Pre-University Calculus MOOC with inquiry based learning as didactic model

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Abstract: *It proves that many starting students at Technical Universities don't have the required mathematical knowledge and abilities. This is caused by educational gaps at secondary schools, disinterest of students and a process of forgetting over time. At TUDelft a MOOC has been developed to train new students in mathematical calculus during the summer holidays before start of the academic year. The underlying didactic model is based on inquiry learning. The MOOCs can be downloaded on mobile devices and the used didactic model can be combined with cooperation and network learning.*

Key words: *MOOCs, mathematics, pre-university courses, inquiry-based learning, network learning, FETCH 2.0 FETCH 2.0 FETCH 2.0.*

INTRODUCTION

For many years starting students are tested on their mathematical knowledge and abilities at TUDelft. It proves that many students show great deficiencies caused by inadequate mathematical education at secondary school, erosion of knowledge over time but also lack of interest and motivation of students. Similar results can be found at other Technical Universities. Deficiencies in mathematics at start of a technical study is a serious problem. All students have to take mathematical courses in the first year and lack of mathematical knowledge and abilities have their impact on other courses in the first year. Gomes et al. state in [1] that Programming is hard to learn to most novice students. This can be caused from inherent difficulties of the subject to the lack of mathematical problem solving competences that students should have acquired before.

To solve the problem some Universities offer summer courses in mathematics or special courses at start of the year. These voluntary courses are at the cost of regular, compulsory courses and not highly appreciated by teaching staff and students. To solve the problem TUDelft took the initiative to develop a special MOOC on pre-University Calculus. That initiative supports the ambition to have MOOCs for people interested in an academic study at TUDelft. Similar ambitious and initiatives can be observed at many well known Universities cooperating in edX, Coursera and other consortia focussed at promoting MOOCs [2].

To motivate students the MOOC should include evidence of the need on mathematics for a successful study at a Technical University. Applications of mathematics, mathematical modelling and simulation should be stressed. In the current MOOC more advanced students report about the need of mathematics in their study to solve many real life problems and to create a better future of the world.
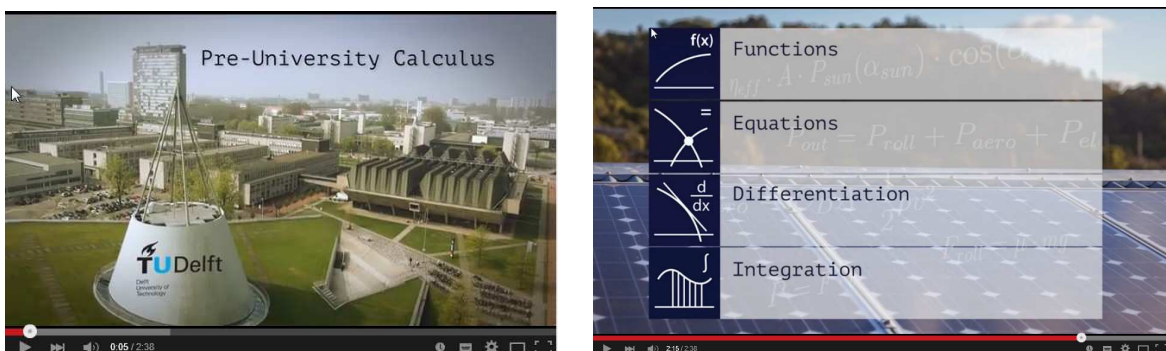

Fig 1: Screenshots of the MOOC Pre-University Calculus

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A key part in the development of MOOCs is the use of new ways of teaching and learning. In the current MOOC there is a focus on cooperative, network learning. Students meet each other in the "cloud" to share their learning experiences and knowledge. The used didactic model is based on inquiry based learning [3]. Students are stimulated to define questions stimulated by the lectures and the learning material. Fellow students in the network are invited to answer the questions and commenting solutions in the course forum. This is common practice in mathematics learning. To enable learning anytime, everywhere, in the current MOOC teaching and learning material can be downloaded on smart, mobile devices. The described didactic approach an extension of the didactic model FETCH 2.0 as introduced in [4].

The outline of the paper is as follows. In the second section we discuss related work. In the next sections we discuss some modules of the developed MOOC and discuss the new didactic models and initiatives to stimulate students to network, cooperative learning. Finally we report about the first test results during development of the MOOC and plans for the future.

RELATED WORK

The didactic Adagio of the famous Dutch mathematician and didactic specialist in mathematics Freudenthal was [5], "You can learn mathematics only by doing and discover mathematics in the real world". For him was teaching mathematics an educational task and it should be context sensitive and application oriented. Students should be able to design mathematical models and translate real world problems formulated in natural language in a mathematical language. Gomes et al. state in [1] It is very important to give students opportunities to reflect on and clarify their thinking about mathematical ideas. They discovered that one of the obstacles students frequently cope with in solving a programming problem lies in transforming a textual solution into mathematical language.

Most of current didactic models fits in the discovery learning tradition developed around 1960. Piaget, Dewey, Vygotsky and Freire and many others support constructivist learning. Up to then drill and practice was one of the favorite pedagogical principle in mathematics. Now the focus is on learning based on personal and societal experience. Our developed didactic model FETCH 2.0 is based on similar ideas [4]. The question is of course how to implement this didactic model in the developed MOOC. The oldest, and still the most powerful, teaching tactic for fostering critical thinking is Socratic teaching. In Socratic teaching we focus on giving students questions, not answers. The next step is that students themselves learn to generate questions around a learning text.

Mathematicians are trained to ask (critical) questions reading a scientific journal. These questions are stimulated by the learning material but also by the surrounding environment and context. Developing a critical attitude by students is not limited to mathematics. In [5] Freudenthal speaks about "Mathematics as an educational task".

At TUDelft a tool was developed which enables students to formulate questions during the teaching process. These questions become visual to the teacher and gives him the opportunity to comment them real time. The idea to ask questions is also implemented in our MOOC. Because there is no access to the teacher, the questions are defined in the cloud and visible for all students in the connected network. A list of questions and comments become visible on communication boards. The didactic approach based on defining questions is known as inquiry based learning.

ONLINE QUESTIONING SYSTEM

The wide spread availability of mobile devices, the development of communication software for such devices will have an impact on e-learning and mobile learning. Last year TUDelft invest a lot in the development of MOOCs and other forms of digital learning. This has stimulated some start-up companies at the campus of TUDelft to develop educational

tools to stimulate and facilitate the use of mobile devices in the process of teaching and learning. One of these companies FeedBackFruits developed a tool for mobile devices which enables students to ask questions during a lecture. The questions are visualised on a display in front of the teacher. It proves that students consider the tool as an interesting option. But defining questions takes some time and usual the lecture is going on. It is up to the teacher if he introduces breaks to allow and discuss questions. Some questions can be used by the teacher to summarize a topic. If there are many questions about the same topic the teacher has the option to explain the topic in an different way or to come up with some examples. In this way questions of the students can be considered as an online feedback system for the teacher. Of course there are many other ways for students to show that they lost interest or are not able to follow the lecture. Some students ask questions not about the current topic but about a topic from some time ago, a general topic or a combination of topics. To answer such questions has a great impact on the flow of the lecture, so usually answering these questions is postponed or neglected.

Last years the questioning was tested during some courses. Only a limited number of students used the opportunity to ask questions. The main reason was that they are heavily involved in listening to the teacher and taking lecture notes. Most of the time he considers the amount of questions as a sign how many students are able to follow the course. The Board of TUDelft decided to extent MOOCs with in-line interaction and peer-to-peer learning. To "flip the classroom" FeedBackFruits was requested to generate a plugin to make the "questioning tool" available via edX, one of the MOOCs consortia. A layer of new functionalities was developed over the edX platform. This enables students to make specific notes inline and make digital notes out of it. The plug-in also allows users to add new content to the course and share a message information board.

Our didactic model in the Pre-University Calculus MOOC is based on inquiry based learning and network learning. The questioning tool app enables students to comment the lectures, downloaded on their smart phone. These questions labelled by time labels or topics in the lecture will be listed on information boards. Other students in the network will be invited to comment the questions. In this way they can take the role of the teacher who is usually not available in the network. Additional teaching and learning takes place in the network of students. One of the options is to annotate the questions as (dis)like. The more students liking the question, the higher the raking order of the question on the list. A great advantage compared to the class room situation is that students are able to pause the video lecture to formulate or answer some questions or to think about it.

A great problem with network based learning is when many students participate and send messages an avalanche of messages can be expected and the bulletin boards will be overloaded. There are several options to solve that problem. One is to limit the amount of messages and when new messages are posted older have deleted. It can be expected that a lot of messages are rather similar. To remove them automatically or to fuse similar questions, advanced Natural Language Processing tools are required, that is currently not an option. It is usually not true that the last message describes the current state of art and other questions beyond a specific time window can be deleted or archived. Students are able to generate different kind of questions, we list some examples

1. The first type of questions are closed to text paragraph and asks for clarification, more details or an example *Ex. What is the outcome of exercise 1?*

2. The second kind of questions link a paragraph/section to other parts of the text *Ex. What is the difference between linear equations and linear differential equations?*

3. The third kind of questions ask for an application *Ex. Where are linear equations used in the project Lunar car?*

4. The fourth type of questions are the questions for generalisation (far) beyond the current text*. Ex. Two linear equations with two variables always have a solution?*

To prevent information overload on our shared information bulletins, we take an alternative solution. Just as a regular courses at University, the participating students population around a MOOC is split up in year cohorts and classes. So the whole network is split up in clusters of small subgroups. Students in such a subgroup are stimulated to communicate with each so get more familiar to each other and generates a strong group cohesion. In [4] we suggested to attach special roles to such groups, some student will take the lead for some time, takes care that members will not leave the group and activate students in the group.

MOTIVATING CONTEXT BASED LEARNING

One of the challenges of the Pre-Calculus MOOC is to motivate students and to offer learning content with a lot of applications and context based. As a topic in the introductory movie of the MOOC, the World Solar Challenge has been chosen (see Figure 1). It is about a race of solar cars using only solar power to cross Australia from Darwin to Adelaide. Students from DUT take part in the race and won the race for many years. In the MOOC, students from different studies explain how they build and manage their own car in a student project of one year with support of the University. In interviews participating students explain that a lot of mathematics is needed to construct such a car, dynamic navigation under different weather conditions and to optimize to whole strategy. In the video students explain that a lot of (linear) equations have to solved, extreme values have to be computed using mathematical calculus and computer software. This mathematical topics belong to the content of the Pre-University Calculus MOOC. Next to the mathematical topics it has been stressed that different technologies are need from mechanical engineering, aeronautics an electrical engineering to show technical student how mathematics is needed and used in different technical areas (see Figure 1).
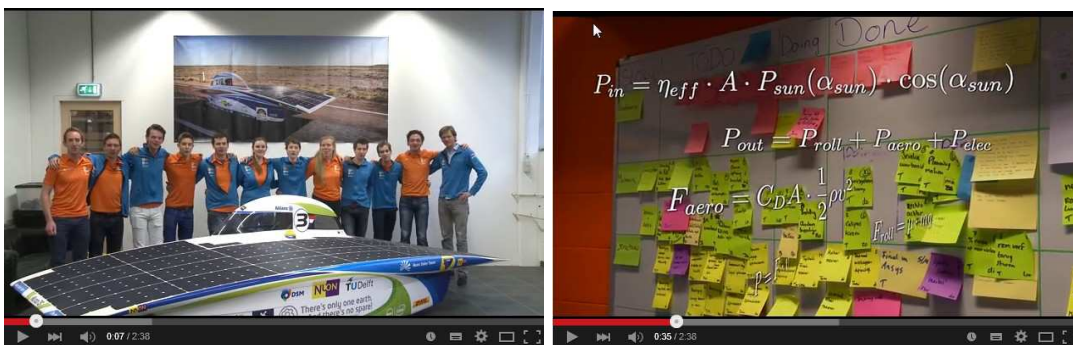

Figure 1: Screenshots of the introduction movie of the Pre-University Calculus
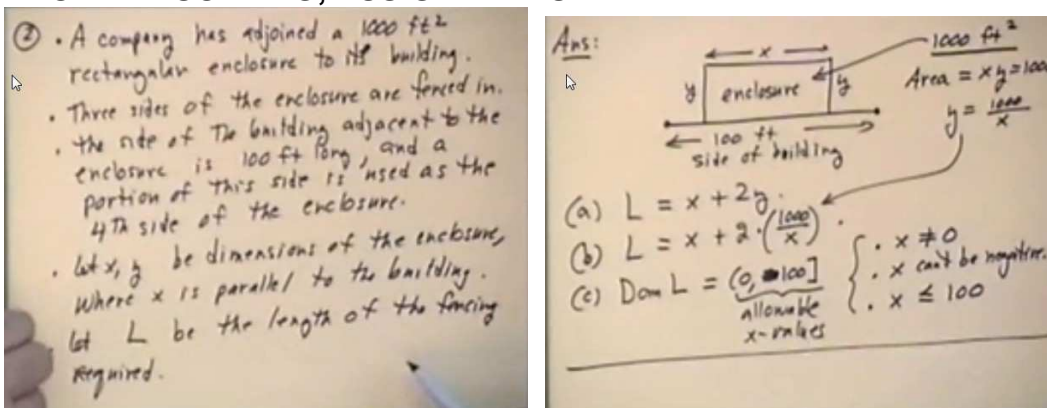
PROBLEM SOLVING, ASSIGNMENTS

Figure 2: Assignment with text based problem and its solutions

Mathematics is about problem solving. In [5] it is stated "Solving a problem a day, makes you happy anyway". In a Calculus course students have to make many assignments. It is not only about routine calculations. Students have to design models, strategies, using computer simulations. Of special interest are the assignments in which students have to describe an observed daily life problem and next have to convert the text to mathematical formula. In [1] Gomes claims that this ability is needed in mathematics but also in computerscience. In Figure 2 we display an example of such an exercise.

The current MOOC is composed of video lectures of maximal eight to twelve minutes lecture videos, exercises, assignments and exams. In Figure 3 we display a teacher giving an introduction to one of the topics functions, linear equations, differentiation or integration. Most of the time details are provided on a white board.
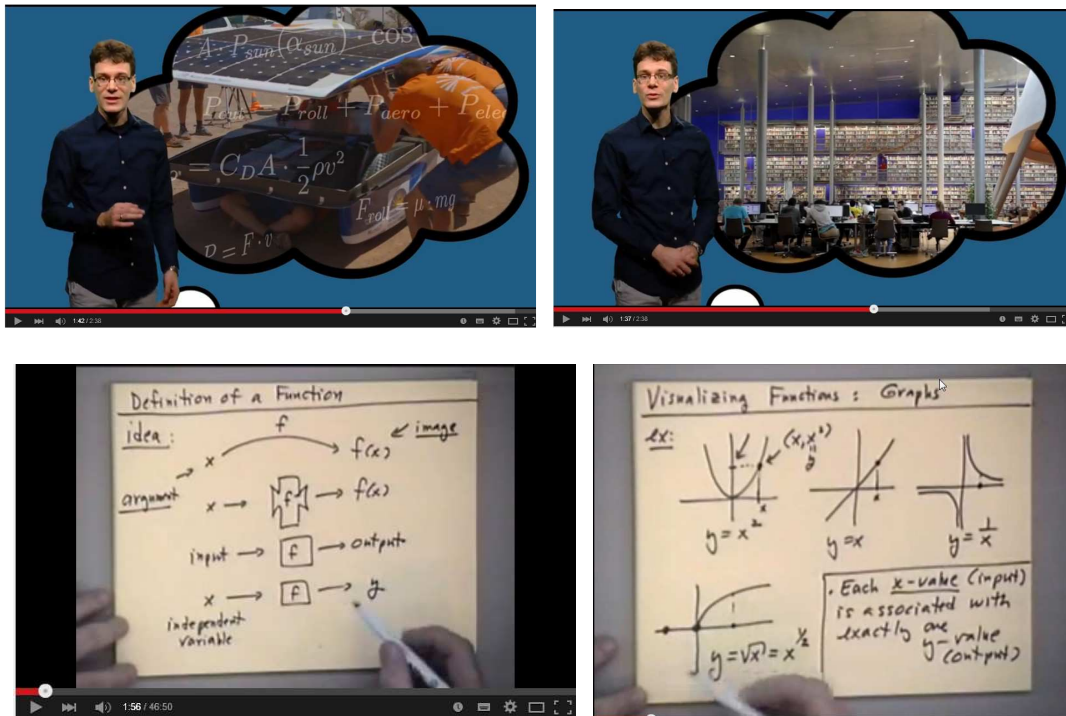

Figure 3: Screenshots of the Pre-University Calculus MOOC

The notes on the white board are real time generated and is not composed of sheets prepared in advance. This corresponds to the common way lecturing mathematics. Step by step the learning material will be build up. This is also important in case a teacher shows the solution of an exercise. Using a thinking aloud strategy the solution is displayed line for line. The end result maybe look chaotic. But the incremental approach, even making/erasing mistakes is an effective way to teach students to solve problems and making assignments. The slow writing speed provides students the time to think about the displayed teaching material and to memorize the displayed concepts and algorithms.

TEST

The Pre-University Calculus MOOCs is online since July 2015. Starting students from TUDelft and other Universities are stimulated to follow the MOOCs to be better prepared for a successful start at a Technical University. Every year more than 2000 students start a new study at Delft. End of July 2015 about 240 students enrolled in the course. From Figure 4 we can see that about 60% didn't start seriously or give up very soon for whatever reasons. About 12% of the students completed the course successfully. The rest of the students completed at least some of the assignments.
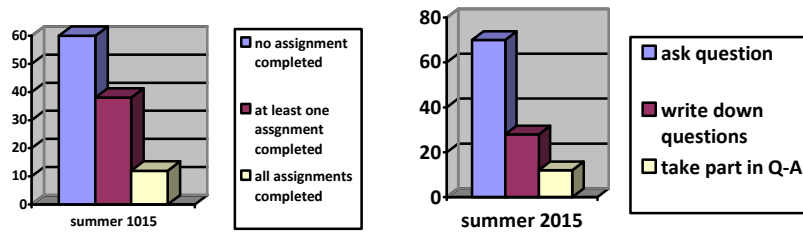
Figure 4: Experimental results

About 70% of the students reported in their final comments, that they were used to ask questions during self-study. But only 28% wrote down the questions invited by the teacher and assignments. A minority of 12% of the students took part in the questioning-answering system in the course forum. Most students prefer individual learning following the video lectures. It is expected that the new version of the MOOC with a lot of interactive, cooperative assignments will change the results.

CONCLUSIONS AND FUTURE WORK

At this moment many Universities invest in the development of MOOCs for different reasons. Delft developed a special MOOC to refresh the mathematical knowledge of students before they start their study at a Technical University. We were able to adapt the didactic model FETCH 2.0 for MOOCs and for mobile platforms. Mobile platforms enable learning at anytime, anywhere. A preliminary test shows mixed results. The number of dropouts is high. If Delft requires the final exam of the MOOC as a compulsory entrance exam the number of dropouts will decrease. But alternatives will be considered. At this moment students of the FETCH network follow the MOOC course and their experiences will be evaluated and results will be presented at the next e-conference

REFERENCES

[1] Gomes, A., L. Carmo, E. Bigotte, A. Mendes. Mathematics and programming problem solving. third E-Learning Conference, Coimbra, Portugal, 7 – 8 September 2006.

[2] https://www.edx.org/

[3] https://en.wikipedia.org/wiki/Inquiry-based_learning.

[4] Rothkrantz LJM. How Social Media Facilitate Learning Communities and Peer Groups around MOOCS. International Journal of Human Capital and Information Technology Professionals,. 6(1):1-13, 2015.

[5] Freudenthal, H. Mathematics as an educational task. Springer Science & Business Media, 1973.

[6] Dostal, J. Inquiry based instruction, Concepts, essence, importance, Olomouce University, 2015.

[7] Schink, A. The Road to Present Day Inquiry-Based Learning, aschinck@calpoly.edu, 2014.

[8] Rothkrantz LJM, Datcu D. 2010. Assessment of Emotion States During e-Learning. Communication and Cognition. 1-2:81–92.

[9] Rothkrantz LJM, Datcu D, Chiriacescu I, Chitu AG. 2009. Assessment of the emotional states of students during e-learning. International Conference on e-Learning and the Knowledge Society - e-Learning-09. :77–82.

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