# Mixed media visualization effect on student perceptions and learning outcomes

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This paper presents a methodology and pilot study rationale to examine the effect of mixed media visualization on learning outcomes in three dimensional (3D) modeling. The context for this study is a university first year undergraduate interactive media and design course. Meta analytic studies in the use of visualizations show positive improvements in learning outcomes among low and high spatial learners. But often these studies are focused on single media and virtual representations. Many multimedia learning studies do not take into consideration important factors that could influence the appropriate selection of media. This exploratory study aims to address this through the evaluation of physical and virtual media using 3D printed, virtual reality and two dimensional (2D) projections. A design science research methodology is proposed outlining several core guidelines evaluating the technology media method through learner blogs. The aim is improved learner engagement and outcomes through more meaningful learning activities.

Keywords: 3D printing, virtual reality, mixed media learning, design science research

## Introduction

The use of multimedia visualization as positive learning support tools are well documented and accepted (Mayer, 2005, 2008). The fundamental question is not whether visualization affects learning but how to take advantage of the various visualization media so that instructions and learning can be more effective (Kozma, 1991, 1994). Meta-analytic studies in two and three dimensional (2D and 3D) visualization show positive improvements in learning outcomes among low and high spatial learners (Höffler, 2010). However, these studies are to date inconsistent (Huk, 2006). Some learners learn better when provided with static pictures affording them the opportunity to build their own mental model (Mayer, 2008). Other learners learn better through provided dynamic models or haptic physical manipulation (Hwang & Hu, 2013). Typical studies examine only single media coding of the visualization (Höffler, 2010) but secondary modality or *multi-modal* instruction is important (Mayer, 2005, 2008).

Learning is considered to be an *active process* influenced by prerequisites of the learner (Mayer, 2005, 2008). In the context of 3D modeling, 3D spatial visualization is necessary, as it is involved in visualizing shapes, rotation of objects, and how pieces of a puzzle fit together (Sternberg, 1990). Compare that when encountering an image of 3D objects projected on a 2D screen or reference photograph. This is the common media used when teaching students 3D modeling. While these representations enabled learners to visualize the subject for modeling, this information literally falls flat. Many multimedia learning studies have not taken into consideration important factors that could influence the appropriate selection of media and have thus failed to yield conclusive design guidelines (Samaras, Giouvanakis, Bousiou, & Tarabanis, 2006).

There are many challenges to visualizing information including choosing between 2D and 3D interfaces, physical or virtual navigation, interaction methods, and selecting an appropriate level of detail (Hwang & Hu, 2013). Visualization for teaching and learning is nearly ubiquitous. In many cases, visualizations represent either reality, or an approximation of a physical reality. In this problem domain cutting edge Virtual Reality (VR) devices could hold the answer as objects can be explored in 3D space but even an object displayed using a 3D VR display can't be touched and held. While haptic technology may hold out the promise of adding the dimension of touch to digital information, there is no substitute on the near-term horizon for gaining the knowledge that we gain by holding and manipulating a physical 3D object. 3D printing offers a way to bridge this gap between the virtual and the real (Loy, 2014).

No particular media is necessary for learning, nor is a particular method however both media and methods influence learning by influencing each other. In good design, media and methods are inexorably confounded (Mayer, 2005, 2008). Media constrains and enables methods and methods take advantage of media capabilities (Kozma, 1991, 1994). This paper presents a rationale for a mixed media approach which affords positive impacts on student learning outcomes in the context of 3D spatial modeling. A design science research methodology is presented outlining several guidelines for conducting and evaluating the pilot study.

## Project rationale

Research into teaching and learning with new technologies is a current and relevant area of inquiry. Educational institutions are increasingly engaged with integrating new technology into the delivery of course materials and in the provision of alternate methods for learning (Johnson et al., 2013). Educational technology has seen a shift from media as conveyors of methods to media and methods as facilitators of knowledge-construction and meaning-making on the part of learners (Kozma, 1991, 1994). There is however, criticism of innovative technology as technology for technology sake (Hooper & Rieber, 1995).

Technology by definition applies current or evolving knowledge for useful purpose. Therefore a differentiation between *innovative* and *substitutive* uses of technology is required (Garrison & Vaughan, 2008). Learners and educators must enter into a collaboration or partnership with technology in order to create a *community* (Zhao & Kuh, 2004) that encourages and supports the learning process. The perspective of the classroom therefore changes to become learner centered (Weimer, 2013) emphasizing a wider range of skills (Huk, 2006). In this model technology must be justified and student expectations addressed to achieve *active engagement* (Smith, Sheppard, Johnson, & Johnson, 2005) or *presence* (Garrison & Vaughan, 2008) through technology. The technology must *afford* (Hooper & Rieber, 1995) an improved and real educational benefit and not mere distraction to meet the opportunities that the technology may offer. This leads to improved engagement, more meaningful learning activities, and greater learner responsibility for their own learning.

As discussed there are many challenges to visualizing information in 2D and 3D. In the context of this study the problem domain is the acquirement of theoretical and practical knowledge about 3D graphics and design. This is an important topic that should be exercised by students in an interactive design curriculum. The fundamental objectives are exploration of 3D geometry including moving, orienting, constructing, visualizing and communicating. The 3D development pipeline emphasizes the importance of exploring different media representations but typical methods involve only 2D reference images and 3D objects projected in 2D. Höffler, 2010 showed that high and low spatial learners show positive improvements in learning outcomes through 2D and 3D visualization but these studies are often inconsistent (Huk, 2006). Typically only single media coding methods are examined but secondary modality or *multi-modal* instruction is important (Mayer, 2005). In exploring a mixed media approach to learning the use of cutting edge VR technology and 3D printing holds great promise (Fowler, 2014; Hwang & Hu, 2013; Loy, 2014).

VR technologies are mature, but the uptake in education has been hindered by cost, expertise and capability. This is now changing with the recent wave of low cost immersive 3D VR technology by vendors such as Oculus Rift ™ (http://www.oculusvr.com/) and powerful interactive 3D visualization software platforms such as Unity3D ™ (http://unity3d.com/). There is an impending market for commercial VR systems highlighted by the recent acquisition of Oculus Rift by Facebook and vendors such as Sony entering into the commercial VR sector. When considering VR there are three defining factors: (i) illusion of three dimensions, (ii) smooth motion, and (iii) level of interactivity (Wann & Mon-Williams, 1996). While the latest technology assists with the first two factors there is still an innate lack of physical haptic feedback that one gains through physical media manipulation (Fowler, 2014).

3D printing offers a way to bridge the gap between the virtual and the real. 3D printing has seen an explosion in the past five years due to low cost fused deposition modeling (FDM) systems by makers such as MakerBot ™ (http://www.makerbot.com/). 3D printing at its basic level uses an additive manufacturing process to build objects up in layers using plastic polymer. Although the process is slow 3D printing creates direct links between a virtual 3D based model and the formation of an accurate physical representation from that model (Loy, 2014). This direct linking of object making to computer modeling, changes the relationship of the student to the making process. With rapid changes in today's digital economy, learners must adapt and comprehend multiple disciplines and skills in design and technology to remain internationally competitive and motivated (Keppell, Suddaby, & Hard, 2011). It is therefore appropriate and timely to not only adopt these cutting edge technologies but appropriate and necessary for students to learn about these technologies and apply their use in the classroom.

## Project methodology

As prior research has revealed there are strengths and weaknesses in the impact of any single technology on learning, and that learners themselves have different styles and capabilities, the research focus is therefore on the synergy among the visualizations to create and reinforce the material to be learned. Thus the first research question is: RQ1: "How do learners perceive the comparative capabilities of visualization media to support learning?" But as learning is a process of gaining new knowledge (of the material in the curriculum) and familiarity (with the technology) it is reasonable to assume that learners perceptions will differ between specific lesson tasks and will change over time. Thus a second question is required: RQ2: "Do learners preferences for visualization technologies change with task or over time?" A design science research methodology (Hevner, March, Park, & Ram, 2004) is proposed for this study and method guidelines addressed including: (i) *artifact design;* (ii) *problem relevance;* (iii) *design evaluation;* (iv) *research contribution;* (v) *research rigor;* (vi) *search process; and* (vii) *research communication*

Table 1 outlines the proposed learning objectives and applied media conditions developed in accordance with the a*rtifact design*. The technology affordances (Hooper & Rieber, 1995) and necessity for a dual coding method (Mayer, 2005, 2008) have been addressed.

**Table 1: Learning objective and applied media conditions**

| Learning Objective | Applied Media Condition | | |
|---|---|---|---|
| | 2D | 3D VR | 3D Print |
| Apply geometry construction methods in the design of 3D models | | Y | Y |
| Demonstrate applied knowledge of curved surfaces in the design 3D models | Y | Y | |
| Apply material shader algorithms in the design of 3D models | Y | Y | |
| Apply texture mapping methods in the design of 3D models | | Y | Y |
| Demonstrate applied knowledge of lighting theory in constructing 3D scenes | Y | | Y |
| Demonstrate applied knowledge of Level of Detail in constructing 3D models | | Y | Y |

To address p*roblem relevance* a technology visualization is constructed for each learning objective and media condition. An illustrative example of the geometry construction learning objective is provided in figure 1. The model is constructed using a benchmark lesson plan (Autodesk, 2013) to construct a 3D temple. The resulting model is 3D printed using a MakerBot $^{TM}$ Replicator$^{2}$ and placed into a VR simulation environment using Unity3D and the Oculus Rift. The result affords *learner centered* (Weimer, 2013); *active engagement* (Smith, et al., 2005) through physical and virtual interaction with the visualization media. This in turn allows both high and low spatial learners to engage and conceptualize the object before constructing their own example.

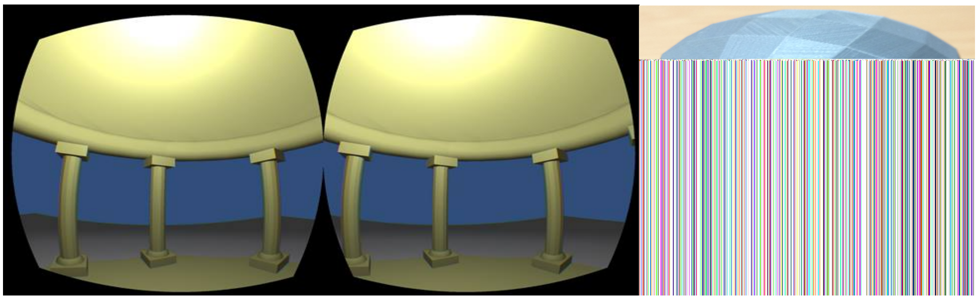

**Figure 1: 3D virtual and physical technology visualization of geometry learning objective**

Learning journals or blogs have been shown to allow learners to record their systematic thoughts and facilitate student self-reflection (Garrison & Vaughan, 2008). This evaluation method satisfies the need to *evaluate the design* and is proposed to record learner observations, testing, and simulation experiences of the media conditions. A dual representation is presented for each media condition enabling direct comparison between the media methods. For each learning objective the following stimuli questions are proposed.

1. Which media form(s) engaged you and what aspect(s) made it engaging?
2. Which media form(s) did you find most memorable in your understanding of the objective and why?
3. Discuss the differences in media form (clarity, visibility & interactivity) and limitations (constraints).
4. For the purpose of demonstrating the objective to a design team, which media would you use and why?

In using design science research the aim is to test how well the media works for the proposed learning objectives and study environment. The *research contribution and rigor* is achieved through creative development and use of the fore mentioned evaluation method. This enables assessment by the learners regarding media fidelity and implementation method and assessment of the learners by assessing the students through creative assessment using the learning objectives as assessment criteria. The outcomes contribute to existing research literature in education technology and visualization. Design science is inherently iterative or the *search process* for the best or optimal design. This reflects well the modeling development pipeline or prototype development cycle. Through multiple iterations and exposures to the technology students will improve not only learning outcomes but an understanding and working knowledge of the media technology and purpose. Finally, the method requires both technology presentation and discussion and a method of pedagogy improvement to *communicate the research* to both technologists and learning managers. The effects of the mixed media visualizations on learning will be evaluated through qualitative analysis of the journals (and supplementary comments) and academic performance in the class. The outcomes will be analyzed using NVIVO$^{TM}$ (http://www.qsrinternational.com) and qualitative analysis correlated against existing literature and student outcomes.

## Conclusion

In this paper, the study rationale, methodology and intended outcomes for a pilot study that seeks to investigate the effect of mixed media visualization on learning outcomes in 3D spatial modeling was presented. A technology framework and set of guidelines for achieving this through design science research is proposed. The developed resource examples as well as qualitative analysis of learner evaluations, relationship to existing literature and learning results will be practical outcomes of the project from which member of the education technology community will benefit.

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