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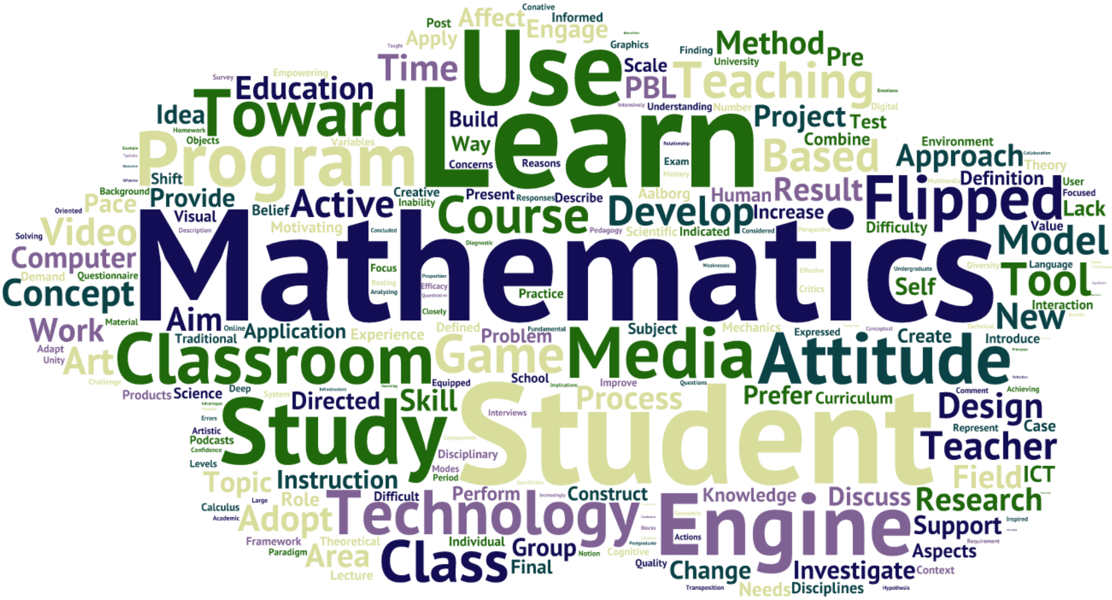

ICT-BASED TEACHING METHODS FOR IMPROVING MATHEMATICS LEARNING FOR MEDIA TECHNOLOGY STUDENTS

INVESTIGATION AND FINDINGS

BY
EVANGELIA TRIANTAFYLLOU

DISSERTATION SUBMITTED 2015

AALBORG UNIVERSITY
DENMARK

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Dissertation submitted

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CV

Evangelia Triantafyllou received the diploma in Electrical and Computer Engineering at Aristotle University of Thessaloniki, Greece, in 2000 and the PDEng (Professional Doctorate in Engineering Design) degree in ICT at Eindhoven University of Technology, The Netherlands, in 2004. She subsequently worked as a computer science teacher on various educational levels. In October 2012, Evangelia was appointed as a PhD Fellow in the Department of Media Technology at Aalborg University Copenhagen, Denmark.

Dedicated to George and our three little treasures.

Στον Γιώργο και στους τρεις μικρούς θησαυρούς μας.

ENGLISH SUMMARY

Over the past years, a number of engineering programs have arisen that transcend the division between technical, scientific and art-related disciplines. Media Technology at Aalborg University, Denmark is such an engineering program. In relation to mathematics education, this new development has changed the way mathematics is used. In these fields, mathematics is increasingly used as the actual building block in various new digital products and creative expressions. This new development has also implications on how mathematics should be taught in these studies. This PhD project investigated and assessed interventions to increase student motivation and engagement in mathematics among Media Technology students. These interventions focused on two directions: a) teaching methods and b) ICT-based learning environments. As far as teaching methods are concerned, this project has applied the flipped instruction model (or the flipped classroom). Regarding ICT-based learning environments, visualizations of mathematical topics have been developed and a game engine (Unity) has been introduced as a domain for mathematical learning. Since many studies have indicated that the attitude towards mathematics influence the achievement of learning goals, Media Technology students' attitudes towards mathematics were also investigated. Several mixed method studies have been conducted in order to explore student attitudes and to assess the impact of these interventions. This project has provided insights in student attitudes towards mathematics in a trans-disciplinary engineering study, namely Media Technology. It was found that these students often lack mathematics confidence and they consider mathematics a difficult subject that they don't like but value. The adoption of the flipped classroom instructional model revealed that students perceive learning with online resources on their own pace as contributing to their understanding and they reported that they could adjust the learning process to their own needs. This PhD project has also proposed the use of a model of reflection for designing activities that promote experience-based learning in flipped classrooms. As far as ICT-based learning environments are concerned, this PhD project has explored two different implementations. The first one was not successful in terms of student improved understanding and engagement, but it was used to improve the design of the second implementation. The second one provided insights on how students apply knowledge from a mathematical model to implement a physical model. This study shed light on students' misconceptions and difficulties but also on their opportunities to challenge their understanding. This project contributed to the discussion of the theoretical foundation of the flipped classroom and discussed aspects of ICT-based mathematics learning for Media Technology. The results of this PhD project can be furthermore used to assess and improve practice in Media Technology and other trans-disciplinary engineering programs.

DANSK RESUME

I de sidste år er der dukket en række ingeniøruddannelser op, som ligger imellem tekniske, videnskabelige og kreative fag. Medieteknologi ved Aalborg Universitet, Danmark er et eksempel på en sådan ingeniøruddannelse. I forhold til matematikundervisning har denne nye udvikling ændret den måde, matematik anvendes på. På disse områder fungerer matematik i stigende grad som byggesten i forskellige nye digitale produkter og kreative udtryk. Denne nye udvikling har også indflydelse på, hvordan matematik skal undervises på denne type uddannelser. Dette projekt har udforsket og vurderet pædagogiske interventioner med sigte på at øge motivation og engagement i matematik blandt Medieteknologi-studerende. Disse interventioner har fokuseret på to forskningsmæssige temaer: a) undervisningsmetoder og b) IKT-baserede læringsmiljøer. Så vidt undervisningsmetoder angår, har dette projekt anvendt "flipped classroom" modellen. Med hensyn til IKT-baserede læringsmiljøer er visualiseringer af matematiske emner blevet udviklet, og der er blevet indført et computerspil "engine" (Unity) som matematisk læringsdomæne. Da mange undersøgelser peger på, at holdningen til matematik påvirker opnåelsen af læringsmål, har dette projekt også udforsket Medieteknologi-studerendes holdninger til matematik. Adskillige blandet metode undersøgelser er blevet gennemført med fokus på at evaluere studerendes holdninger og pædagogiske interventioners indtryk. Dette projekt kaster lys over studerendes holdninger til matematik i en tværfaglig ingeniøruddannelse, dvs. Medieteknologi. Det blev konstateret, at disse studerende ofte mangler selvtillid i matematik, og de anser matematik for et vanskeligt fag, som de ikke kan lide, men sætter pris på. Udviklingsforløbet med "flipped classroom" modellen har vist, at studerende opfatter læring med online-ressourcer i deres eget tempo som bidragende til bedre forståelse, og de har meldt tilbage, at de kunne justere læringsprocessen til deres egne behov. Dette Ph.d. projekt foreslår også brugen af en model for refleksion med hensyn til at designe aktiviteter, der fremmer erfaringsbaseret læring i flipped classrooms. I forhold til IKT-baserede læringsmiljøer har dette projekt undersøgt to forskellige implementeringer. I den første lykkedes det ikke at forbedre studerendes forståelse og engagement, men den blev brugt til at forbedre udformningen af den anden implementering. Den anden implementering anskueliggjorde, hvordan studerende anvender viden fra en matematisk model til at gennemføre en fysisk model. Denne undersøgelse belyser studerendes misforståelser og vanskeligheder, men også deres muligheder for at udfordre deres forståelse. Dette projekt har bidraget til diskussionen om det teoretiske grundlag for "flipped classroom" modellen. Derover har det diskuteret aspekter af IKT-baseret matematiklæring på Medieteknologi. Dette projekts resultater kan desuden anvendes til at vurdere og forbedre praksis på Medieteknologi og andre tværfaglige ingeniøruddannelser.

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Eva Triantafyllou

September 2015

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The second part contains eight scientific papers that are representative of the research carried out in this project. In the following, section 1.1 provides a list of the included papers and section 1.2 mentions other papers, which were authored during this PhD project but are not included in this dissertation.

1.1. PAPERS INCLUDED IN THIS DISSERTATION

In this dissertation, roman numbers are used to refer to each paper.

I. Triantafyllou, E., Misfeldt, M., & Timcenko, O. (2015). Attitudes towards mathematics as a subject and mathematics as a learning and teaching experience in a trans-disciplinary engineering study. Nordic Studies in Mathematics Education (NOMAD).
Journal article (submitted for publication)

II. Triantafyllou, E., & Timcenko, O. (2013). Developing Digital Technologies for Undergraduate University Mathematics: Challenges, Issues and Perspectives. In L. H. Wong, C-C. Liu, T. Hirashima, P. Sumedi, & M. Lukman (red.), Proceedings of the 21st International Conference on Computers in Education (ICCE 2013). (s. 971-976). Chapter 167.Uhamka Press.
Conference proceedings paper presented at ICCE 2013, November 2013, Bali, Indonesia

III. Triantafyllou, E., & Timcenko, O. (2014). Introducing a Flipped Classroom for a Statistics Course: a Case Study. In B. Karaoglan (red.), Proceedings of the 25th International Conference on European Association for Education in Electrical and Information Engineering. (s. 5-8). IEEE Press.
Conference proceedings paper presented at EAEEIE 2014, May 2014, Cesme, Turkey (Best paper award)

IV. Triantafyllou, E., & Timcenko, O. (2015). Student perceptions on learning with online resources in a flipped mathematics classroom. In Proceedings of the 9th Congress of European Research in Mathematics Education (CERME9), 2015.
Conference proceedings paper presented at CERME9, February 2015, Prague, Czech Republic.

V. Triantafyllou, E., & Timcenko, O. (2015). Out of classroom instruction in the flipped classroom: The tough task of engaging the students. In P. Zaphiris, & A. Ioannou (Eds.), (pp. 714-723) Springer International Publishing.
Conference proceedings paper presented at the 2nd International Conference on Learning and Collaboration Technologies in HCII 2015, August 2015, Los Angeles, USA (Best paper award)

VI. Triantafyllou, E., Timcenko, O., & Kofoed, L. B. (2015). Student Behaviors and Perceptions in a Flipped Classroom: A case in undergraduate mathematics. In Proceedings of the Annual Conference of the European Society for Engineering Education 2015 (SEFI 2015).
Conference proceedings paper at SEFI 2015, June 2015, Orleans, France.

VII. Triantafyllou, E. (2015). The flipped classroom: design considerations and Moodle. In Proceedings of the conference Exploring Teaching for Active Learning in Engineering Education 2015 (ETALEE 2015).
Conference proceedings paper to be presented at ETALEE 2015, November 2015, Copenhagen, Denmark.

VIII. Triantafyllou, E., Misfeldt, M., & Timcenko, O. (2015). Mathematics Learning by Programming in a Game Engine: Development of Knowledge and Student Motivation. Technology, Knowledge and Learning. Springer Netherlands.
Journal article (submitted for publication)

1.2. OTHER RELATED PUBLICATIONS NOT INCLUDED IN THE DISSERTATION

- Triantafyllou, E., & Timcenko, O. (2013). Dynamic and multimodal tools for learning and teaching of mathematics at undergraduate university level. Poster session presented at Nordic Educational Research Association Congress, Reykjavik, Iceland. *Poster presentation at NERA2013*

- Triantafyllou, E., & Timcenko, O. (2013). Using GeoGebra for Mathematics Education at University Undergraduate Level. *Abstract presented at Nordic GeoGebra Conference 2013, Copenhagen, Denmark.*

- Triantafyllou, E., & Timcenko, O. (2013). Developing digital technologies for university mathematics by applying participatory design methods. In Proceedings of the 24th EAEEIE Annual Conference : European Association for Education in Electrical and Information Engineering. (Vol. 1, pp. 82-85). IEEE. *Conference proceedings paper presented at EAEEIE2013*

- Triantafyllou, E., & Timcenko, O. (2013). Applying Constructionism and Problem Based Learning for Developing Dynamic Educational Material for Mathematics At Undergraduate University Level. In PBL Across Cultures: Proceedings from the 4th International Research Symposium on PBL 2013, Kuala Lumpur, Malaysia. (pp. 335-340). Aalborg Universitetsforlag. *Conference proceedings paper presented at IRSPBL2013*

- Triantafyllou, E., & Timcenko, O. (2014). Technology-Enhanced Mathematics Education for Creative Engineering Studies. In Proceedings of the 14th IEEE International Conference on Advanced Learning Technologies (ICALT) : "Advanced Technologies for Supporting Open Access to Formal and Informal Learning". (s. 777-779). IEEE Press. *Conference proceedings paper presented at the Doctoral Consortium of ICALT 2014*

- Triantafyllou, E., Timcenko, O., & Triantafyllidis, G. (2014). Reflections on Students' Projects with Motion Sensor Technologies in a Problem-Based Learning Environment. In C. Busch (red.), Proceedings of the 8th European Conference on Games Based Learning – ECGBL 2014 hosted by Research and Training Center for Culture and Computer Science (FKI) University of Applied Sciences HTW Berlin Berlin, Germany 9-10 October 2014. (s. 563-569). Academic Conferences and Publishing International Limited. (Academic Bookshop Proceedings Series). *Conference proceedings paper presented at ECGBL2014*

- Triantafyllou, E., & Timcenko, O. (2014). Peer Assessment in Engineering Group Projects: a Literature Survey. In Y. Cao, T. Väljataga, J. K. T. Tang, H. Leung, & M. Laanpere (Eds.), New Horizons in Web Based Learning: ICWL 2014 International Workshops, SPeL, PRASAE, IWMPL, OBIE, and KMEL, FET, Tallinn, Estonia, August 14-17, 2014, Revised Selected Papers. (pp. 66-71). Springer Publishing Company. (Lecture Notes in Computer Science). *Conference proceedings paper presented at ICWL2014 (PRASAE workshop)*

- Triantafyllou, E., & Timcenko, O. (2014). Opportunities and Challenges of Using Technology in Mathematics Education of Creative Technical Studies. In

C. Stephanidis (red.), HCI International 2014 - Posters' Extended Abstracts: International Conference, HCI International 2014, Heraklion, Crete, Greece, June 22-27, 2014. Proceedings, Part II. (Vol. 435, s. 171-176). Springer. (Communications in Computer and Information Science). *Conference proceedings paper presented as poster at HCII2014*

- Reng, L., Triantafyllou, E., & Triantafyllidis, G. (2015). Rethinking and Redesigning an Image Processing Course from a Problem-Based Learning Perspective. In Proceedings of the 5th International Research Symposium on PBL (IRSPBL). *Conference proceedings paper presented at IRSPBL2015*

- Triantafyllou, E., Misfeldt, M., & Timcenko, O. (2015). A Problem-Based Learning Approach of Teaching Mathematics to Media Technology Students Using a Game Engine. In Proceedings of the 5th International Research Symposium on PBL (IRSPBL). *Conference proceedings paper presented at IRSPBL 2015*

CHAPTER 2. INTRODUCTION

This dissertation discusses ICT-based teaching methods for motivating and empowering Media Technology students. In the following section, the characteristics making the Media Technology different than other engineering programs are discussed and the motivation for researching mathematics education in this program is mentioned.

2.1. TRANS-DISCIPLINARY ENGINEERING AND MATHEMATICS

The rapid pace of technological and scientific change is driving profound changes in the role of engineering in society. The transitions in the global economy change the workforce needs and as a result the nature of engineering practice has been changed. Nowadays, engineers should be equipped with broader skills than just the mastery of scientific and technological disciplines (Spinks, Silburn, & Birchall, 2007). Therefore, there is demand for a paradigm shift in engineering research and education in order to better address the needs of a rapidly changing world (Duderstadt, 2010).

Over the past years, engineering education has been challenged to embed innovation into undergraduate and postgraduate programs, in order to produce graduates who can easily adapt to these changes (Badran, 2007; Jørgensen & Busk Kofoed, 2007; Zhou, 2012). Moreover, a number of engineering programs have arisen that transcend the division between technical, scientific and art-related disciplines (e.g. Architecture and Design, Media Technology, Sustainable Design). In relation to mathematics education, this new development has led to 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 such engineering studies.

The specificities of mathematical education for engineering students have been widely investigated. Morgan investigated the problem of the lack of mathematical expertise by engineering students (A. Morgan, 1990). In order to identify areas of difficulty, he designed a multiple-choice diagnostic mathematics test, which was taken by incoming engineering students over a period of five years. He was able to identify certain areas of mathematics which appear to be difficult to a large proportion of students and common errors made by students in certain topic areas. He concluded that engineering students often have difficulties with understanding the mathematical concepts due to their lack of fundamental understanding of difficult concepts or due to their inability to perform deductive reasoning. Finally, he proposed a reconsideration of the teaching methods in order to produce conceptual understanding, not just mechanical skill with standard problems and a new curriculum that will cover only the essential topics in context.

Maull and Berry developed a questionnaire to elicit from engineering students their concept images attached to key mathematical concepts (Maull & Berry, 2000). They collected responses from over 200 students in the schools of mathematics and engineering and the results suggested that engineering and mathematics students do have different concept images, and in particular that engineering students gradually adopt mathematical ideas into their engineering knowledge in a way that makes sense to them. They also found that although engineering students appear to regard themselves as visual people, they seem to prefer verbal representations of mathematical concepts, while in mechanics problems they preferred the pictorial ones.

Bingolbali et al. explored mechanical engineering students' conceptions of and preferences for conceptions of the derivative, and their views on mathematics (Bingolbali, Monaghan, & Roper, 2007). They employed pre-, post- and delayed post-tests and a preference test, they conducted interviews with students and they performed an analysis of calculus courses. Moreover, they used data from mathematics students to make comparisons with engineering students. Their results indicated that engineering student conceptions of and preferences for the derivative develop in the direction of the rate of change aspects while those of mathematics students develop in the direction of tangent aspects, and confirmed that the engineering student sees mathematics as a tool, and therefore wishes to see the application side as part of the course.

Other researchers focused on engineering students' mathematical background. Such studies acknowledged that there is increasing academic diversity among the student population and this diversity was found to cause difficulties in disciplines such as engineering (Mustoe, 2002; Roberts, 2002). Morgan, who investigated anecdotal evidence that physics and mathematics A-levels are not sufficient for undergraduate physics and engineering courses, stated in his report: '…a lack of fluency in mathematics was an obstacle to students achieving their full potential in the long term, and … affected their department's ability to deliver an optimal programme of study' (B. Morgan, 2011). Moreover, he found that there is a common belief among students and academics that studying further mathematics should be made a requirement of studying engineering.

However, little is known about the emerging field of mathematics education in studies, where engineering is combined with other fields. The literature has yet to discuss how different and media-oriented modes of application influence the students' conception and attitude towards mathematics. The teaching of mathematics to students of such disciplines represents a challenge to the education system because typically these disciplines are more related to arts and humanities. Moreover, mathematical applications in these disciplines are closely associated with technological applications.

The Media Technology program is an example of such a trans-disciplinary study. The following section presents the Media Technology curriculum and comments on its trans-disciplinary character.

2.2. THE MEDIA TECHNOLOGY PROGRAM OF AALBORG UNIVERSITY

The Media Technology program at Aalborg University is a program resting on the same fundamentals as information technology (i.e., mathematics, electronics, computer science) with a focus on media technologies such as audio, video, voice, image, film and multimedia. These media technologies are also seen from the user perspective, therefore human-computer interaction, interaction design, psychology and related fields are also important. Thus, Media Technology is an education that focuses on research and development, which combines technology and arts and looks at the technology behind areas such as advanced computer graphics, games, electronic music, animations, interactive art and entertainment, to name a few.

In order to better explain the trans-disciplinary character of the Media Technology program, I will describe parts of the curriculum supporting different scientific fields (engineering, arts and humanities). During the span of the Media Technology education, students are given a strong technical foundation, both in theory and in practice. The curriculum includes five programming courses, which cover the following areas: image processing, audio synthesis, computer graphics, and artificial intelligence. In these courses, students learn different programming languages depending on the area, (e.g. Processing, Java, C++, C#, CG) and they are given real-world projects to implement. The artistic dimension of the program is expressed by courses such as ‘Audio-Visual Sketching, ‘Audio Processing’, ‘Rendering and Animation Techniques’, which aim at teaching the students theories and techniques for artistic expression in various forms. The humanistic field is supported by courses such as ‘Interaction Design’, ‘Human Senses and Perception’, ‘Screen Media’, ‘Ethnographically Informed Design’, and ‘Theory and Practice of Game Design and Development’, which aim at provide the students with knowledge on how humans perceive their surroundings (including media) and how to perform experiments using this knowledge.

Mathematical topics in Media Technology are covered by one course in the second semester of the study, namely ‘Mathematics for Multimedia Applications’. This coursed reviews topics from upper secondary mathematics that are relevant for the study. A detailed presentation of these mathematical topics and their application in other courses in the program is given in Paper II. This PhD project was initiated in order to address issues of student low performance and low motivation in mathematics in Media Technology.

The overall aim of this PhD project was to investigate ways to improve mathematics learning for Media Technology students. However, many studies have indicated that achievement of learning goals in mathematics may be impeded by negative attitudes towards mathematics (Ma, 1999; Pierce, Stacey, & Barkatsas, 2007). Therefore, Media Technology students' attitudes towards mathematics were also investigated. For this investigation mathematics was considered both as a subject and as a teaching and learning experience. Based on findings on student attitudes towards mathematics and deriving inspiration from the Problem-Based Learning (PBL) pedagogy, which Aalborg University applies in all its programs (Barge, 2010), this PhD project investigated and assessed interventions to increase student motivation and engagement in mathematics among Media Technology students. These interventions focused on two directions: a) teaching methods and b) ICT-based learning environments. As far as teaching methods are concerned, this project has applied the flipped instruction model (or the flipped classroom). Regarding ICT-based learning environments, visualizations of mathematical topics have been developed and a game engine has been introduced as a domain for mathematical learning. The following section reviews research on these three fields, namely attitudes towards mathematics, the flipped classroom, and ICT-based environments for mathematical learning.

CHAPTER 3. BACKGROUND

This chapter provides an overview of background work on the three research directions of this PhD project, namely on 1) attitude towards mathematics, 2) the flipped instructional model (flipped classroom), and 3) ICT-based environments for learning mathematics.

3.1. ATTITUDES TOWARDS MATHEMATICS

Many studies have investigated student attitudes towards mathematics as a subject (Aiken Jr & Dreger, 1961; Fennema & Sherman, 1976). More recent studies have combined attitudes towards computer use and technology along with attitudes towards mathematics (Pierce et al., 2007; Pilli & Aksu, 2013; Reed, Drijvers, & Kirschner, 2010). However, there is not consensus in the literature on the definition of the notion of attitude as different studies adopt different definitions (Di Martino & Zan, 2001). Therefore, I present in the following an overview of different approaches to the notion of attitude and then I clarify the perspective adopted in this dissertation.

Various researchers such as Ruffell et al. (1998) have adopted attitude as a multi-dimensional construct consisting of three interwoven components: (1) the cognitive, which is compiled by the beliefs that the individual has regarding mathematics, (2) the affective, which contains (a positive or negative) feelings that one associates to mathematics, and (3) the conative, which is defined by expressions of behavioral intention. As Di Martino and Zan (2001) point out, the multi-dimensional character of attitude in this definition does not allow for it to be quantified with a single score. This has lead researchers adopting this definition to combine qualitative methods, such as individual and group interviews, with quantitative ones, such as questionnaires and attitude scales.

Other researchers have proposed a definition focusing mainly on the affective dimension, which describes attitude as the emotional disposition toward mathematics, i.e. the degree of affect associated with mathematics (Fennema & Sherman, 1976; Hannula, 2002; McLeod, Metzger, & Craviotto, 1989). This widely adopted definition leaves out the cognitive and conative aspects but it stays unclear how the cognitive and conative (i.e. beliefs) aspects can be separated by the affective (emotions) aspects in many questionnaires who adopted this definition (Di Martino & Zan, 2001).

In this project, I examined attitude as a construct containing both cognitive and behavioral aspects. In order to study attitude towards mathematics, I separated it in three evaluative variables: (1) mathematics confidence, (2) affective engagement, and (3) mathematics value. I adopted mathematics confidence as 'a student's perception of their ability to attain good results and their assurance that they can handle difficulties in mathematics' (Pierce et al., 2007), which builds upon self-efficacy as defined by Bandura (1977). To affective engagement, I assigned the meaning found in Pierce et al. (2007), i.e. 'how students feel about the subject'. Finally, I defined mathematics value as it was defined in the framework proposed by Hannula (2002), i.e. 'the value of mathematics-related goals in the student's global goal structure.'

Apart from mathematics as a subject, I have considered mathematics as a teaching and learning experience. Therefore, I have investigated preferences for mathematics teaching and learning environments. I have adopted the scale for measuring such preferences proposed by Tait et al. (Tait, Entwistle, & McCune, 1998; Tait & Entwistle, 1996). This scale is based on the approaches to studying introduced by Marton and Säljö (1984) and descriptions on strategic approaches to studying by Entwistle and Ramsden (1982). By analyzing student responses on this scale, I aimed at discovering whether students favor mathematics teaching and learning environments who support understanding and are related to a deep approach to learning or environments who transmit information and are related to a surface approach to learning (Paper I).

3.2. THE FLIPPED CLASSROOM INSTRUCTION MODEL

One of the recent developments in teaching is the flipped (or inversed) classroom approach (Berrett, Mangan, Neshyba, Talbert, & Young, 2015). In a flipped classroom the traditional, lecture and homework sessions are inverted. Students are provided with online material in order to gain necessary knowledge before class, while class time is devoted to clarifications and application of this knowledge. The course content, which is provided for self-study, may be delivered in the form of video casts and/or pre-class reading and exercises, while class time is mainly used for group work activities. The hypothesis is that there could be deep and creative discussions when the teacher and students physically meet. This teaching and learning approach aims at making students owners of their learning trajectories, and relies heavily on current technology.

Surveys in the literature commenting on strengths and weaknesses of this new teaching approach have appeared the last several years. Herreid and Schiller (2013) combined their findings from a survey of the 15,000+ members of the National Center for Case Study Teaching in Science Listserv with Kathleen Fulton's article (2012) and compiled the following list of advantages of the flipped classroom: (1) students can learn at their own pace; (2) doing assignments in class gives teachers better insight into student difficulties; (3) teachers can more easily update the curriculum; (4) teachers can use classroom time more effectively and creatively; (5) increased levels of student achievement, interest, and engagement have been reported by teachers; (6) various learning theories support the new approaches; (7) flexible use of technology; (8) teachers have more time to spend with students on authentic research; (9) students may get more time working with equipment that is only available in the classroom; (10) students who are absent can still watch the lectures; (11) the method promotes in-class and out-of-class thinking; and (12) students are more actively involved in the learning process (Herreid & Schiller, 2013).

Along with advantages, Herreid and Schiller noted also the following weaknesses of flipped learning: (1) Students may resist to the new idea of working at home prior to classes. As a result, they may come to class unprepared and not being able to participate in active learning activities and (2) the out-of-class instruction material must be carefully tailored for the students in order to prepare them for the in-class activities. However, teachers have reported that finding or creating good quality videos is difficult. Moreover, the quality of teacher-created videos is often reported to be marginal and creating them can be a time demanding process (Herreid & Schiller, 2013).

In the field of mathematics education, various researchers and instructional designers have sought to investigate the advances of flipped classrooms. Kay and Kletskin introduced problem-based video podcasts covering key areas in mathematics (Kay & Kletskin, 2012). The video podcasts were created as self-study tools, and used by higher education students to acquire pre-calculus skills. The results indicated that a majority of students used the video podcasts frequently, viewed them as easy to use, effective learning tools, rated them as useful or very useful, and reported significant knowledge gains in pre-calculus concepts. Love et al. compared a classroom using the traditional lecture format with a flipped classroom during an applied linear algebra course (Love, Hodge, Grandgenett, & Swift, 2014). Students in the flipped classroom environment had a significant increase between the sequential exams compared to the students in the traditional lecture section, but they performed similarly in the final exam. Moreover, the flipped classroom students were very positive about their experience in the course, and particularly appreciated the student collaboration and instructional video components.

While the aforementioned approaches report on benefits of the flipped classroom, there are also critics to this approach (Kellinger, 2012; Nielsen, 2012). Concerns include among others: criticism about the accessibility to online instructional resources, the growing move towards no homework, increased time requirements without improved pedagogy, teachers concerns that their role will be diminished, lack of accountability for students to complete the out-of-class instruction, poor quality video production, and inability to monitor comprehension and provide just-in-time information when needed.

In this PhD project, the flipped classroom approach has been adopted for teaching mathematics to Media Technology students. Regarding the theoretical underpinnings of this choice, I have been inspired by the Aalborg PBL model (Barge, 2010). PBL is a student-centered instructional approach, which encourages collaborative learning and self-adapted learning. Moreover, the Aalborg model promotes group work, which fosters the development of communication, collaboration, and self-directed learning skills. Finally, PBL represents a paradigm shift from the traditional one way instructional methods, since it promotes a teacher, who is not an instructor, but rather a tutor, who guides, supports, and facilitates the learning process. Therefore, the flipped classroom that employs computer-based individual instruction outside the classroom and devotes classroom time to group activities with the teacher as facilitator is well justified by the aforementioned principles of PBL. The goal of a flipped classroom is to let the student study individually at her own pace while providing the appropriate support material for out-of-class instruction and then come into class, where groups of students engage in group activities facilitated by the teacher. Therefore, I decided to introduce the flipped classroom approach in mathematics-related courses for Media Technology students based on the hypothesis that a flipped classroom would allow these students to work on lesson preparations at their own pace, empowering them to ask relevant questions during class. Moreover, I aimed at engaging these students in mathematics during the active learning phase in classes, where the teacher can support the learning process and provide feedback, when needed.

3.3. ICT-BASED MATHEMATICS LEARNING ENVIRONMENTS

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 (Ainley et al., 2011). The use of visualizations and interactive applets 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 graphic calculators in capturing and analyzing experimental data allow learners to explore mathematical concepts in ways that were impossible before.

The technological evolution has also made possible mathematical learning in ICT-based environments. In the late 1960s, Seymour Papert inspired by the principles of constructivism developed the programming language LOGO, where children can guide a small turtle around the screen. The turtle leaves a trace while moving around, allowing the child to create various geometrical figures (Papert, 1980). His suggestion was that children can familiarize themselves with mathematics concepts while developing constructs or predicting turtle’s movement in LOGO. Papert described LOGO as a “mathematical microworld” that allows children to engage in such projects. In the 1980s, researchers were convinced that LOGO and other programming languages would radically reform mathematics teaching. However, the reality did not live up to the expectations. There are various reasons for the disappointing results. For instance, student work in LOGO can become non-mathematical, as students easily overlook the pieces of mathematical knowledge (Ainley, Pratt, & Hansen, 2006; Hoyles & Noss, 1992).

Programming for mathematical learning has been also introduced in secondary and upper secondary education. Instead of using LOGO, teachers have introduced common programming languages such as BASIC and PASCAL to support learning. In the 1990s, Dubinsky proposed that the use of programming helps in mathematical learning by making abstract concepts concrete and even by introducing students to a syntax involving arithmetic variables and arithmetic operations (Dubinsky, 1995). He developed also a theoretical framework (the APOS Theory), which views mathematical knowledge as gained when individuals perceive mathematical problem situations and construct mental actions, processes, and objects organized in schemas to make sense of these situations and solve the problems (Dubinsky & McDonald, 2001). This theoretical framework was applied to improve the development of the process conception of function in undergraduate mathematics and employs computers for enriching the numerical calculations that constitute the necessary foundation for concept formation (Breidenbach, Dubinsky, Hawks, & Nichols, 1992).

During the last years, digital games have been applied in many educational fields to enhance learning motivation (Prensky, 2001). Since game environments or engines allow users to customize their gaming experiences by building and expanding game behaviour, games offer new directions in relation to learning mathematics by programming, which have not been extensively explored. El-Nasr and Smith have proposed the use of modifying, or modding, existing games as a means to learn computer science, mathematics, physics, and aesthetic principles (El-Nasr & Smith, 2006). In two exploratory case studies, they presented skills learned by students as a result of modding existing games and they discussed the benefits of learning computer sciences skills, among others 3D graphics and mathematics.

Such ICT-based environments for learning mathematics shape the development of mathematical meanings and mathematical knowledge and at the same time they are shaped by student conceptions (Hoyles & Noss, 2009). Hoyles and Noss underlined the fact that technology per se does not influence significantly the development of mathematical concepts. It is the design of such environments and the activities that take place in these that can support mathematical development and specific learning objectives. However, pedagogic task design is not a trivial procedure. Ainley et al. (2006) for instance have discussed the tension that teachers face when they design tasks (known as the planning paradox). If teachers plan guided by learning objectives, the tasks are likely to lack reward for students and mathematical richness. On the other hand, if teachers plan from tasks, they may increase students' engagement but then it is difficult to focus on student activity and assess their learning.

3.4. RESEARCH QUESTIONS

Building upon the research presented in the previous sections, this PhD project addressed the following research questions:

1. What attitudes do Media Technology students hold towards mathematics as a subject and mathematics as a teaching and learning experience?
2. What is the effect of active learning methods such as the flipped instruction model to Media Technology students’ motivation, engagement and understanding in mathematics?
3. How does mathematical learning in ICT-based environments affect conceptual understanding and motivation of Media Technology students?

CHAPTER 4. REFLECTION ON METHODS

In order to address the aforementioned research questions, various methodological approaches have been adopted. Figure 1 summarizes the interventions and data collection methods that took place during this PhD project.

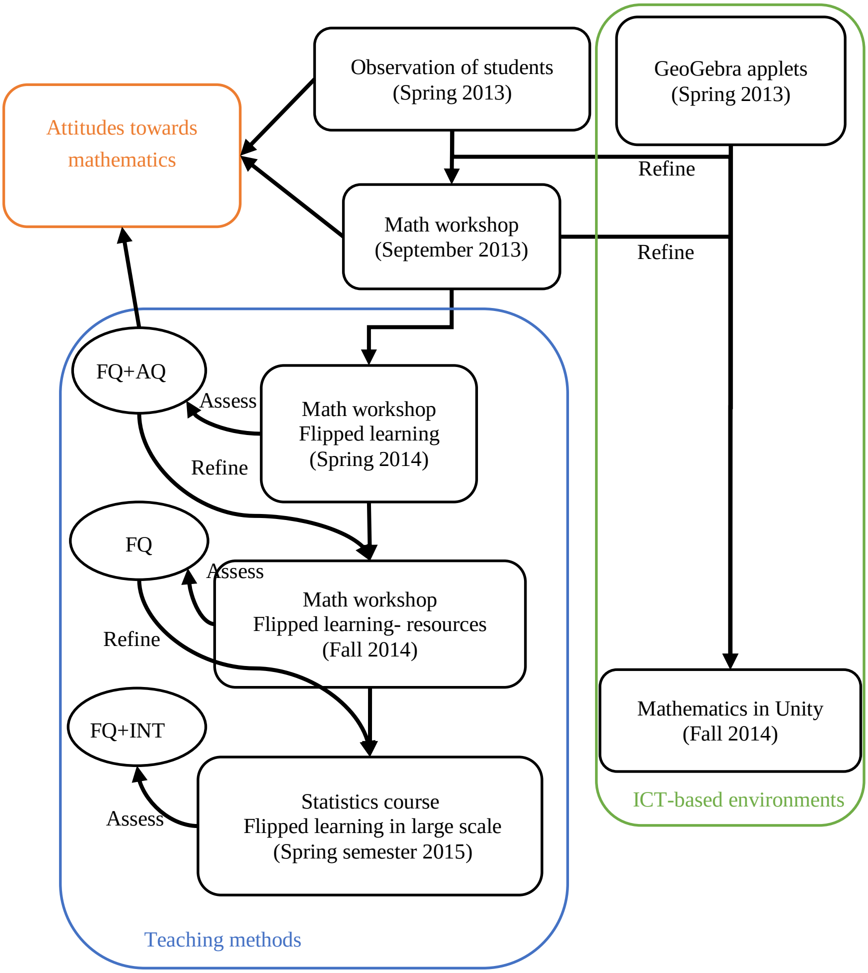


Figure 1 Interventions and data collection methods in chronological order (FQ: Flipped classroom Questionnaire, AQ: Attitude Questionnaire, INT: focus group INTerviews)

The project started with an exploratory research phase, where observations of students working in mathematical exercises were conducted during one academic semester. This phase aimed at gathering information on student attitudes towards mathematics, student approaches on mathematical problem solving and student competences (Paper I). In regard to research on ICT-based learning environments, two approaches have been designed and assessed during this project. The first one consisted of the design and implementation of a set of dynamic GeoGebra applets, which were introduced and evaluated in the 'Mathematics for Multimedia Applications' course (Paper II). The second consisted of a use case study exploring development of student mathematical knowledge and effect on student motivation, when mathematics is being taught by programming in a game engine (Paper VIII). As far as the flipped classroom approach is concerned, two use case studies and a statistics course redesign and assessment took place (Papers III, IV, V, VI, and VII). In the context of this project, remedial mathematical workshops were initiated in Media Technology. The Media Technology curriculum contains in the second semester one mathematics course, which reviews upper-secondary mathematical topics relevant for this program (more information on this course is given in Paper I). Therefore, these workshops aimed at recapitulating mathematical knowledge for students failing a pretest in the beginning of mathematics-demanding courses in the fourth and fifth semester.

During these interventions, I employed various methods for data collection. I used qualitative methods, such as attitude questionnaires, qualitative methods, such as focus group interviews, and have also combined such methods in mixed method studies (Borrego, Douglas, & Amelink, 2009). Detailed description of the methods I applied can be found in each of the included papers. In the following, I will reflect on the general methodological approach of this project.

This PhD project was situated in a specific educational context, i.e. mathematics education for media technology. Therefore, its results can be used to assess and improve practice in this context and most probably in similar contexts, i.e. other trans-disciplinary engineering programs. Moreover, the interventions carried out during this project were designed in collaboration with other researchers and practitioners and after assessing the local context. For the assessment of the local context, I conducted student observations and interviews, and interviews with practitioners. These interventions were implemented and assessed by mainly mixed methods, using a variety of research tools and techniques. The results of the assessment of such implementations were applied to refine the design of the interventions, which were again tested in educational practice. Therefore, the interventions concerning the flipped classroom instruction model and those concerning ICT-based learning environments evolved through multiple iterations. In the field of flipped classroom, three iterations took place with the last one spanning a whole semester and thus providing rich data and time for reflecting over practice. In the field of ICT-based environments only two iterations were possible because of the predefined length of PhD studies. Therefore, there is room for further improvements and subsequent evaluation, which future research should address.

Despite this project being situated in a local project, the design of the interventions built upon established educational theories. The attitude studies drew upon research on mathematics attitude (Paper I), the flipped classroom implementations on PBL and active learning (e.g. Paper V), and the research on ICT-based learning environments on theories addressing the use of technological tools in mathematical learning, i.e. the anthropological approach in didactics and the instrumental genesis (e.g. Paper VIII). The scope of this project was therefore to reveal, explore, and confirm theoretical relationships, while providing guidance for educational practice. Therefore, this project aimed at creating an impact on learning in the local context while contributing to theoretical and basic understandings.

During this project, I had a close cooperation with teachers and teaching assistants for initial problem identification, intervention design and construction, implementation, and assessment of educational practice. Moreover, I was responsible for teaching during the mathematics workshops. In these cases, my role was twofold: researcher and teacher. I have been always aware of the bias such a dual role could bring in the study and I have always involved other researchers and practitioners in all stages, i.e. preparation, implementation, and evaluation, of these workshops.

Summarizing the aforementioned methodological considerations, one could argue that this project followed a change-oriented research (Jamison, 2010). Change-oriented research is characterized by the ambition of the researcher to engage in processes of social or cultural change and it is problem-driven. Similarly, this project aimed at investigating ways to improve educational practice and student attitudes in a specific context. However, it also contributed with new educational design principles in the field of flipped learning while at the same time confirmed that already existing theoretical relationships also hold in this local context.

CHAPTER 5. CONTRIBUTIONS

The main contributions of this project have been published in the attached scientific publications. The project addressed the previously mentioned research questions and contributed in three fields: Media Technology students' attitudes towards mathematics, the flipped classroom approach, and ICT-based mathematics learning environments. In Figure 2, the relation between the attached papers and project research themes is presented.

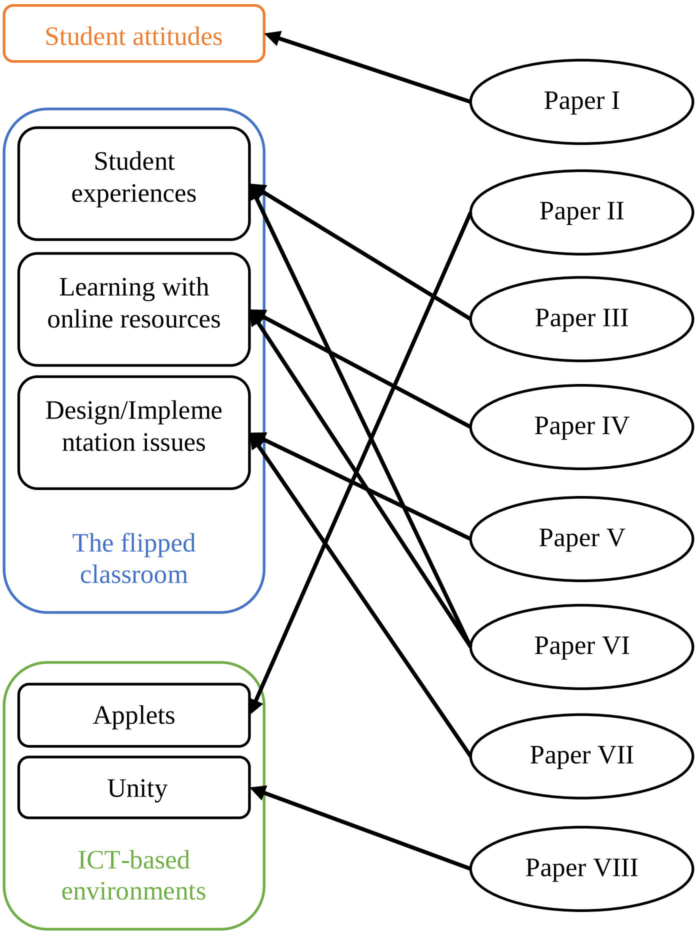


Figure 2 Relation between the attached papers and project research themes.

5.1. MEDIA TECHNOLOGY STUDENTS' ATTITUDES

In this project, attitude towards mathematics as a subject was evaluated based on three variables: (1) mathematics confidence, (2) affective engagement, and (3) mathematics value. Apart from mathematics as a subject, mathematics was also considered as a teaching and learning experience. Therefore, preferences for mathematics teaching and learning environments have been also investigated. In order to better conceptualize the variables examined, I developed a model to represent the connection between attitude towards mathematics as a subject and the attitude towards mathematics as a teaching and learning experience. This model builds upon the model representing the relationship between attitude towards mathematics and other classroom variables as introduced by Haladyna et al (1983). In this project, the study of attitude took place in and is framed by the context of mathematics for computer applications. Paper I presents this model and defines its evaluative variables. Moreover, it discusses the instruments employed for gathering data on student attitudes.

Attitudinal data collection and analysis during three academic semesters revealed that Media Technology students do not have a strong opinion on confidence and self-efficacy in mathematics and higher-semester students tend to be less confident than lower-semester ones. Our analysis showed that more competent students tend to be more confident while non-confident may be more inclined to fail or drop out and most importantly may exhibit low confidence even after achieving good results. Furthermore, the Media Technology students acknowledged a sense of satisfaction and reward when solving mathematical problems but they did not favor mathematics over other courses and considered it to be difficult.

The collected data also indicate that Media Technology students realize the importance of mathematics both in their studies and in real-word situations and they wish to see application aspects of this subject. This is a confirmation of what have already been mentioned in the literature related to mathematical education of other engineers (Bingolbali et al., 2007). However, their answers regarding teaching and learning environments suggest that these students do not intend to gain deep understanding in mathematics. Moreover, they reported a lack of trust to the mathematics teacher.

The aforementioned findings contributed in the reform of educational practice. The conceptualization and design of the interventions conducted during this project aimed at improving the climate in mathematics classrooms. The flipped learning approach was adopted in order to actively involve students during classes and make them owners of their learning. Moreover, applications aspects were included during lectures and programming was employed for mathematical learning in order to connect mathematics with students' interests and future professional life.

This PhD project provided some intriguing insights into student attitudes towards mathematics and preferences for teaching and learning in mathematics. The findings indicate patterns which support previous research in the area of mathematics attitudes and preferences of engineering students while at the same time bringing forth issues (e.g. lack of confidence and mathematics anxiety) worthwhile attention and further investigation.

5.2. THE FLIPPED CLASSROOM

In this project, the flipped classroom instruction model was applied in three different semesters. The last implementation spanned a whole semester and generated valuable feedback both from students and teachers. Papers III, IV, V, VI, and VII present the studies conducted and the results obtained. The project contributions concern three research themes: student experiences in the flipped classroom, learning with on-line resources, and design and implementation considerations for the flipped classroom.

5.2.1. STUDENT EXPERIENCES

In order to empirically investigate student experiences in the flipped classroom, this project has adopted the theoretical framework proposed by Abeysekera and Dawson (Abeysekera & Dawson, 2015). This framework was developed for exploring the potential of flipped classrooms to cater for motivation and better management of the cognitive load. Self-reported student behaviors indicated that the flipped classroom has helped students to better manage the cognitive load. The out-of-classroom instruction was found to offer the opportunity to students to adjust learning according to their own expertise and their own pace. Moreover, the explanations provided in the videos were valued and the opportunity to use such explanations for exam preparation or refreshing knowledge was mentioned by students. However, students have mentioned the lack of support, while they work in out-of-class activities.

Regarding motivation, the results of this project indicate that students appreciated the support and help they got while conducting in-class activities. Being able to solve the assignments and getting clarifications contributed to their feeling of success. Nevertheless, the results also revealed that not all students could handle the offered autonomy and came to classes unprepared. On one hand, this may be attributed to the fact that students needed time to adjust to the new instructional model and its requirements. On the other hand, the relatively high number of students reporting not to have checked the preparation material provided food for thought regarding the time and effort that students should devote to out-of-class activities. These considerations are mentioned in the following section on design considerations for flipped classrooms.

In the survey responses gathered, there were some students who underlined the importance of the teacher's role and in-classroom explanations. This may be attributed to the fact that the teacher's role is different in flipped classrooms compared to traditional lectures, where the teacher uses most of the classroom time. In the literature, there have been reported similar comments from students who think that the teacher's role is reduced in flipped classrooms (Gnaur & Hüttel, 2014), and they can be attributed to the transition phase from a traditional to a flipped setting. In such transitional phases, students will need time to get used to their teacher's new role.

5.2.2. ONLINE RESOURCES

This project also surveyed Media Technology students on their perceptions on learning with online resources in mathematics flipped classrooms. Responses on these surveys indicated that online resources were seen by students as a valuable and useful aid to learning and to preparation before lectures. Since working with mathematics by themselves is perceived by students the most important learning (Sikko & Pepin, 2013), the decision of which tools should support this individual learning is a crucial one. Students reported that watching screencasts is more engaging than reading online resources, while by reading online they can find explanations that make sense to the individual. However, students still perceived face-to-face instruction as paramount, mentioning the problems of the inability to follow comprehension and the lack of just-in-time explanations.

5.2.3. DESIGN AND IMPLEMENTATION OF FLIPPED CLASSROOMS

The iterative design and implementation of flipped classrooms involved continuously assessing and refining the design based on experiences and feedback gathered. Therefore, a set of design principles and implementation guidelines was compiled during this project (Papers V and VII). The implementation guidelines refer mainly to how to integrate the flipped classroom model to a Virtual Learning Environment (VLE), namely Moodle. Moodle was chosen because it is the environment used at Aalborg University and also employed during this project.

In regard to design principles, the following aspects were considered: 1) type of out-of-class and in-class activities, 2) duration of out-of-class and in-class activities, 3) student motivation for out-of-class preparation, and 4) control of student comprehension (both for students and teachers). These considerations are discussed in Papers V and VII.

The most important conclusion on the type of activities was that they should be carefully designed and based on a pedagogical framework in order to ensure that they will result in meaningful mathematical work and student learning. As far as the time devoted to out-of-class activities is concerned, it was found that teachers tend to underestimate the time needed for preparation. Therefore, this aspect should be very carefully considered when out-of-class activities are designed. Furthermore, a guided reading curriculum can help students structure their out-of-classroom studying and not get lost in the provided information. In order to ensure that students complete their out-of-class instructions, diagnostic tests have been employed during this project. Such diagnostic tests help also students and teachers to control comprehension over the studied material.

During this project, it was observed that students were very good at reflecting on the learning process but not on the learning content. Therefore, it was proposed to employ Cowan's model for reflection when designing activities (Cowan, 1998). Cowan combined the analytical reflection from Kolb's experienced-based learning cycle "experience-reflect-generalize-test" (Kolb, 1984), with Schön's evaluative reflection for creating this model of reflection loops (Schön, 1983). Schön's reflection-for-action is the reflection that takes place prior to actions, while his reflection-in-action and the actual action take place at the same time. Kolb's reflection-on-action is more systematic than reflection-in-action and a means to get from experience to conceptualization. Provided that the out-of-class and in-class activities are designed properly and the reflection process is facilitated by the teacher, the flipped instruction model with its out-of-class, in-class and after-class phases can be utilized to involve students in reflection loops and to progress experienced-based learning.

Regarding implementation aspects, the project results confirmed the fact that new teaching and learning methods need careful introduction and detailed information about how student behavior has to change to use the new learning strategy. Moreover, clear instructions about how and when answers and clarifications will be given are required, in order to avoid student frustration. Since it was found that initial technical problems played a decisive role in student motivation, good structure and organization is also of paramount importance. For the integration of flipped classrooms in VLEs, Paper VII presents features of Moodle that can be used to support such classrooms. It is suggested that quizzes serve as motivation and self-control tools for students during pre- or post-class activities, but also as tools for teachers to get insight into students' common mistakes and adjust their class sessions accordingly. Furthermore, feedback activities (i.e. surveys) can stimulate students to reflect on their own practice and also to post questions to the teacher before or after class. They can also serve course evaluation purposes, by gathering student opinions and experiences. Finally, Moodle reports can provide teachers with usage data and activity logs, which are useful for checking student behaviour during out-of-class time and improving the way information is transmitted. There can also be valuable course evaluation tools.

5.3. ICT-BASED MATHEMATICS LEARNING ENVIRONMENTS

In this project, two use cases on ICT-based mathematical learning have been designed and evaluated. The first one involved the use of applets as in-class demonstrations of mathematical concepts. Aspects of this use case are discussed in Paper II. These applets were designed and developed with GeoGebra in cooperation with two mathematics teachers in Media Technology. They were dynamic visualizations allowing the user to change various parameters and observe the resulting visual changes. The hypothesis was that students exploring these applets would get insight and better understanding of the mathematical concepts they visualized. These applets were connected to specific lectures and topics of the 'Mathematics for Multimedia Applications' course. The teacher of the course presented the applets during lectures and encouraged the students to explore them after class. However, no specific activities were designed around these applets. Class and individual students' observations showed that only a few students were able to understand what these applets visualized and even fewer experimented with them after class. There was also a conflict regarding the chosen environment (GeoGebra) because students had to use Matlab for four mini-projects during this course. Since almost all students had no previous knowledge of these two environments, they were reluctant to devote time on learning both. These results confirm what Hoyles and Noss have noted, i.e. that the fact that technological tools per se do not influence significantly the development of mathematical concepts (Hoyles & Noss, 2009). It is the design of such environments and the activities that take place in these that can support mathematical development and specific learning objectives.

The learning process of the first intervention contributed to refine the design of the second one. In the second use case, programming in a game engine (Unity) was used to teach Media Technology students the mathematical calculation of the reflection and refraction vectors. The theoretical framework, design, implementation and results of this use case are presented in Paper VIII. During this intervention, it was observed that the majority of the students participating in this study were challenged when they had to use their general mathematical knowledge for understanding the mathematical model of reflection and refraction. Regarding the programming part, the study showed that most students were well acquainted with tasks and techniques in Unity, but in some cases they were missing the theoretical block that would make these tasks contextualized and meaningful.

On the other hand, there were students who used creatively the affordances of this environment for testing their assumptions or validating their answers. Moreover, it was found that the affordances of the Unity environment helped students to challenge their own knowledge, because they could observe the visual representation of their implementation and realize that it did not look 'right'. Finally, it was noted that although almost all students were able to solve a mathematical exercise, very few could explain and apply the result in the Unity model.

In this study, self-reported student motivation was also investigated. The students reported that they felt more engaged while working in Unity. Furthermore, they acknowledged the value of integrating domain-specific applications to mathematics and connecting student practice and professional practice. Finally, they reported that the effort of matching a mathematical model with a Unity model increased their mathematical understanding.

CHAPTER 6. CONCLUSION

6.1. DISCUSSION ON CONTRIBUTIONS

This project has provided insights in student attitudes towards mathematics in a trans-disciplinary engineering study, namely Media Technology. It was found that these students often lack mathematics confidence and they consider mathematics a difficult subject that they don't like but value. Therefore, interventions concerning both teaching methods and learning tools have been designed and assessed to increase mathematics confidence among Media Technology students and engage them with mathematical practice in meaningful ways.

The flipped classroom instructional model was adopted in order to better support Media Technology students and engage them with in-class and out-of-class activities. Although the results obtained during this project revealed that students perceive learning with online resources on their own pace as contributing to their understanding and they reported that they could adjust the learning process to their own needs, it is difficult at this stage to draw firm conclusions in terms of improvements to student achievement as at it has not been possible to measure this quantitatively. During the first intervention a pre- and post-test method was employed and the results were positive, but since this intervention spanned only a few lectures, it is not possible to generalize this result. However, the last intervention concerned the redesign of a semester course and therefore student grades can at least be examined and compared to previous years. This was not feasible during this project due to time limitations.

This PhD project has also proposed the use of Cowan's model of reflection for designing activities in flipped classrooms that involve students in reflection loops. Such reflection loops promote experience-based learning and contribute to getting from experience to conceptualization. Figure 3 presents the adaptation of Cowan's model to the flipped classroom instruction model. The dashed line separates the reflection loops taking place outside the classroom from those taking place in the classroom.

As far as ICT-based learning environments are concerned, this PhD project has explored two different implementations. The first one was not successful in terms of student improved understanding and engagement, but it was a valuable learning process and provided input for designing the second implementation. The second one provided insights on how students apply knowledge from a mathematical model to implement a physical model. The results of this study shed light on students' misconceptions and difficulties but also on opportunities for them to challenge their understanding. Moreover, they revealed that students do not always internalize the mathematical knowledge they acquire, and they may get correct results without understanding their mathematical meaning.

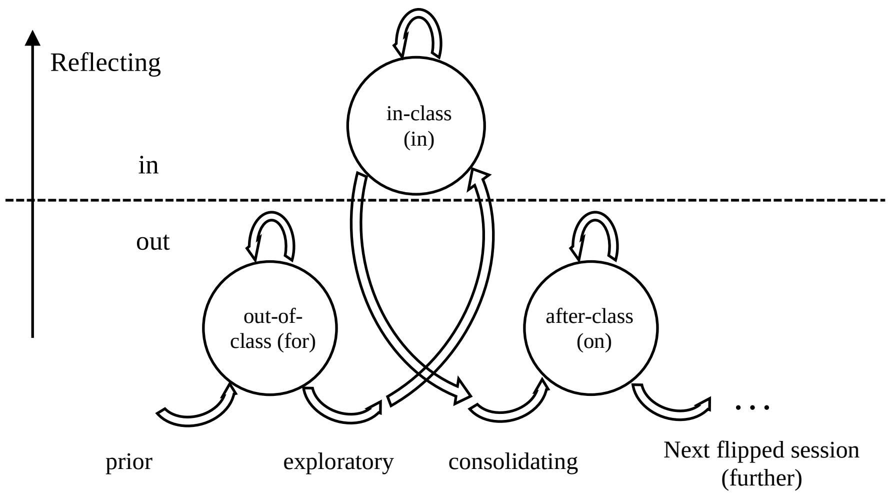


Figure 3 Cowan's model adapted to the flipped classroom instruction model

Apart from contributing to theoretical discussion on the effect of the flipped classroom and learning with technology, this project has also provided concrete design and implementation principles for the flipped classroom. Moreover, the findings of this project offer some implications for mathematics teaching of Media Technology students. Some efforts to this direction have been implemented during this project. These findings and their implications for mathematics education in Media Technology provide valuable insights and can be used as foundation for assessing educational practice in other trans-disciplinary engineering studies.

6.2. DIRECTIONS FOR FUTURE WORK

This PhD project has investigated teaching and learning methods to improve mathematics education for Media Technology students. It has also studied student attitudes towards mathematics, since they have been found to affect the achievement of learning goals. These contributions offer several directions that future research can address.

In regard to the flipped classroom approach, the adaptation of Cowan's model for enhancing reflection as presented in this dissertation can be employed for designing activities and for observing and analyzing student practice and behaviors. Then the impact on student learning should be evaluated in order to retain or reject the hypothesis that implementing reflection loops in the flipped classroom will result in improved learning and understanding. Regarding evaluation of student learning in flipped classrooms, the employment of qualitative studies that examine student performance throughout a semester can contribute to draw firm conclusions in relation to this aspect.

In the field of ICT-based learning environments, the use case of employing programming in Unity for mathematical learning should be extended in time in order to cover more mathematical topics and get a complete insight in student thinking and conceptualizations. Engaging students in this kind of learning for a longer period of time will also offer concrete evidence on the impact of this approach in student learning and performance.

Finally, this project has also discussed opportunities and challenges of using Moodle to facilitate flipped classrooms. It has been shown that this VLE can support student and teacher practice in such classrooms and it can accommodate communication between them. However, limited student use of Moodle and technical problems may hinder the acceptance of such tools (Costa, Alvelos, & Teixeira, 2012). It would be therefore interesting for future research to investigate how teachers and students experience such learning environments in flipped classrooms, and which factors are decisive for creating positive attitudes towards their use.

LITERATURE LIST

Abeysekera, L., & Dawson, P. (2015). Motivation and cognitive load in the flipped classroom: Definition, rationale and a call for research. *Higher Education Research & Development, 34*(1), 1-14. doi:10.1080/07294360.2014.934336

Aiken Jr, L. R., & Dreger, R. M. (1961). The effect of attitudes on performance in mathematics. *Journal of Educational Psychology, 52*(1), 19.

Ainley, J., Button, T., Clark-Wilson, A., Hewson, S., Johnston-Wilder, S., Martin, D., et al. (2011). Digital technologies and mathematics education.

Ainley, J., Pratt, D., & Hansen, A. (2006). Connecting engagement and focus in pedagogic task design. *British Educational Research Journal, 32*(1), 23-38.

Badran, I. (2007). Enhancing creativity and innovation in engineering education. *European Journal of Engineering Education, 32*(5), 573-585. doi:10.1080/03043790701433061

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review, 84*(2), 191.

Barge, S. (2010). *Principles of problem and project learning, the Aalborg PBL model*. Aalborg: Aalborg University. doi:http://www.aau.dk/digitalAssets/62/62747_pbl_aalborg_modellen.pdf

Berrett, D., Mangan, K., Neshyba, S., Talbert, R., & Young, J., R. (2015, The Chronicle og Higher Education). A guide to the flipped classroom, http://images.results.chronicle.com/Web/TheChronicleofHigherEducation/%7B422bb09a-27eb-42ba-ad69-a455e627572b%7D_AD-CHE-FlippedClassroomBooklet.pdf.

Bingolbali, E., Monaghan, J., & Roper, T. (2007). Engineering students' conceptions of the derivative and some implications for their mathematical education. *International Journal of Mathematical Education in Science and Technology, 38*(6), 763-777.

Borrego, M., Douglas, E. P., & Amelink, C. T. (2009). Quantitative, qualitative, and mixed research methods in engineering education. *Journal of Engineering Education, 98*(1), 53-66.

Breidenbach, D., Dubinsky, E., Hawks, J., & Nichols, D. (1992). Development of the process conception of function. *Educational Studies in Mathematics, 23*(3), 247-285. doi:10.1007/BF02309532

Costa, C., Alvelos, H., & Teixeira, L. (2012). The use of Moodle e-learning platform: A study in a Portuguese university. *Procedia Technology, 5*, 334-343. doi:http://dx.doi.org/10.1016/j.protcy.2012.09.037

Cowan, J. (1998). *On becoming an innovative university teacher: Reflection in action* Society for Research into Higher education & Open University Press.

Di Martino, P., & Zan, R. (2001). Attitude toward mathematics: Some theoretical issues. *PME CONFERENCE,* 351.

Dubinsky, E. (1995). ISETL: A programming language for learning mathematics. *Communications on Pure and Applied Mathematics, 48*(9), 1027-1051.

Dubinsky, E., & McDonald, M. A. (2001). APOS: A constructivist theory of learning in undergraduate mathematics education research. *The Teaching and Learning of Mathematics at University Level: An ICMI Study,* , 273-280.

Duderstadt, J. J. (2010). Engineering for a changing world. *Holistic engineering education* (pp. 17-35) Springer.

El-Nasr, M. S., & Smith, B. K. (2006). Learning through game modding. *Computers in Entertainment (CIE), 4*(1), 7.

Entwistle, N. J., & Ramsden, P. (1982). Understanding student learning.

Fennema, E., & Sherman, J. A. (1976). Fennema-sherman mathematics attitudes scales: Instruments designed to measure attitudes toward the learning of mathematics by females and males. *Journal for Research in Mathematics Education,* , 324-326.

Fulton, K. (2012). Upside down and inside out: Flip your classroom to improve student learning. *Learning & Leading with Technology, 39*(8), 12-17.

Gnaur, D., & Hüttel, H. (2014). How a flipped learning environment affects learning in a course on theoretical computer science. *Advances in web-based Learning–ICWL 2014* (pp. 219-228) Springer.

Haladyna, T., Shaughnessy, J., & Shaughnessy, J. M. (1983). A causal analysis of attitude toward mathematics. *Journal for Research in Mathematics Education,* 19-29.

Hannula, M. S. (2002). Attitude towards mathematics: Emotions, expectations and values. *Educational Studies in Mathematics, 49*(1), 25-46.

Herreid, C. F., & Schiller, N. A. (2013). Case studies and the flipped classroom. *Journal of College Science Teaching, 42*(5), 62-66.

Hoyles, C., & Noss, R. (1992). *Learning mathematics and LOGO* MIT Press.

Hoyles, C., & Noss, R. (2009). The technological mediation of mathematics and its learning. *Human Development*, *52*(2), 129-147.

Jamison, A. (2010). In search of green knowledge: A cognitive approach to sustainable development. *African Journal of Science, Technology, Innovation and Development, 2*(1), 168-182.

Jørgensen, F., & Busk Kofoed, L. (2007). Integrating the development of continuous improvement and innovation capabilities into engineering education. *European Journal of Engineering Education*, *32*(2), 181-191. doi:10.1080/03043790601116964

Kay, R., & Kletskin, I. (2012). Evaluating the use of problem-based video podcasts to teach mathematics in higher education. *Computers & Education, 59*(2), 619-627. doi:http://dx.doi.org/10.1016/j.compedu.2012.03.007

Kellinger, J. J. (2012). The flipside: Concerns about the “New literacies” paths educators might take. *The Educational Forum, , 76*(4) 524-536.

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development* Englewood Cliffs, NJ: Prentice-Hall.

Love, B., Hodge, A., Grandgenett, N., & Swift, A. W. (2014). Student learning and perceptions in a flipped linear algebra course. *International Journal of Mathematical Education in Science and Technology*, *45*(3), 317-324. doi:10.1080/0020739X.2013.822582

Ma, X. (1999). A meta-analysis of the relationship between anxiety toward mathematics and achievement in mathematics. *Journal for Research in Mathematics Education, 30*(5), 520-540.

Marton, F., & Säljö, R. (1984). Approaches to learning. *The Experience of Learning, 2*, 39-58.

Maull, W., & Berry, J. (2000). A questionnaire to elicit the mathematical concept images of engineering students. *International Journal of Mathematical Education in Science and Technology, 31*(6), 899-917.

McLeod, D., Metzger, W., & Craviotto, C. (1989). Comparing experts' and novices' affective reactions to mathematical problem solving: An exploratory study. *Proceedings of the Thirteenth International Conference for the Psychology of Mathematics Education,* 296-303.

Morgan, A. (1990). A study of the difficulties experienced with mathematics by engineering students in higher education. *International Journal of Mathematical Education in Science and Technology, 21*(6), 975-988.

Morgan, B. (2011). *Mind the gap: Mathematics and the transition from A-levels to physics and engineering degrees*. London, UK: EdComs, Institute of Physics.

Mustoe, L. (2002). The mathematics background of undergraduate engineers. *International Journal of Electrical Engineering Education, 39*(3), 192-200.

Nielsen, L. (2012). Five reasons I'm not flipping over the flipped classroom. *Technology & Learning, 32*, 10-46.

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas* Basic Books, Inc.

Pierce, R., Stacey, K., & Barkatsas, A. (2007). A scale for monitoring students' attitudes to learning mathematics with technology. *Computers & Education, 48*(2), 285-300. doi:http://dx.doi.org/10.1016/j.compedu.2005.01.006

Pilli, O., & Aksu, M. (2013). The effects of computer-assisted instruction on the achievement, attitudes and retention of fourth grade mathematics students in north cyprus. *Computers & Education, 62*, 62-71.

Prensky, M. (2001). *Digital game-based learning* New York: McGraw-Hill.

Reed, H. C., Drijvers, P., & Kirschner, P. A. (2010). Effects of attitudes and behaviours on learning mathematics with computer tools. *Computers & Education, 55*(1), 1-15. doi:http://dx.doi.org/10.1016/j.compedu.2009.11.012

Roberts, G. G. (2002). SET for success: The supply of people with science, technology, engineering and mathematics skills: Review (London: Department for education and science).

Ruffell, M., Mason, J., & Allen, B. (1998). Studying attitude to mathematics. *Educational Studies in Mathematics, 35*(1), 1-18. doi:10.1023/A:1003019020131

Schön, D. A. (1983). *The reflective practitioner: How professionals think in action* Basic books.

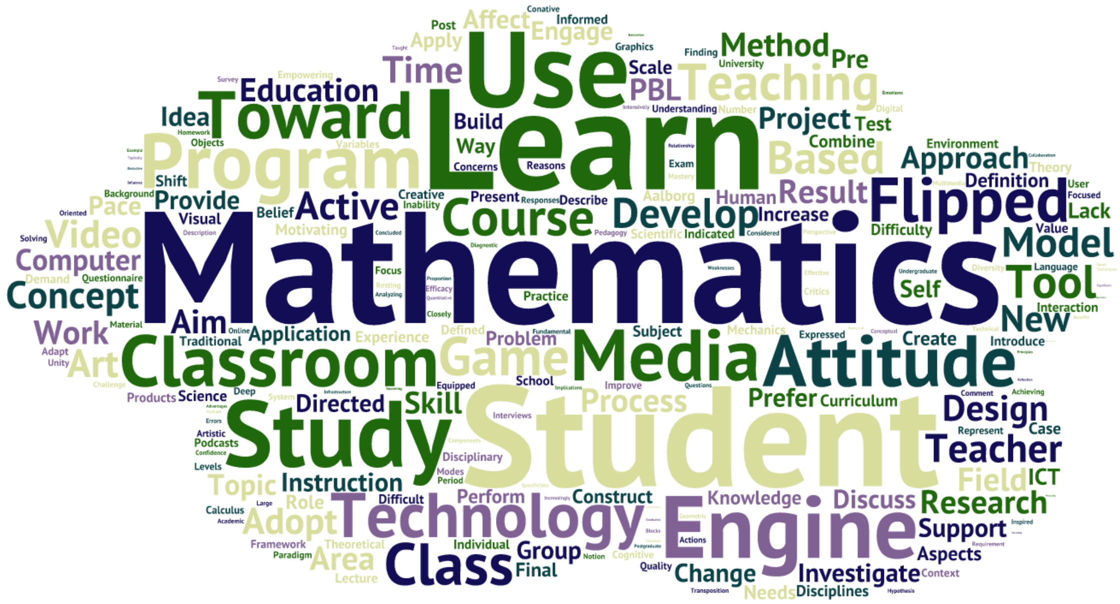
Sikko, S. A., & Pepin, B. (2013). Students' perceptions of how they learn best in higher education mathematics courses. *Proceedings of the 8th Congress of the European Society for Research in Mathematics Education, Antalya, Turkey,* 2446-1980.

Spinks, N., Silburn, N. L., & Birchall, D. W. (2007). Making it all work: The engineering graduate of the future, a UK perspective. *European Journal of Engineering Education, 32*(3), 325-335.

Tait, H., Entwistle, N., & McCune, V. (1998). ASSIST: A reconceptualisation of the approaches to studying inventory. *Improving Student Learning: Improving Students as Learners,* 262-271.

Tait, H., & Entwistle, N. (1996). Identifying students at risk through ineffective study strategies. *Higher Education, 31*(1), 97-116. doi:10.1007/BF00129109

Zhou, C. (2012). Fostering creative engineers: A key to face the complexity of engineering practice. *European Journal of Engineering Education, 37*(4), 343-353. doi:10.1080/03043797.2012.691872



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