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Exploring a simple visualization tool for improving conceptual understanding of classical beam theory

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Abstract

First year students struggle to understand the concepts in introductory engineering physics courses. Computer generated visualizations have proven their value for improving learning in tertiary education. However, it remains often unclear how visualization software can be effectively deployed in classrooms to best improve learning outcomes. In this paper we put a freshly developed educational software entitled "The virtual beam demonstrator" to a first test in a physics and mechanics lecture at Oslo University College. The intention of this work was to explore how to get the balance between technology, pedagogics, and content knowledge right to best support student learning. We evaluated student learning outcomes of our initial attempt to use the software in a classroom based on a student evaluation form. While initial results are promising, we cannot claim to have significantly improved student learning in our initial attempt at using the software. The evaluations showed only slight improvement in conceptual understanding by the students. This finding was not unexpected as we anticipated that finding the right approach for putting this software to use would take several attempts. To turn failure into success, we would need a stronger emphasis on customized pedagogic methods. Relevant theory is explored and an approach based on "Interactive Lecture Demonstrations" is proposed.

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Keywords: classical beam theory; visualization; coherence; engineering education; interactive lecture demonstrations

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1. Introduction

Several studies in the past three decades have shown that traditional lectures ("chalk and talk", "teaching by telling", "deductive" as opposed to "inductive" [15]) are not the best way of improving students' conceptual understanding within engineering education. Sokoloff and Thornton claim to see no more then 5-15% learning improvements after a physics course run exclusively based on traditional lectures [1]. Similarly, a large longitudinal 10-year study (1999-2009) run at the University of Sydney showed an improvement of 13-19% in students' conceptual understanding after a 5-week introduction physics course (Newton's laws, velocity and acceleration) lectured in a traditional manner [13]. Inspired by such research outcomes, Sokoloff and Thornton developed a novel pedagogical approach called «Interactive lecture demonstrations» [1]. Their pedagogical approach is designed to encourage discussion, reflection and understanding. In consecutive studies they report up to 80% improvement in conceptual understanding from courses where this approach is implemented [13]. Some of the findings from these studies suggest that student learning can be significantly improved when emphasizing conceptual understanding by making use of appropriate technology [14].

Although a range of such teaching concepts are available, civil engineering courses are still typically lectured in a more traditional manner. Consequently, many first year engineering students find it difficult to obtain conceptual understanding from what is presented on the blackboard alone. Laboratory work is the typical solution to this problem. However, increasing class sizes limit the use of practical lab work in basic physics courses. In this paper, we contribute to the discussion of how virtual demonstrations of physical concepts and principles could contribute to increasing learning outcomes in civil engineering. At last year's Creative Construction Conference, we presented an article introducing an early prototype of a software developed for the purpose of providing first year engineering students with an initial understanding of classical beam theory [2, 3]. The software features a three-dimensional view of different beam structures and their response to applied forces (e.g. deflection, bending moments, shear forces, stresses). It emphasizes visualization and ease of use to ensure that the system can be readily used in classroom settings. Following up on an initial test by ten first year students at Oslo University College in 2014, the software has been refined throughout 2015. This article picks up where its predecessor left off and we report our experiences from the first practical implementation of the system in a lecture on "Physics and Mechanics" at Oslo University College held in early October 2015 with more than 90 engineering students attending. The research question asked was: *How can the 'Virtual beam demonstrator' be used best in a lecture hall to support students' conceptual understanding of classical beam theory?*

We argue that this research is important beyond the context of Oslo University College and that lecturers elsewhere may find useful ideas for teaching their students based on our work. Placing our self-made program 'virtual beam demonstrator' at the core of our study rather than using other commercially, available software allowed us for changing the software based on student requirements as we went along. This provided us with the some flexibility to fine-tune the technology based on emerging pedagogical and content knowledge. This was a precondition for creating a successful learning system. We made the software freely available on the web[1] and the two versions (e.g. 1.0 and 2.0) have been downloaded altogether more than 100 times indicating interest in our work. To understand how to best use the software in a classroom setting we ingrained our work in the Technology, Pedagogy and Content Knowledge (TPACK) framework stemming from the literature on pedagogics [12]. This framework has been developed for exploring how technology can be utilized to its full potential within education. While our work is limited in that we study a local Norwegian visualization-based teaching solution, we argue that our findings related to developing a teaching 'system' combining pedagogical, technological and content knowledge are relevant beyond our context. However, this would need to be verified by research into other visualization based teaching solutions elsewhere. The remainder of the article is structured as follows: first we introduce the TPACK theory informing our work, second the method is briefly presented, third the findings of the student evaluations are presented. Last, the discussion and conclusions of our work are introduced.

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1 http://www.mathworks.com/matlabcentral/fileexchange/49780-virtual-beam-demonstrator