Development of mathematics curriculum for Medialogy students at Aalborg University

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Abstract
This paper addresses mathematics curriculum development for Medialogy education. Medialogy as a study line was established in 2002 at Faculty for Engineering and Natural Sciences at Aalborg University, and mathematics curriculum has already been revised tree times. Some of the reasoning behind curriculum development, lessons learned and remaining issues are presented and discussed.

Keywords: mathematics curriculum development, non-mathematics majors, problem-based learning

1. INTRODUCTION

Medialogy is 6 years old study line at engineering department of Aalborg University. The idea behind this education is to "educate global problem-solvers in the technology world", both on Bachelor and Masters levels. As it is stated on Medialogy web-presentation aimed for future students [2]:

> "Medialogy focuses on education and research, which combine technology and creativity as means to design new processes and tools for art, design and entertainment – we do this to meet the requirements of our contemporary media industry. In authoring and designing Interactive Media, it is becoming increasingly evident that the largest challenge lies in bringing together different disciplines. Medialogy's interdisciplinary approach acknowledges that mastering and combining such a variety of disciplines requires a strong technical foundation, both in theory and in practice."

The educational approach is Problem based learning, as at all other studies at Aalborg University. Students are exposed to the curriculum which combines technical and humanistic courses, like screen media, digital sound synthesis, sensor technology, perception, aesthetic, media sociology, computer graphics, human-computer interaction, interface design, etc. Mathematics and programming are now thought on Bachelor level, as they are needed in order to understand technical courses needed for successful project work.

Typical educational background of Medialogy students is either gymnasium education or Multimedia Design College. In both cases, mathematics is typically the subject that students are not particularly interested in, although they are aware that they need some mathematical skills in order to be successful in their work. During the first two semesters the students are exposed to standard mathematics course for engineering students, comprising of 5ECTS of introduction to calculus and 3ECTS of introduction to linear algebra. On the 5th semester they have advanced linear algebra course, and on 6^{th} a course on differential equations.

This paper presents results of 6 years work on adjustment mathematics courses for Medialogy students. The curriculum changed three times during 6 years, based both on input from the students and teachers of mathematics and technical subjects. Matlab and Maple are used as educational tools, as well as Maya, animation software tool that students use for production of short animated movies during their project work.

Methodologies used to gather data for this paper are overview of the study plans and existing valuation documents, interviews with teachers previously teaching the courses and students who have graduated Medialogy bachelor studies, as well as discussions with teachers of other technical and non-technical courses. Questionnaires about attitudes towards mathematics are distributed twice to the same group of students – before they started Advanced Linear Algebra course on 5^{th} semester and after the exam on Differential Equations course on 6^{th} semester. Students' answers are compared and analyzed.

The paper is organized as follows. First the short history of teaching mathematics at Medialogy is told in the second part, and then some of the major challenges are listed in the third part. They are double entry point for studies and generally low level of previous mathematics knowledge on the negative sides, but students' awareness of their skills and seeing the purpose of studying mathematics on positive sides. The fourth part of this paper presents some questions and ideas for future curriculum development, and fifth part is the conclusion. In the Appendix, excerpts from all Medialogy mathematics study plans are listed.

2. A SHORT HISTORY OF TEACHING MATHEMATICS AT MEDIALOGY

2.1. First phase: 2002-2004, no mathematics

Aalborg University established Medialogy study line for the first time in fall 2002 at its department of Software and Media technology in Esbjerg. The idea was to offer a university education at both bachelor and master levels to graduates from short 2-years programs, chiefly to multimedia designers and people with short programming education (data-technologists). In 2004 Medialogy education also started at the Copenhagen department, and in 2006 at main Aalborg University campus in Aalborg.

At the beginning, the intention was to merit the students from short educations with 3 semesters, and to require 3 more semesters of studying Medialogy in order to obtain the bachelor diploma. No mathematics was initially planned as a part of Medialogy curriculum, but a combination of technical and humanistic subjects, like screen media, digital sound synthesis, sensor technology, perception, aesthetic, media sociology, computer graphics, human-computer interaction, interface design, etc., which would together enable the students to become "global problem-solvers in the technology world, independently on the problem"[1]. However, very soon it became apparent that the students who had enrolled into the education did not have enough mathematical skills to follow technical subjects [3]. Dropout rate due to this inability was very high. Thus, on students' request and with full agreement of teachers, the first Mathematisc course at Medialogy studies was offered in fall 2004, in a form of a free-study activity. Majority of the students enrolled in the course, and it was very popular.

2.2. Second phase: 2004-2006, specialized Medialogy mathematics courses

Following this development, it was decided that Medialogy studies should last 4 semesters (3^{rd}, 4^{th}, 5^{th} and 6^{th} of bachelor studies) for those who have graduated Multimedia Design or Data Technology, and that mathematics should be taught during the first 3 semesters of the studies, i.e. on the 3^{rd}, 4^{th} and 5^{th} semesters. Subjects were named Medialogy Mathematics 1, 2 and 3, and were designed with an intention to explain mathematics needed for technical subjects [4].

While the first course was basically a repetition of a high-school mathematics in order to ensure that all the students are brought up to an acceptable level in Mathematics, the next two courses clearly had more "medialogy" flavor, in the sense that they explained mathematical context of image analysis, computer graphics and sound synthesis courses. Exams on all the courses were oral, which allowed for checking students' understanding of the subject.

Although this intention was sound in theory, the practice it did not work as expected. Namely, the average mathematical level of the students was too low, so it was impossible to improve that with a single 3CTS course. This was noticed immediately, while the course was running for the first time, and a course "Written and Oral Presentation of Mathematics 1", in a form of 1ECTS free-study activity was offered for the students. The course ran in January, after the ordinary mathematics course, but before the mathematics 1 exam. Lots of students have used this offer, but it just made the problem smaller, and did not completely solve it.

Especially many complains from students' side considered Mathematics 3. It was not clear to students whether they are studying mathematics, programming or virtual reality during math classes. They had lots of difficulties to understand more applied topics. The fact that the course was taught by 3 different teachers (teaching Image analysis, Programming and Virtual reality as their main teaching/researching areas) just added to students' confusion and dissatisfaction. As a compromise, Mathematical tools for visualization and 3D reconstruction from stereo were not accessed on the exam, and the study plan was sent for a revision.

In a meanwhile Medialogy education was gradually becoming more popular, and students graduating from high school had also expressed interest in starting Medialogy studies immediately after high school. Thus a basic year of Medialogy studies was established in September 2005. However, in December 2005, an evaluation made by Danish Evaluation Institute [3] has shown that the criterion of "admitting the students with a relevant previous study background and sufficient level of knowledge" was only partially met when mathematics is concerned.

2.3. Third phase: 2006-now, mathematics courses common for all Engineering and Natural science students
From September 2006 two different kinds of students started on the 3rd semester of Medialogy studies in Copenhagen: those coming from the basic year, and those who have finished short tertiary educations and got 1 academic year of merit [3].

As a result, the new Medialogy study plan from August 2006 addressed changes in the mathematics curriculum. It was decided that all the students enrolling into Medialogy should follow standard Mathematics courses for all students on technical and natural sciences at the Basic year at Aalborg University. Mathematics 1 is taught on B level for 5ECTS, and Mathematics 2 on the C level for 3ECTS, during the first year students spend studying Medialogy.

Medialogy Mathematics 3 was renamed to Advanced Linear Algebra. Although context is still relevant for computer graphics and 3D virtual environments, there are also mathematics tools which could be useful during further Masters studies for signal analysis. For the details, see Appendix.

A new course on integrals and differential equations was established on the 6th semester, with the idea to empower students with skills to deal with dynamic inputs for multimedia systems they will eventually develop during further studies and work. Initially this course was planned for 3ECTS, but the students complained in December 2007 before the course got the chance to be run for the first time in spring 2008. The students argued that 3ECTS course is too much of a burden for their bachelor project work, and that they do not want and do not need to use those skills for bachelor projects. Based on this input, the Study board has changed the duration of the course to 2ECTS, also changing the form of the exam from initially planned written to oral. The fact that the duration of the course got shortened allows for only brief introduction to differential equations.

3. CHALLENGES OF TEACHING MATHEMATICS AT MEDIALOGY

3.1. Double entry point for studies

The double entry point for Medialogy studies creates a unique challenge for teaching mathematics, as the idea is that everybody should have the same mathematical background when they reach the fifth semester of studies, i.e. the last study year after which they will get the Bachelor diploma. Basic year at Aalborg University is well established during years of experience and research as an important year for achieving transfer from pupils to students [10], but Medialogy education faces this problem even on the third semester with an intake of new students from different short tertiary educations.

From mathematics perspective, there are two groups of students on the third semester: those who have already followed mathematics 1 and 2, and those who still need to follow those two courses. These two groups of students are merged for other courses, and they are also mixed in project groups. This merging helps "the newcomers" on the third semester to integrate into study environment, but does not help to resolve mathematics curriculum problems.

The solution to this issue adopted for now is that high school graduates have Mathematics 1B (5ECTS) during their first semester at university and Mathematics 2C (3ECTS) during their second semester. During 3rd and 4th semesters the students who had a basic year do not have any mathematics courses, but Esthetics and Design on the 3rd semester and Media Sociology on the 4th semester, while at the same time their colleagues with previous short education who started on the 3rd semester have Mathematics. The schedule is organized in a way that 1st and 3rd semester students follow the same Mathematics 1B, and 2nd and 4th semester students follow the same Mathematics 2C courses. Thus, when the students reach 5th semester, everybody was exposed to two mathematics courses, and two more mathematics courses are needed before graduation on Bachelor studies.

The experience gathered during several years of teaching mathematics in these conditions, together with responses to questionnaires obtained from students, shows that:

1. The students coming from the Basic year have typically passed previous mathematics courses for more than a year ago, and majority of them have forgotten majority of the material;
2. Lots of the students with previous short education, who have enrolled at the third semester, have not yet passed previous mathematics courses, which mean that they do not have the knowledge necessary to follow mathematics courses on the 5th and 6th semesters – but they anyhow try to follow these courses, hoping that somehow they will succeed in passing those exams.

The consequence is that a vast majority of students coming to 5th semester is not fit or does not feel fit to follow advanced applied mathematics courses. However, they are aware that they need mathematics either in order to follow technical subjects, or they accept the fact that they must pass mathematics exams in order to graduate – so motivation to study some mathematics on 5th semester is high.

3.2. Generally low level of mathematics knowledge among students

The independent evaluation study [3] conducted by Danish evaluation institute in 2005 has pointed to this problem. I will illustrate it here with a number of class anecdotes.

During differential equation course (the fourth, last mathematics course Medialogy students have during the bachelor studies, hold on 6th semester), while presenting methodology of solving a class of differential equations, there appeared a fraction on the left hand side of the following expression:

$$\frac{a+px}{x} = \frac{a}{x} + p$$

The teacher immediately wrote the expression on the right hand side. One of the students required explanation how the left side of the expression is equal to the right side – and the whole class agreed that just writing this expression is not good enough – that the transformation was not at all obvious to them.

A similar example appeared on the exam in the same course, when a student appeared to be confused while explaining some integration, and in order to help, a teacher asked him to sum up one third and one half. The student without much hesitation wrote:

$$\frac{1}{3} + \frac{1}{2} = \frac{1+1}{3+2} = \frac{2}{5}$$

Yet another example is when a teacher wrote:

$$\sqrt{9+81} = 3\sqrt{10}$$

a 4th semester student said: “Wait a moment – I need to check it on my calculator!”.

The last two examples could be taken as purely anecdotal, as they include single students. Every mathematics teacher could surely reproduce something similar. The first example is the most striking. It included the majority of the students in the class, who agreed that the more detailed explanation is needed, and carefully listened to it and wrote it in their notebooks.

3.3 Students’ attitude towards mathematics

As it has been mentioned in the short history of mathematics at Medialogy, the first mathematics course was organized on students’ request. This means that majority of Medialogy students are aware that they need mathematics knowledge if they want to be successful in their profession.

The results of the questionnaire distributed to the students at the beginning of the 5th semester, fall 2007, support this claim. 45 out of 46 students enrolled into the semester answered the questionnaire, and on the question “Your attitude towards mathematics”, 31 of the students have chosen the answer: “I could see that it might help with other technical subjects, so I am motivated to learn it, although I am not really good at it”. 7 students claimed that they are good in mathematics or that they love it, but 7 others claimed that either they are very bad in mathematics, or that they cannot see a clear purpose of studying it at Medialogy.

Slightly different results were obtained with the same students during 6th semester, in spring 2008, just after their Differential Equations exam. 34 out of 42 students answered this questionnaire (4 have decided to leave the

education during the school year). Now 12 students claimed that they are good in mathematics and could see its purpose on Medialogy, 11 could see the purpose, but still believe they are not good enough, and 11 claim that they cannot see the purpose of studying mathematics on Medialogy, and that they are bad in mathematics. On the exam, 36 out of 42 students have passed the exam, so there is significant number of students who have passed the exam, but still feel that they are bad in mathematics.

It is interesting to note that in both questionnaires, the answer "I am pretty good in mathematics, but I do not see why we should study it on Medialogy" was not chosen by a single student.

Another important input from students' answers is that while majority of the students pointed to usefulness of Advanced Linear Algebra course in other technical subjects, many of them wondered why they needed to study differential equations.

From these data a conclusion can be driven that a mathematics teacher on Medialogy studies faces a class of students with inadequate level of previous knowledge. The students are aware of their lack of knowledge, but willing to study, as a vast majority of them can see the purpose. Teaching such a class is a challenging task.

From one side, the students would like to see some application on the mathematics they learn to computer graphics, sound synthesis or physical interface design – but from the other side, general level of mathematics skills is so low, that the majority of time in the class is spent in explaining basic mathematics operations.

There are also positive anecdotal examples from teaching mathematics to Medialogy students. Although using Matlab as calculating and visualization tool was met with resistance during Linear Algebra course on the 5th semester, as students looked at it as yet another programming environment they need to master without any consequence to a grade on the exam, during Differential equation course the students were significantly more willing to use it for homework, as the exam was in a form of a micro project, that would require writing and explaining a program in Matlab for solving a class of differential equations. On Figure 1 is a part of the homework received on 6th semester differential equation course. The task was to write Matlab program which will produce a family of solutions to a given differential equation, and a student called the graph "a beautiful flower", just giving more evidence to famous saying of Henry Matisse "There are flowers everywhere, for those who bother to look".

```
inter = [-10 10 -20 20]

fplot('(-33/32)*exp(-x/3) -
4*exp(x)', inter)
hold on

for i = -3 : 4
    k = int2str(i);
    a = '(-33/32)*exp(-x/3) + ';
    b = '*exp(x)';
    fnch = [a, k, b];
    fplot(fnch, inter)
end

hold off

%it's like a beautiful flower  :)
```

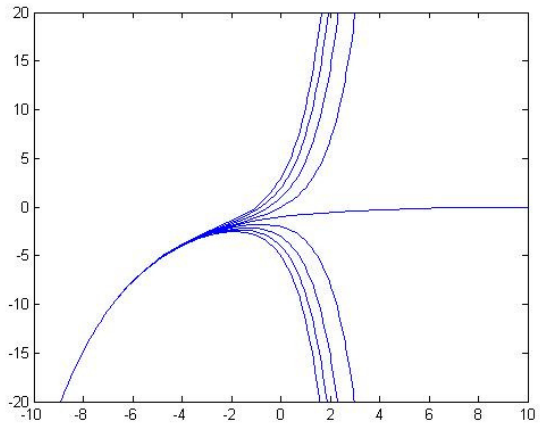

Figure 1. Excerpt from the homework in the course on differential equations on 6th semester of Medialogy. The comment by the end of the program is written by a student

4. CHALLENGES FOR FUTURE MEDIALOGY MATHEMATICS CURRICULUM DEVELOPMENT

The reality is that not the best mathematicians from high schools enroll into Medialogy studies. The reality is also that for many technical subjects the students need some mathematics basic. In current practice of teaching mathematics at Medialogy two approaches have been tried: teaching specialized mathematics courses to directly help technical courses, and teaching general mathematics courses. Strengths and weaknesses of both approaches have been experienced and learned.

The important question that still waits for a proper answer is not only what is minimal acceptable level of mathematics knowledge Medilogy students need, but also how to enable majority of the students to achieve (or even surpass) that level. This is also a valid question for many other technical and non-technical studies, even for those well-established through centuries like biology [6], [7]. Further on, there is a vast research how technology can help learning mathematics on a different level, providing the students with some meta-understanding without being able to do each single calculating step by hand, and vast research of effect of problem-based teaching approach to learning output, see for example [8], [9]. I believe that some transfer of experiences in teaching mathematics to different non-mathematics majors is possible and desirable.

All mathematics courses on Medialogy are so-called SE-courses. This means that they do not need to be used in the project work, but the students need to go on separate exams. However, as main Aalborg University teaching paradigm is problem-based learning, and the essence of mathematics is problem solving, it would be interesting to investigate whether mathematics courses on Medialogy could be taught somehow different, to emphasize problem-solving skills. Numerous issues, some of them partially mentioned in the third part of this paper are against this idea, but I believe that some work in this direction is still possible. The Medialogy Mathematics curriculum needs to be further refined, maybe even without major changing the study plans, with tree major goals in mind:

1. Start from the actual knowledge that students have, but take their willingness to learn more as the positive starting point;
2. While giving them necessary basic apparatus, show how those tools could be used in technical subjects.
3. Try to connect mathematics learning with problem-based learning and project work.

Only if the goal 3 could be achieved, teaching of mathematics on Medialogy will become successful. However, that is a very ambitious and difficult goal.

5. CONCLUSION

Mathematics courses development at Medialogy department in Copenhagen has suffered from typical issues with new educations. At least 9 different teachers have been teaching mathematics courses at Medialogy Copenhagen department since 2004, and the study plan got 3 major revisions. Now there are 4 mathematics courses, covered by two teachers who have those courses as a major teaching activity. Mathematics curriculum was developed as a best example of “learning by doing” principle. The courses were established and changed in response to students’ and teachers’ observations during the years. The tendency was to add more and more mathematics courses, of more and more general nature, so there are 4 semesters of teaching mathematics during 6 semesters of bachelor studies now, summing up to 5+3+3+2=16 ECTS points. Although the main issue from 2004 – extremely high dropout rate due to insufficient mathematical knowledge- has been resolved by introducing several mathematical courses and although those courses have been refined during years, there is still a huge work remaining in order to make those mathematics courses more useful for majority of the students.

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APPENDIX:

A1. Study plan [4], from May 2004 for Medialogy Math1, taught on 3rd semester, for the extent of 3ECTS:
Purpose: To enable the students to comprehend**:**

- Linear equations and systems of linear equations;
- Functions;
- Vectors, matrices and operations between them;
- Trigonometry and trigonometric functions;
- Basic statistical terms;
- Analysis of mathematical equations using software packages;
- How mathematical formulas apply to the topics of the current semester.

Content:

- Linear equations and systems of linear equations.
- Functions: what is a function, graphs of functions.
- Quadratic and higher order functions.
- Vectors, matrices and operations: sum, multiplication, convolution.
- Introduction to trigonometry: angles and triangles, trigonometric functions.
- Basic statistics: mean, median, variance, standard deviation.
- Introduction to derivatives.
- Formulas to find derivatives: power rule, sum rule, difference rule, product rule, quotient rule, chain rule.

A2. Study plan [4], from May 2004 for Medialogy Math2, taught on 4th semester, for the extent of 3ECTS:
Purpose: to enable the students to acquire comprehension on:

- Operations on sinusoids;
- Basic signal processing principles;
- Analysis of basic signal processing operations by using a software package;
- How mathematical formulas apply to the topics of the current semester.

Content

- Mathematical representation of signals.
- More on sinusoids: addition, multiplication.
- Spectrum representation:
    - The spectrum of sinusoids.
    - Periodic waveforms
    - Beating, AM, FM.

- Vectors derivatives.
- Matrix computations.
- Basic FIR filters: frequency response.
- Basic IIR filters: frequency response.

A3. Study plan [4], from May 2004 for Medialogy Math3, taught on 5th semester, for the extent of 2ECTS:
Purpose: To enable students to comprehend:
- Mathematical foundations of computer graphics and vision-based 3D reconstruction.
- How mathematical formulas apply to the topics of the current semester.

Content
- Elementary and 3D geometry.
- Mathematical tools for visualization:
    - pin-hole camera model
    - coordinate transformation
    - homogeneous transformation
    - perspective projection
- 3D reconstruction from stereo (correspondences, epipolar geometry).
- Position estimation of 3D objects from 2D to 3D geometry.

A4. Study plan [5] from August 2006 for Mathematics 1B, taught on 1st semester of Basic studies and 3rd semester for the students with different short tertiary educations, for the extent of 5ECTS:
Purpose: To enable the students to comprehend:
- Functions of multiple variables.
- Trigonometry and trigonometric functions.
- How mathematical formulas apply to motion and simulation;

and to enable the students to acquire knowledge on mathematical modeling.
Content:
- Functions of one or more variables.
- Advanced trigonometric functions
- Logarithmic an exponential functions.
- Partial differentiation
- Geometry in 2 and 3 dimensions
- Parametric curves, velocity, acceleration
- Introduction to mathematical modeling and applications.

A5. Study plan [5] from August 2006 for Mathematics 2C, taught on 2nd semester of Basic studies and 4th semester for the students with different short tertiary educations, for the extent of 3ECTS:
Purpose: To enable the students to acquire comprehension of:
- Linear algebra.
- Matrices operations.
- How mathematical formulas apply to simulation and modeling.

Content
- Linear algebra
- Linear systems of equations.
- Matrix manipulation, inverse matrices
- Mathematical modeling, application to simulation of interactive media

A6. Study plan [5] from August 2006 for Advanced Linear Algebra, taught for the first time in Fall 2007 for all Medialogy students on the 5th semester, for the extent of 3ECTS:
Purpose: to enable students to comprehend linear algebra and to enable students to apply (application) linear lgebra to processing and analysis of data.
Content
- Subspaces, basis, dimensions.
- Changes of basis

- Determinants
- Eigenvalues
- Complex numbers
- Complex exponential functions

A7. Study plan [5] from August 2006 for Integrals and Differential Equations, taught for the first time in Spring 2008 for all Medialogy students on the 6th semester: (The course was originally planned for 3ECTS, but on the students' request and with the permission of the Studyboard it got shorten to 2ECTS,without changing the context):
Purpose: to enable students to comprehend integrals and differential equations and to apply these topics in mathematical simulation for interactive media.
Content

- Integrals for functions of one variable
- Integral function
- Riemann integral
- Integration techniques
- 1st order differential equation
- 2nd order differential equations with constant coefficients