem will be modelled. The framework used for the intervention, adapted from Dominguez et al., (2015) and develop further by the authors is termed *5CT building framework*. This framework aims to assist students to find and develop blocks of information and connect them as part of the building model blueprint (see figure 1).

Fig 1. 5CT modelling framework

The first brick of the frame will be called *components* these are the parts of the system in discussion that are to be found. The second brick will be called *cases*, where a brief case description has to be completed by students. The third brick will be called *connection* where specific tasks have to be defined and matched to the *cases*. The fourth brick will be called *compilation* where the students connect relevant parts of each of the 4C steps to finally *construct* the model solution, completing the 5CT building framework to obtain a trophy as part of the gamified learning progression. Intermediate and advanced levels will be introduced to reinforce concepts for students and to help them to develop models of different levels of difficulty.

Research methods

Pre- and post- testing will be performed with students group A and B on different tutorial exercises. Data regarding students' learning outcomes in different conditions will be compared using a quantitative approach. The goal is to provide research data on those completing the exercises with the traditional UML approach to teaching modelling and those completing the exercises after implementation of the gaming/mixed reality intervention. Student learning outcomes in the experimental conditions will be compared with the traditional approach by using SPSS to help analyze quantitative data.

The students will be surveyed and the zones of improvements will be identified based on their actions. Additionally, by interviewing participants, the aim is to explore students' conceptual understanding, how learners break down the problems and integrate components to design an ICT model. Qualitative assessment exploring student motivation, communication, engagement, and their satisfaction on performing activities will be performed. The utilization of a 5-point Likert scale can quantitatively assess students *feeling* about using the new visualization tools, by comparing their perception before and after the intervention. Finally, focus groups will be used to reflect on conducting the research and allow the researchers to formulate action and planning by incorporating students' feedback. In addition, the reflections gathered will lead the investigation to the next planning stage.

Conclusions

This proposal has presented an intervention using mixed visualization and gamification to assist understanding the complexities of teaching and learning System Analysis and Design in an ICT subject in an Australian University. This study proposes a framework to support students' conceptual understanding using gaming and visualization alongside the instructions given while building their models. This investigation has proposed that the use of gamification and visualization can enhance a traditional teaching approach to modelling in the classroom; by using these techniques practitioners may promote active engagement by providing challenges to continue playing the game. These approaches will lead to an improved learning process and student outcomes compared to a traditional approach. Students will be able to work together and to share their findings, experiences and observations of the gameplay learning process.

The research design uses an action research framework and a combination of research methods: qualitative interviews, focus groups, surveys and quantitative questionnaires. These approaches will assist in gathering data and information for comparison and analysis as well as providing evidence on whether the intervention and implementation have made a difference in regards to conceptual understanding. Through the results of this work we can expect by integrating visualization and model construction the conceptual understanding of ICT modelling and design will be improved. Researchers and academics can use visualization and gamification techniques to create new learning opportunities for different learning styles and to incorporate techniques such as game challenges, hints and puzzles. For future research the use of visualization tools and gamification in ICT subjects has the potential to increase student motivation, enjoyment and engagement in learning in addition to improving comprehension of the system being engineered.

References

Adams Becker, S., Cummins, M., Davis, A., & Yuhnke, B. (2016). NMC Technology Outlook for Australian Tertiary Education: A Horizon Project Regional Report. Austin, Texas: New Media Consortium.

Barjis, J., Gupta, A., Sharda, R., Bouzdine-Chameeva, T., Lee, P.D & Verbraeck, A. (2012). Innovative teaching using simulation and virtual environments, *Interdisciplinary Journal of Information, Knowledge and Management*, 7(1), 237-255.

Brandt, C. (2013). *Review: Smartdraw 2013 Helps You Go With The Flow*. Retrieved from: http://www.pcworld.com/article/2025308/review-smartdraw-2013-helps-you-go-with-the-flow.html

Dicheva, D., Dichev, C., Agree, G., & Angelova, G (2015). Gamifying in Education: A systematic mapping study, *Educational Technology and Society*, 18(3), 75-88.

Dominguez, A.D., Saenz-de-Navarrete, J., de-Marcos, L., Fernandez-Sanz, L., Pages, C., & Martinez-Herraiz, J.J. (2013). Gamifying learning experiences: Practical implications and outcomes, *Journal of Computer and Education*, 63, 380-392.

Estapa , A., & Nadolny, L (2015). The Effect of an Augmented Reality Enhanced Mathematics lesson on Student Achievement and Motivation, *Journal of STEM education*, 16 (3), 40-48.

Fayoumi, A., & Loucopoulos P. (2016). Conceptual modelling for the design of intelligent and emergent information systems, *Journal of Expert Systems with Applications*, 59, 174-194.

Furian, N., O'Sullivan, M., Walker, C., Vossner, S., & Neubacher, D. (2015). A conceptual modelling framework for discrete event simulation using hierarchical control structures, *Journal of Simulation Modelling Practice and Theory*, 56(1), 82-96.

Gemino, A., & Wand, Y. (2005). 'Complexity and Clarity in conceptual modelling: Comparison of mandatory and optional properties', *Data and Knowledge Engineering*, 55, 301-326.

Hamari, J., Koivisto, J., & Sarsa, H. (2014). Does Gamification Work? A literature review of empirical studies on gamification, *47th Hawaii International Conference on System Science*, 3025-3034.

Hodgson, Y., Benson, R., & Brack, C. (2013). Using action research to improve student engagement in a peer-assisted learning programme, *Educational Action Research*, 21(3), 359-375.

Kim, B. (2015), *Understanding Gamification' Library Technology Reports*, 51(2), pp. 20-28.

Kemmis, S., & Mc Taggart, R., (2005). *Participatory action research: Handbook of qualitative research*, 271-330.

Martin, S., Diaz, G., Sancristobal, E., Gil, R., Castro, M., & Peire, J. (2011). 'New technology trends in education: Seven years of forecast and convergence', *Journal of Computer and Education*, 57, 1893-1906.

Mayer, R.E. (2005). *Cognitive theory of multimedia learning*. The Cambridge handbook of multimedia learning, 31-48.

Moreno, R., & Mayer, R.E. (2007). Interactive Multimodal Learning Environments, *Journal of Educational Psychology*, 19, 309-326.

Prensky, M., Gibson, D., & Aldrich, C (2007). *Games and simulation in online learning: Research and development frameworks*. Hershey USA: Information Science Publishing.

Robson, K., Plangger, K., Kietzmann, J.H., McCarthy, I., & Pitt, L. (2015). Is it all a game? Understanding the principles of gamification, *Business Horizons*, 58, 411-420.

Sankey, M.D., Birch, D., & Gardiner M.W. (2011). The impact of multiple representations of content using multimedia learning outcomes across learning styles and modal preferences, *Journal of Education and Development*, 7(3),18-35.

Satzinger, J.W., Jackson, R.B., & Burd, S.D. (2015). *Systems analysis and design in a changing world.* (7th ed.). Boston MA: Cengage learning.

Sedrakyan, G., Snoeck, M., & Poelmans, S. (2014). Assessing the effectiveness of feedback enabled simulation in teaching conceptual modelling, *Journal of Computers and Education*, 78, 367-382.

Schenk, K.D., Vitalari, N.P., & Davis, S. (1998). *Differences between novice and expert systems analyst: what do we know and what do we do?, Journal of Management Information Systems*, 15(1), 9-50.

Sharples, M (2013). Mobile Learning: Research, Practice and Challenges, *Institute of Educational Technology*, 3 (5), 5-11.

Siau, K., & Loo, P. (2006). Identifying difficulties in learning UML, *Information System Management*, Vol. 23, 3, 43-51.

Starks, K. (2014). Cognitive behavioral game design: a unified model for designing serious games, *Frontiers in psychology*, 5(28), 1-10.

Wang, Y., Vincenti, G., Braman, J., & Dudley, A. (2013). The ARICE Framework: Augmented Reality in Computing Education, *International Journal of Emerging Technologies in Learning*, 8(6), 27-34.

Wei, X., Weng, D., Liu, Y., & Wang, Y. (2015). Teaching based on augmented reality for technical creative design course, *Journal of Computer and Education*, 81, 221-234.

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

Please cite as: Muñoz, J.C., Cowling, M. & Birt, J. (2016). Using Gamification and Mixed Reality Visualization to Improve Conceptual Understanding in ICT System Analysis and Design. In S. Barker, S. Dawson, A. Pardo, & C. Colvin (Eds.), *Show Me The Learning*. *Proceedings ASCILITE 2016 Adelaide* (pp. 455-460).

Note: All published papers are refereed, having undergone a double-blind peer-review process.