Chapter 33
Application of an Online Interactive Simulation Tool to Teach Engineering Concepts Using 3D Spatial Structures

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ABSTRACT

Simulations can be powerful learning tools that allow students to explore and understand concepts in ways that are not possible in typical classroom settings. However, research is lacking as to how to use simulations most effectively in different types of learning environments. To address this need, we designed a study to examine the impact of using online interactive simulations on the learning and motivation of 109 undergraduate architecture students from two large public universities. The simulation tool allowed students to create models of spatial structures and analyze the effects of loads on structural member forces and deflections. The authors incorporated the simulations into our instructional design using an inquiry approach because it was consistent with our goals of teaching students concepts and the process of deriving the concepts. They documented that online interactive simulations delivered through inquiry-based instruction can be an effective means to help students learn and apply concepts.

INTRODUCTION

New technologies have made simulations powerful learning tools that can be used to create more realistic, experiential learning environments (Bell & Kozlowski, 2007). A simulation is generally defined as "a simulated real life scenario displayed on the computer, which the student has to act upon" (Tessmer, Jonassen, & Caverly, 1989, p. 89). Further, in using simulations in educational environments: "An instructional simulation involves interaction with a dynamic, changing, computable model; new states of the model are determined by the learner's actions toward the

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model or by its own continuous computations" (Gibbons, McConkie, Seo, & Wiley, 2009, p. 171).

For some educational objectives, simulations can offer several advantages over other types of instruction. First, simulations can focus learners on the key contextual characteristics related to the educational objectives by removing distracting elements that may be present in real-world situations (Alessi & Trollip, 2001; Schiflett, Elliott, Salas, & Coovert, 2004). Second, students can receive feedback that they would not otherwise receive in the real world (Joyce, Wei, & Calhoun, 2004). For example, simulations make it impossible for students to construct a building with many different configurations, apply various loads to it, and measure the member forces and deflections. Third, an advantage of *online* simulations is that they can be used completed asynchronously at any location where there is an Internet connection. Online courses have also been shown to have some positive effects on students' motivation (Jones, Watson, Rakes, & Akalin, 2013). Fourth, students who use interactive simulations or games have been shown to have significantly higher cognitive gains and better attitudes towards learning than students who receive traditional teaching methods (Vogel, Greenwood-Erickson, Cannon-Bowers, & Bowers, 2006). For these reasons, simulations are being used with more frequency in academia and industry (Faria, 1998; Faria & Nulsen, 1996). Despite the potential advantages of simulations, their use is limited by several factors. The cost of developing simulations can be high and research is lacking as to when and how to use simulations most effectively in learning environments (Bell, Kanar, & Kozlowski, 2008).

To better understand how simulations can be used in the context of a university course, we designed a study to examine the impact of using online interactive simulations on students' learning and motivation. We conducted our study with undergraduate architecture students after developing a web-based simulation, titled "Structure And Form Analysis System" (SAFAS), that allows students to create models of spatial structures and analyze the effects of loads on structural member forces and deflections. SAFAS is particularly appropriate for use by architecture students because, as future architects, their main responsibility will be to define the overall form of their design. In addition, they are often required to complete structural engineering courses to increase their understanding of structural concepts. Learning these concepts helps them to create more efficient designs and develop the understanding needed to communicate with engineers. One important ability that students obtain in these courses is an understanding of the effects of loads on structures by sizing and calculating forces in structural members. However, other important information that can be learned is a conceptual understanding of how structures can be designed most efficiently through: the number and location of columns, changing the depth of structural members, examining the effects of overhang length, using different support types, and using different grid configurations for spatial structures. We hypothesized that the use of SAFAS as an online simulation tool would allow students to learn these types of concepts. The use of a simulation tool is critical because it is impractical for students to test these concepts in the real world with building materials.

To incorporate the use of SAFAS into undergraduate structural courses, we developed six online assignments that could be used by instructors to teach specific structural concepts. We chose to place the assignments online so that students could use them with SAFAS and learn the structural concepts on their own, completely online. The assignments allowed students to learn how to use SAFAS and provided opportunities for them to gain a conceptual understanding of important structural engineering concepts. We chose to incorporate the simulations and assignments into our instructional design through the use of an inquiry-based approach (e.g., Collins & Stevens, 1983; Furtak, Seidel, Iverson, & Briggs, 2012). The purposes of this paper were (a) to