

INQUIRY BASED LEARNING AS DIDACTIC MODEL IN DISTANT LEARNING

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Abstract: Recent years many universities are involved in development of Massive Open Online Courses (MOOCs). Unfortunately an appropriate didactic model for cooperated network learning is lacking. In this paper we introduce inquiry based learning as didactic model. Students are assumed to ask themselves questions interacting with a learning text. The model has been tested for students of DUT taking a MOOC in mathematics. The didactic model and test results are presented.

Key words: inquiry based learning, didactic model, experiments, MOOCs, mathematics.

1. INTRODUCTION

In ancient times wondering was already considered as the start of wisdom. Science is more than memorizing and knowing facts. Students should be triggered by phenomena, asking questions about what is going on and increase their knowledge in an active way of thinking. During the discovery learning movement in the 1960s inquiry based learning was developed as a didactic model. The method was rather popular in teaching mathematics.

Since three years teachers from Delft University of Technology are heavily involved in developing MOOCs. At this moment 20 MOOCs are available via edX, a consortium started by MIT and Harvard focused on distributing MOOCs. At start MOOCs were mainly video recorded lectures. But nowadays MOOCs also include movies, simulations, experiments and projects. What is still missing is an adequate didactic model. In this paper we research the use of inquiry based learning in distant learning including MOOCs.

As test material a special MOOC on Pre-University calculus has been used. It proves that starting 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. 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. To solve that problem a special MOOC was developed by teachers of TUDelft discussing the essential of mathematics lectured at secondary schools. All starting student at TUDelft are strongly advised to take that course during the summer weeks before the start of the academic year.

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. Viewing the web based lecture or reading other study material, students are supposed to define questions. A special tool has been developed to type these questions such that questions become visible for fellow students, teachers or are published on bulletin boards. As we will explain in section 3 the idea is that these questions will not be answered or discussed by other students on the first place but serve another goal. The main idea of inquiry based learning is that students learn to process the learning in a critical, active way by defining questions. Similar to thinking aloud methods, students are supposed to start a discussion with themselves.

To enable learning anytime, everywhere, in the current MOOC teaching and learning material can be downloaded on smart, mobile devices. The described didactic approach is an extension of the didactic model FETCH 2.0 [1,2,3].

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.

2. RELATED WORK

The didactic Adagio of the famous Dutch mathematician and didactic specialist in mathematics Freudenthal was [4], “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 [5], 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 [6,7]. 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 [1]. 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 [8] Freudenthal writes about “Mathematics as an educational task”. Many mathematicians use the inquiry based methods also during reading or reviewing a paper, or documents or listening to a presentation. It proves that inquiry based method is an efficient way to keep the reader/listener alert and is a first step to processing the presented information.

3. MODEL OF INQUIRY BASED LEARNING

Learning is the outcome of the interaction process between students, teacher and teaching material. The basic idea of inquiry based learning is posing questions, listening to the teacher or reading text material. The presented material should not be accepted by the students as true and imitated and memorized. The basic attitude of students is to analyse the presented material in a critical way, relate it to other concepts and integrate it in the learning process, theoretical model learned so far. The process of asking questions should be stimulated by the way of teaching of the lecturer and the way of presenting the learning material [9,10].

A teacher is assumed to use the thinking aloud method. The learning material should not be presented in the way as it is written down in a textbook or on well-structured power points sheets. The lecturer is assumed to think aloud about what to present, how it is related to presented material and what is the expected outcome and goal. A common way of teaching mathematics is to present a sequence of definitions, theorems, proofs, followed by some examples and exercises. Using the inquiry based method the teacher should start with some examples and counterexamples and defines the requirements in an iterative way. Then he should start to philosophy about the possible ways how to prove the theorem. The text material should also be ordered or structured around leading questions instead of titles of chapters or paragraphs. An option is to put questions in the margins of the text. In this way students learn to put questions in the margin after reading a text.

We stressed the fact that posing questions in the inquiry based didactic enables students to process the learning material in an active way. Not only passive reading or listening. Asking the right questions is the first step in processing new information. Most questions are rhetoric by nature and don't need to be answered.

In the learning material it is assumed that the presented information is correct, complete and unambiguous. But in real life this not true. Asking critical questions and research questions is essential in solving real life problems or specifying the context and conditions that these problems can be solved.

The inquiry based didactics will be used in MOOCs. By its massive nature, the interaction student-teacher is usual minimal. MOOCs are designed for cooperative and network learning. Posed questions of individual students can be placed on bulletin board visual for other students. This should stimulate other students to pose their own questions. Some questions will stimulate discussions between students in the network. These discussions are different from discussions about the (solutions) of assignments which are usual technical from nature.

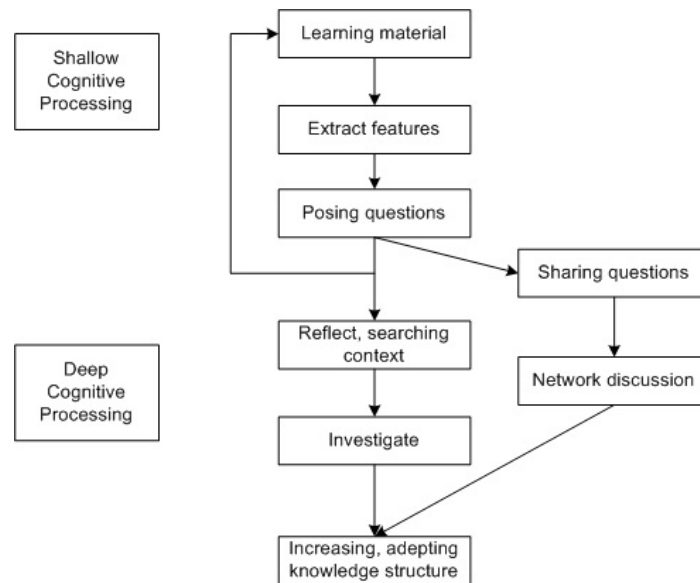


Fig. 1. Schematic overview of the didactical model of inquiry based learning

Our inquiry based didactic model has been visualized in Fig 1. In the first circle of shallow cognitive processing, special features in Web-lectures or other learning material or network activities should trigger students to pose questions. The first questions just come up and don't require much cognitive processing (thinking via spinal brain). In the second circle the process of posing questions stimulate students to think it over and to find related context if time and willingness for further cognitive is available. Via the network students can start sharing questions and start a discussion, Finally new acquired knowledge will be integrated in existing knowledge structure or result in extension or adaptation of

these knowledge structure. Questions from individual students stimulate discussions in the network of connected students. Posing the right questions is even better than giving the right answer. It proves that students are triggered to pose questions if the presented learning material is ambiguous, incomplete, doesn't fit in the existing knowledge structure of the students,

Examples of questions from the experiments described in the next section

Teacher: As we have seen before.

Student: Where and when did we see that?

Teacher: The proof of this proposition is trivial.

Student: What is trivial?

Teacher: We can visualise the problem as follows.

Student: How do you find such visualisations from the exercise?

Teacher: Every continuous function on a closed interval has extreme values.

Student: What do you mean by that?

Teacher: Every polynomial function is a continuous function.

Student: How to prove that statement?

4. EXPERIMENTS

4.1. Learning material

To test our model for inquiry based learning we selected two open online courses: The first course is a classical video lecture from Professor Delaware from University of Missouri Kansas City (UMKC) (see Figure 2). It is selected because at this moment video lectures are used by many teachers at Universities. During real life lectures many teachers are used to pose many questions. Usually it takes some time before some students are willing to answer the question and even some students feel uncomfortable if they are selected to answer the question. During video lectures, there is no real life audience and posed questions by the teacher are not supposed to be answered but have the function to keep students more involved to the lectures. The notes on the white board are real time generated and are 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 may 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.

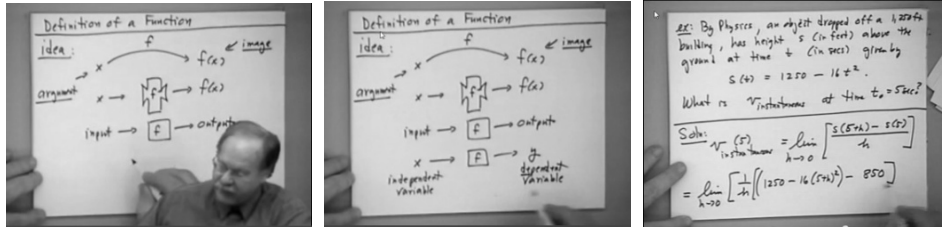


Fig.2. Some screenshots of the video lecture of a teacher in action and display of learning material



Fig. 3. Some screenshots of Pre-Calculus MOOC

The second MOOC we used in our experiment is the Pre-Calculus MOOC developed at Delft University of Technology (see Figure 3). The goal of that MOOC was to upgrade and refresh the supposed mathematical knowledge of freshman before the start of the academic year. One of the challenges of the Pre-Calculus MOOC is to motivate students and to offer learning content with a lot of applications and is context based. As a topic in the introductory movie of the MOOC, the World Solar Challenge has been chosen (see Figure 3). 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 solar cell 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 be solved, extreme values have to be computed using mathematical calculus and computer software. These 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 needed from mechanical engineering, aeronautics and electrical engineering to show technical students how mathematics is needed and used in different technical areas (see Figure 3).

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 some screenshots 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.

4.2. 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 invested 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 usually 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 a 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 the teacher 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 [11]. 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 [12]. 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.

5. RESULTS

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. But the MOOC is via the edX consortium available worldwide and thousands of student followed the first version of this MOOC. End of July 2015 about 240 Dutch 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.

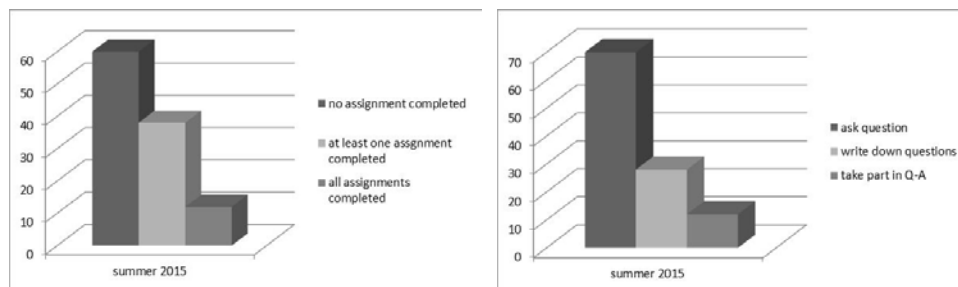


Fig. 4. Overview of experimental results

We selected a group of 23 students from two secondary schools, planning to start a study at TUDelft in September 2015. During the summer they enrolled in the course. In special sessions at school they were instructed how to use the inquiry based learning didactic. About 70% of the students reported in their final comments, that they were used to ask questions during self-study. But only 30% wrote down the questions invited by the teacher and assignments. A minority of 15% 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. At this moment the results of the pilot group are available. End of the year the whole cohort of participating students will be available.

Based on the results of the pilot study we conclude that the inquiry based didactic is a promising didactic model for MOOCs on mathematics. This is supported by a long year of experience in classical classroom teaching. The evaluation of the MOOCs end of the year 2015 will show if the inquiry based method is a useful model for large scale applications in MOOCs.

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Emeritus Professor Leon Rothkrantz, PhD, was for many years involved in scientific research and teaching at TUDelft and the Netherlands Defense Academy. His interests are Artificial Intelligence, Intelligent Human Computer Interaction, Smart Sensors and Distant Learning. Currently he is appointed as visiting researcher at the Faculty of Transportation Sciences, Czech Technical University of Prague