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Technology-Enhanced Mathematics Education for Creative Engineering Studies

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Abstract—This project explores the opportunities and challenges of integrating digital technologies in mathematics education in creative engineering studies. Students in such studies lack motivation and do not perceive the mathematics the same way as mathematics students do. Digital technologies offer new possibilities for mathematics representation, for interacting with mathematical concepts, and for positioning mathematics in the context of their studies. First, we are going to investigate how mathematics is used in their professional and academic work, and how important mathematical concepts are conceptualized. Then, we are going to apply this field data in designing learning technologies, which will be introduced in university classrooms. The effect of this introduction will be evaluated through educational design experiments.

Keywords - *technology-enhanced education; mathematics; engineering studies; participatory design;*

I. INTRODUCTION: MOTIVATION FOR THE RESEARCH

Over the past years a number of educational programs have arisen that transcend the division between technical, scientific and creative disciplines (e.g. Architecture and Design, Media Technology, Sustainable Design). 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 technical studies.

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 [1]. The use of digital images and video clips to stimulate modeling with 2D geometry and algebra, the use of 3D geometry software to develop visualization and modeling in space, and the use of hand-held devices with dataloggers in capturing and analyzing experimental data allow learners to explore mathematical concepts in ways that were impossible before. However, the use of such technologies has not met

yet the initial expectations on reforming teaching and learning [2].

II. PROBLEM DEFINITION

Teaching of mathematics to students of disciplines not directly connected with mathematics represents a challenge to educational system. Students in such studies lack not only background in mathematics but also motivation to study this subject, since the relation between mathematics and their study is often not evident. The typical student of such studies has been a low achiever in school math, and does not relate to the standard applications of mathematics (for example in science and economy) mentioned in textbooks [3].

Moreover, the problem of teaching mathematics to such students is becoming more and more relevant because applications of mathematics are rapidly increasing [4]. The broad picture of mathematics' role in society and value production is that we are going from a (industrial) situation, where mathematics 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 means that the division between the "creative" designer or architect and the "scientific" engineer is increasingly challenged and transcended.

Many researchers have suggested that the use of digital technologies could support this kind of mathematics as building blocks [5]. However, there are many challenges when such technologies are employed [6]. These research efforts show that teachers and students conceptualize technology in mathematics in quite distinct ways. This project explores the opportunities and challenges of integrating digital technologies to support mathematics teaching and learning at more creative technical studies.

III. THEORETICAL FRAMEWORK

The main pragmatic criterion for considering mathematics as a meaningful and true endeavor has been the discipline's efficiency in terms of supporting the scientific investigation of nature. In studies where mathematics is used as a tool understanding nature is only a minor aspect of the reason for studying mathematics. Another reason is the ability to synthesize or create new products, interactions, and expressions with mathematics. Hence a mathematical concept or theory will be of high value if it allows us to construct new interactions and experiences. Of course the

construction of new interactions, experiences and products can very well build on understanding nature, but it is our hypothesis that we can find other uses of mathematical concepts/theories among students in these studies. Information about such uses can inform the question of what mathematics is about, and how mathematics relates to societal needs and development.

The relation between a mathematics class and the mathematics used by professionals in the area can be viewed as a question of teaching mathematics towards a specific work life situation. In the area of vocational training recent discussion revolves around transcending the concept of transfer from knowledge learned (in formal schooling) to knowledge used (in the work life), towards a focus on subjectivity/identity and social practices contextualized in disciplines and crafts [7]. The specificities of mathematics in teaching towards the engineering profession, has been specifically investigated. Students often have difficulties with understanding the mathematical concepts due to a lack of fundamental understanding of difficult concepts or due to an inability to perform deductive reasoning. Maull and Berry state that engineering students hold different concept images than the mathematics students [8]. Bingolbali et al. found that the conceptions of various calculus concepts are different for engineering students than for mathematics students and furthermore that the engineering student see mathematics as a tool and therefore wishes to see the application side as part of the course [9].

A use of technology in mathematics teaching could be 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 [10]. We argue that this could be also applied to the more creative engineering programs.

However in the field of mathematics education it is not known how the different (and more constructive) modes of application will influence the students' conception and attitude towards mathematics. Moreover, since these students are typically low achievers, the use of ICT in mathematics could add more complexity for them [11].

IV. RESEARCH QUESTIONS

In this project we are aiming to answer the following research questions:

- What is the nature of mathematical praxeologies in creative design industry, and how can these praxeologies be used when designing technology-enhanced mathematics courses in programs directed towards such industries?
- How is mathematics and its relation to digital technology conceptualized in these disciplines?

- What aspects of a description of professional and academic mathematical practices resonate with teaching situations?
- How digital technology can support teaching situations where mathematics is connected with professional and academic mathematical practices?
- What is the effect of such digital technologies on student performance and motivation?

V. METHODS

In order to answer the aforementioned research questions, data are being collected by combining quantitative methods (tests in mathematics), qualitative methods (questionnaires and interviews) by using triangulation [12]. Furthermore, we employ ethnographic methods (lesson and exercise solving observations).

In order to evaluate students' knowledge of the related topics, tests are administered, which address questions regarding the requirements in mathematics for each semester. These tests provide also an insight into what students recall from previous semesters and how students deal with mathematical problems.

For observations, an observation schedule is employed to follow lecturers and students' activities. These observations are compared with students' notes and assignments. Our intention is to gain insights into which mathematical concepts or topics are challenging for students, and how students deal with mathematical assignments.

Interviews are also conducted with Media Technology teachers and teaching assistants, who are involved in mathematics courses and students (volunteers). Moreover, questionnaires are given to students before each semester. The purpose is to gain insight into students' attitudes towards mathematics, mathematics confidence and self-efficacy, and preferences for teaching and learning in mathematics.

Moreover, we adopt participatory design methods, in order to investigate conceptualizations of technology in mathematics education by teachers and students and to define design requirements for digital technologies in mathematics education [13].

Participatory design – also called cooperative design – is the inclusion of all stakeholders (e.g. employees, partners, customers, citizens, end users) within a development team, such that they actively help in setting design goals and planning prototypes [14]. It is an approach that attempts to ensure that the product designed meets the stakeholders' needs.

In the field of technology-enhanced learning, participatory design has been used in order to enable teachers and/or students to participate effectively in the design of digital educational tools [15]. It is expected that active participation of the target group will result in tools that will correspond to their needs and interests, and thus be engaging and better accepted [16].

Since we are focusing on students who lack motivation, we decided to adopt a participatory design method. By involving students in the design, we aim at developing learning material that students will find interesting and

attractive, and consequently at increasing their motivation to study. Furthermore, we want to investigate how teachers and students can contribute to this design collaboration. We are guided by beliefs that both groups should participate effectively in the design of educational applications, and that their expertise in education (each group is considered to be an expert in different aspects of education) could be especially critical. Each participant should be seen as an equal element contributing to the design, but at the same time none of them should have the full responsibility for the participatory design decisions.

Our participatory design involves two teachers, two teaching assistants, and seven students from the Media Technology department at Aalborg University Copenhagen. Our collaboration with this group takes part as focus group discussions. We chose focus group discussions rather than interviews because focus group discussion produces data and insights that would be less accessible without interaction found in a group setting.

In order to get insight in the process of teaching and learning in its natural setting, we have been conducting overt, direct observations of various lectures and exercise sessions. These observations provide data on individual behaviors of students and teachers and interactions between them. These findings will be incorporated in the future steps of our design.

VI. EXPECTED CONTRIBUTION

This project aims at providing insight on how digital technologies can support mathematics education for creative engineering studies. We aim at investigate how technology can be used for supporting students' conceptualizations in such studies and for connecting mathematics with its use in professional and academic life. So far we have conducted two educational experiments. In the first, a set of interactive applets were introduced to support a mathematics course in Media Technology, following teachers' suggestion. The applets were developed in developed in GeoGebra [17]. Our results showed that students could not relate to this kind of mathematics representations. For the second experiment, we developed digital learning material, where mathematics was connected to its use. Our results showed that motivation and attitude towards mathematics of students who used this material improved compared to students who were taught with traditional material [18]. In the future we are going to enrich this material based on more field data. Furthermore we are planning to test different ways of instruction based on this material. We believe that this project will provide useful insight on how more creative students relate to mathematics and how technology could be used in order to improve teaching in such students. Finally, the outcome of this study can be used to create a profile of a typical student in creative engineering and to develop tailor made innovative approaches for teaching mathematics to these disciplines.

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