Opportunities and Challenges of Using Technology in Mathematics Education of Creative Engineering Studies

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Abstract. This paper explores the opportunities and challenges of integrating technology to support mathematics teaching and learning in creative engineering disciplines. We base our discussion on data from our research in the Media Technology department of Aalborg University Copenhagen, Denmark. Our analysis proposes that unlike in other engineering disciplines, technology in these disciplines should be used for contextualizing mathematics rather than introducing and exploring mathematical concepts.

1 Introduction

Over the past years, changes in the engineering profession and engineering education have followed changes in technology and society (1). Disciplines were added and curricula were created to meet the critical challenges in society and to provide the workforce required to integrate new developments into our economy. To this end, a number of creative engineering educational programs have arisen (e.g. Architecture and Design, Media Technology, Sustainable Design). Such programs transcend the division between technical, scientific and creative disciplines. By focusing on innovation and new technologies, they aim at fostering creative thinking ability in their students (2).

In relation to mathematics education, this new development means that we experience a transposition from an industrial use of mathematics, where it is employed intensively by mechanical and construction engineers as a tool in order to develop products and build constructions, towards a situation where mathematics is increasingly used as the actual building blocks in various new digital products and creative expressions. This transposition has implications on how mathematics should be taught in more creative engineering disciplines.

The teaching of mathematics to students of such disciplines represents a challenge to the educational system; typically these disciplines are more related to arts and humanities, and constructed in specific opposition to the technology and science. The typical student lacks basic skills in mathematics and does not relate to the standard applications of mathematics (for example in science and economy) mentioned in textbooks (3). Those students often do not approach or perceive the mathematics the same

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way as mathematics students do, and moreover mathematics is used in a different way in creative disciplines than in science.

This paper emerges from our research set out to explore the opportunities and challenges of integrating technology to support mathematics education in creative engineering disciplines. In order to better inform our research, we conducted a study at Media Technology Department of Aalborg University Copenhagen, Denmark. This study focused on investigating different ways of introducing technology in mathematics education. Our results proposed that unlike in other engineering disciplines, technology in these disciplines should be used for contextualizing mathematics rather than introducing and exploring mathematical concepts.

2 Background Work

In the last decades, the rapid development in ICT has provided new possibilities for education to integrate digital technologies into schooling, and thus enhance teaching and learning. Such technologies have been widely used to face challenges in mathematics education both in primary and secondary schools, and in a lesser extent in universities (4). However, the use of such technologies has not met yet the initial expectations on reforming teaching and learning (5).

The use of technology for mathematics teaching and learning can be classified in two dimensions: 1) design and evaluation of theoretical frames that are used in technology-related research in the domain of mathematics education (6) and 2) the introduction of domain-specific technological tools. In the following, we cite some research approaches related to both dimensions.

In the field of theoretical frames, some researchers proposed the use of technology to develop applications of mathematics to the specific tasks required in the profession or towards a domain understanding of mathematics that resembles the understanding in the target profession. Within engineering education Shaffer has developed a framework designed to support the didactical transposition in terms of a relation between an epistemic frame (describing professional knowledge), and an epistemic game – a didactical design aiming at re-creating this professional knowledge in a school situation (7).

Other researchers favored blended learning designs that combine online and face-to-face instruction. Kashefi et al. designed a blended learning environment based on computer-based mathematical thinking and creative problem solving aimed at improving generic mathematics skills (such as communication, teamwork, problem solving, and technology skills) in a group of undergraduate engineering students (8).

Regarding the introduction of technological tools in university mathematics education, Matlab, GeoGebra and Computer Algebra Systems (CAS) have been the most popular choices. Matlab, which is an environment for numerical computation, visualization, and programming, has been particularly popular in mathematics courses intended for engineering students. It has been used by Chang for in-class activities that demonstrate linear algebra concepts (9), and by Pennell et. al for designing illustrative examples of differential equations in an engineering mathematics course (10).

Based on a threefold learning concept comprising mathematical methods, Matlab programming, and practical engineering, Behrens et al. developed a laboratory course for engineering students where mathematical basics were transferred to algorithms in Matlab in order to control Lego Mindstorms robots (11).

GeoGebra is open source dynamic mathematics software that combines the ease-of-use of dynamic geometry software with some basic features of computer algebra systems (Hohenwarter & Preiner, 2007). Diković has used GeoGebra to reform a part of a calculus course for undergraduate students in Business-Technology (Diković, 2009). Jaworski has used it to promote inquiry and facilitate conceptual understanding of students in a first year university mathematics course for engineering students (Jaworski, 2010).

CAS are software programs that support manipulation of mathematical expressions in symbolic form. During the past decades, a number of studies examined various educational uses of CAS (Brito et al., 2009), students' learning in CAS-equipped environments (Connors & Snook, 2001), and innovative teaching practices with CAS in university classrooms (Thomas & Holton, 2003).

However, little is known about the emerging field of technology for mathematics education in creative engineering. In the literature, it has not been discussed how technology could support the different (and more constructive) modes of application of mathematics and how it could influence the creative students' conception and attitude towards mathematics. Getting inspiration from the aforementioned research approaches, we conducted research in order to identify what kind of approach would best fit these creative disciplines. We attempt to answer these questions in the following sections.

3 Methods

With the aim of investigating how technology can support mathematics education in creative engineering, we conducted research, based on qualitative and quantitative methods. Our research was carried out at the Media Technology (MT) department of Aalborg University Copenhagen, Denmark in the 2012 – 2013 and 2013 – 2014 academic years. Aalborg University is unique in a Danish context because it has a portfolio of trans-disciplinary educational programs where the division between the "creative" designer or architect and the "scientific" engineer is increasingly challenged and transcended. The program in MT is one example of such educational programs.

The MT bachelor and master programs link many areas within film and media science, animation, sound design, computer science and psychology together to meet the growing need to understand new applications and to develop technology and program design that speaks to people's needs and taste (12). Thus, MT is an education that focuses on research, which combines technology and creativity.

We have been gathering data during three semesters in MT, in order to get insight in the process of mathematics teaching and learning in this department. During the

first semester of our research, we introduced GeoGebra applets in the "Mathematics for Multimedia Applications" course, which is taught during the second semester of the bachelor study. During the second semester, we organized a math brush-up workshop, which used technological tools for putting mathematics into context (13). During the third semester, we organized a math brush-up workshop, which used a blended learning approach. During this workshop, students were given solved exercises as pencasts and online material for self-studying before each lecture. Lectures were dedicated to solving assignments.

Data were collected by combining quantitative methods (pre- and post-tests before and after the workshops), qualitative methods (questionnaires and interviews) and ethnographic methods (lesson and exercise solving observations).

Based on this data, we draw conclusions on which approach is better suited for creative engineers and discuss opportunities and challenges of introducing technology in creative engineers in the next section.

4 Results

Based on the methods described in the previous section, we were able to collect data on students' performance and preferences on technology in mathematics education in MT. Regarding performance, MT students are low achievers in mathematics and show low retention. This is mainly due to lack of basic skills and conceptual understanding.

The analysis of our data also revealed that although MT students are technology oriented and prefer visual methods in many of their courses, they are reluctant to use technology for mathematics education. More specifically, 34.6% of the students do not like to use a computer for doing mathematics, while only 30.4% of them would like to do mathematics on a computer (the rest are responded neutrally). Our qualitative data showed that this is because of lack of confidence with mathematics. Students are afraid that the introduction of technological tools will result to added complexity. For the same reasons, students often prefer not to use visual methods when attempting to solve mathematical problems and therefore showed little interest in using GeoGebra applets for visualization of mathematics.

The blended learning approach was not successful either, because students were not diligent enough. Many of students did not perform the self-study required before the lectures, and therefore were unable to solve their assignments or to ask relevant questions. Our data shows that students accept their lack of knowledge in mathematics but at the same time they are not willing to work for getting this knowledge.

MT students favored the approach, which focused on using technology for putting mathematics into context. They stated that contextualization makes mathematics more interesting and improves their motivation to learn mathematics. Moreover, our data show that students' reported increased confidence on mathematics after they followed the workshop with mathematics into context.

5 Discussion

The results of our research showed that the introduction of technology in mathematics education presents both opportunities and challenges for creative engineering students. On one hand, technology could discourage these students, because they often have difficulties in mathematics due to lack of basic skills and conceptual understanding or due to an inability to perform deductive reasoning. Technological tools can provide visualizations and methods to interact with mathematical concepts, but they also require a basic understanding of these concepts. Therefore, students with low understanding in mathematics cannot take advantage of such tools, and they feel frustrated if they are obliged to use them. Moreover, students lack motivation and therefore they are not willing to invest time on studying mathematics. Therefore, methods that require extra effort by their side tend not to be successful.

On the other hand, technology could be used for connecting mathematics to its applications in professional or academic practices. Creative engineering students reported that they are aware of the importance of mathematics and would like to see its application aspects in their studies. Therefore, we believe that the introduction of technology in mathematics education for these students contributes to increase motivation and interest, when it offers new possibilities for creating contextualization of mathematics

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