# Mathematics Courses: Fostering Individuality Through EMOOCs

**Authors**

**Dr. Bastian Martschink**
bastian.martschink@h-brs.de

Hochschule Bonn-Rhein-Sieg, University of Applied Sciences, Germany

When it comes to university-level mathematics in engineering education, it is getting harder and harder to bridge the gap between the requirements of the curriculum and the actual mathematic skills of first-year students. A constantly increasing number of students and the consequent heterogeneity make it even more difficult to fulfil this task. This article discusses the possibility of complementing an introductory course in mathematics with learning environments designed by the international ROLE project in order to use a MOOC to provide an internal differentiation of large learner groups such that it gets easier for students to gain the knowledge needed for the content of the curriculum.

This article examines the project Vorkurs mit Open Educational Resources in Mathematik (VOERM) (Mathematical Introductory Course with Open Educational Resources (OER)) that as first offered at the Bonn-Rhine-Sieg University of Applied Science in the winter term of 2013. The course was conducted in September and October 2013. The course is not part of the curriculum but is taught every year during orientation. The objective of the project is to turn parts of the course into a MOOC. Following a short summary of the actual situation, we will present the idea of the project as well as research questions and aims. Furthermore, we reflect on the experience and possible future developments.

**Tags**

mathematics, MOOC, orientation, role, differentiation of learners

## Introduction

### Problems in mathematics courses

In general, mathematics continues to play a dominant role in our everyday life. Technologies, techniques and procedures, like for example the optimization of parameters or chain supply management, are fundamentally mathematical based (Ziegler, 2006). In order to keep pace with modern technology and also to understand existing concepts, future engineers have to have a deeper understanding of mathematics. Thus, mathematics continues to play an important role in their education.

When it comes to engineering education, a German survey dealing with sustainable university development in 2011 has shown that nearly half of engineering students cancel their studies and one in four students is still leaving the university without a university degree. Students stated that the most common cause for dropping out of studies in these courses is that academic entry requirements often ask too much of them (Hetze, 2011). During their orientation phase at university and their first semester courses, students decide whether they continue their studies or give it up.

Engineering disciplines are fundamentally based on mathematics and problem solving. As a consequence, the entry requirements of these courses still represent a major obstacle for the students due to their heterogeneous levels of mathematical knowledge. Mathematics education at school level differs from school to school and unfortunately some contents are hardly taught anymore. Thus, students lack formal and important symbolic elements. Due to changes in the school curricula the learning behaviour has also changed so that for example "teaching to the test" does not stimulate the integration of knowledge in the long-term memory.

After finishing school students also often mention that there are inadequate overall conditions at universities when it comes to repetition of school mathematics. As a consequence, the gap between the initial requirements of the mathematical courses at universities and the prior knowledge of the first semester students is steadily enlarging (Knorrenschild, 2009). Students lack the mathematical ability needed for their future courses. A constantly increasing number of students and the consequent heterogeneity make it even more difficult to fulfil the task of bridging the gap. Hence, the problem of giving lectures for large audiences with heterogeneous levels of mathematical knowledge must be resolved.

## MOOCs

In order to deal with a large number of students and with the problems of prevalent passivity of students in a large audience, information must be presented in different ways. The lecturer has to support each individual learner and their individual learning processes. One way of doing this is the usage of ***M**assive **O**pen **O**nline **C**ourses* (MOOCs). The term was first used as a result of a large online course run by George Siemens and Stephen Downes in 2008 (Cormier/Siemens 2010). The *massive* part of a MOOC "comes from the number of participants, which could range from hundreds to thousands to hundreds of thousands" (Bond 2013). Discussions have suggested that a group of 100 participants is a minimum. The word *open* comes from the fact that "anyone is free to register … [and that] [t]here are no prerequisites, other than Internet access, and no fees are required" (Bond 2013). Typically, open source software is involved and OER are used as material for the course. Online refers to the fact that the internet is used for the courses and the word *Course* itself states that MOOCs are courses with "schedules and facilitators, readings or other course materials, and sometimes projects, all organized around a central theme or topic" (Bond 2013).

In (Powell/Yuan, 2013) there are different issues and challenges for MOOCs mentioned. Three of the main challenges are pedagogy, quality and completion rates. The concept of MOOCs raises the question of whether the courses and their organizational approach to online learning will lead to quality outcomes and experiences for students. New pedagogies and strategies are required to deliver a high quality learning experience for the students. On the one hand, MOOCs provide great opportunities for non-traditional teaching styles and getting the focus on the individuality of each learner. Each learner can experience his own difficulties and the lecturer is able to provide material so that each student is able to work on his deficits using his own speed. Individual or alternative routes of learning can be taken and online communities can always answer to given problems. On the other hand, the lecturer is not able to deal with each student personally. Social learning experience is not provided by MOOCs. Also, as a consequence of the lack of structure of the online courses, the self-directed learning demands from the students that they motivate themselves to participate and structure the online material for themselves. Lectures demand a certain level of digital literacy from their participants.

In order to deal with the heterogeneity of first-year students, the Bonn-Rhein-Sieg University of Applied Science intends to use a MOOC as an extension of the traditional mathematical introductory course. The above mentioned gap between output orientation, the minimum mathematical requirements of the course of studies, and the input orientation, the compensation of personal mathematical shortcomings of the first-year students, cannot be sufficiently filled by the introductory courses at universities. In only a few weeks before the semester starts, the lecturer is not able to communicate new subject matters completely (Knorrenschild, 2009). Each student has different mathematical abilities after finishing school and is lacking some topics that will be important for his engineering studies. Since the university is facing approximately 300 students the lecturer is not able to provide an individual learning environment for each student in a traditional lecture. Instead this should be put into practice by an extra MOOC that supports the traditional lecture. The next section outlines the idea of the new project.

# The VOERM project

## The ROLE platform

In order to solve the problems mentioned in the previous section the Bonn-Rhein-Sieg University of Applied Science in cooperation with the Frauenhofer Institute for Applied Information Technique (FIT) tries to combine the traditional mathematical introductory course with a MOOC. This course uses the so-called ROLE platform of the FIT. ROLE is an acronym for ***R**esponsive **O**pen **L**earning **E**nvironments* and is a European collaborative project with 16 internationally renowned research groups from 6 EU countries and China. ROLE technology is "centred around the concept of self-regulated learning that creates responsible and thinking learners" (ROLE 2009). On the ROLE platform the lecturer is able to develop the open personal learning environments for his students where they work on material that is provided by the lecturer. There are platforms available for several topics of school or university education.

On the ROLE platform the lecturer can choose between many widgets, which are small graphic windows that can be integrated as a small program on the online platform. Each widget can be individually fitted to the learning material of the subject matter and some are even developed especially for certain topics. Examples for widgets are the *Language Resource Browser Widget*, where students can use a web browser, that is adjusted to finding texts matching the actual subject matter, to search the internet for texts and use a translator and a vocabulary trainer for these texts, or the *WolframAlpha Widget*, which can be used by students for example to plot functions or solve logarithmic equations.

Using these widgets, students are able to:

- structure their own learning process individually,
- search for learning material on their own,
- learn and
- reflect their own learning process and progress.

For the collaboration with the Bonn-Rhein-Sieg University the FIT will set up a platform that will be accessed by the students via their online account for the eLearning platform of the university. Thus, there are only little administrative difficulties since the students have to create their online accounts anyway. Next, lecturers of the introductory courses in mathematics were able to create their own spaces on the ROLE platform by using widgets from the existing compilation of the ROLE project. If widgets performing a certain needed function were missing, the FIT tried to create these widgets on their own. Before the creation process began, the lecturers got an instruction for the ROLE platform and the widgets, and the staff of the FIT accompanied each step of the creation of the online space. Assistance and ideas for improvements were given for the choices of the different widgets and for the usage and production of OER. Furthermore, lecturers were able to exchange experiences with the eLearning team of the university.

## The introductory course

The project started at the university in the winter term of 2013 and the introductory course is divided into three different phases that are presented in Figure 1.

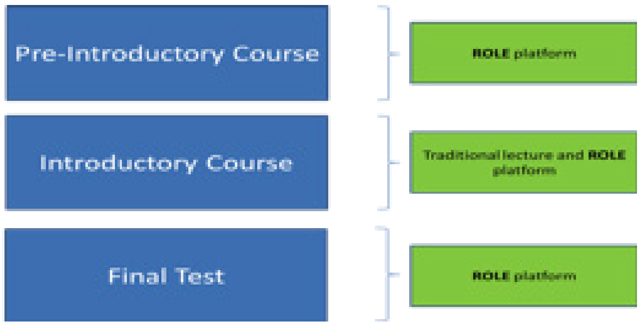


Figure 1. The structure of **VOERM**

The course lasts ten days. The first phase is a pre-introduction and lasts three days. The first-year engineering students of the university will be welcomed and alongside information about their upcoming studies the structure of the new introductory course and the platform of the ROLE project will be presented by the lecturer. On the following two days the students will work on the ROLE platform. This phase is a MOOC and thematically deals with the mathematical fundamentals needed for the rest of the course (equations, algebraic signs, brackets and number range). For this purpose the lecturer has assembled several widgets with OER contents:

- Videos
- PDF documents
- Exercises
- Calculator, tools for formulas, function plotter

- Forum
- Bulletin board
- …

An *Activity Recommender* contains instructions on how the MOOC works and how the widgets can be used by the students. This recommender also helps to create a *To-learn list*. The students are able to cross off the points on this list to mark the completed tasks. The forum can be used to discuss problems, exchange further material or get in contact with fellow students or the lecturer. The videos can be taken from the pool of OER found for example at YouTube or the famous *Khan Academy,* which produces online learning material for mathematics since 2007. For the project at the Bonn-Rhein-Sieg University, the lecturer produced most videos were in advance. Thus, the videos are exactly fitted to the subject matter. Additionally several other tools, like for example the previously mentioned *WolframAlpha Widget* or the *MathBridge Widget*, which is a search engine for mathematical phrases, are integrated. In general, students are free to use each widget when they want to. They can decide on their importance for themselves and on the order in which they are using the widgets. Hints for advisable combinations can be found in the *Activity Recommender*.

After this online experience the second phase of the introductory course is a mixture of a traditional lecture and the online course. During the next six days, several topics of engineering mathematics, such as trigonometry, powers or roots, are discussed in class. After each lecture the students are able to log onto the ROLE platform and work on the topics discussed earlier that day. For different topics, there are different spaces on the platform, which can be given to the students one at a time. These spaces were prepared in advance in the same way as the spaces for the first three days of the introductory course. The advantage for the lecturer is that the space can contain the material of the traditional lecture and additional material for each topic so that students who realized that they have deficits in some areas can pick the learning material that is most suitable for them. Additionally, more difficult tasks can be given to students whose mathematical ability is more advanced. In summary, if students decide that they prefer to work online they are not depending on the traditional lecture in order to get the information and material needed.

The third phase of the project involves testing the online platform, which will be conducted on the last day of the project. This test checks whether the students have understood the topics presented during the last nine days. It contains ten questions and each student is supposed to work on the test alone. The results will be used to identify students lacking the mathematical ability for their engineering education so that the lecturer can provide a special mentoring program for them during their first year of studies.

In summary, the project should support individual learning strategies and the acquisition of mathematical skills through an internal differentiation by giving students the possibility to work with their own speed on the topics of the subject matter that are the greatest obstacles for them. Students lacking elementary skills get the chance to fill in gaps in their own time without the pressure of their peer students and also students that show a deeper understanding of the subject matter can be challenged by more difficult tasks on the online platforms. Additionally, students can contact the lecturer in private and not in front of a large audience via personal chats. Thus, students who apprehend that any form of oral communication in huge classrooms would humiliate them in front of their fellow students are encouraged to use these personal chats.

## Aims and Research Questions

The research questions of the project **VOERM** are the following:

1. What is the access frequency of the elements on the **MOOC** platform?
2. Has the result of the final test improved in comparison to the last year where there was no **MOOC**?
3. Do students express that the **MOOC** has supported their acquisition of knowledge?
4. Is the **MOOC** platform more suitable than the traditional lecture to support the students' learning processes? Do some students even prefer the MOOC and skip the traditional lecture?
5. Can an improvement of the mathematical ability be experienced during their first-year of studies in comparison to the last years?

The aim of the **VOERM** project is to use an additional **MOOC** to bridge the gap between the input and output orientation mentioned in the introduction. Students should reach a higher mathematical ability that enables them to perform better during their studies. They should dispose of their mathematical deficits and get ready to understand the subject matter of their later mathematical courses.

Short-term aims are an increase in students' motivation and facilitation of students' academic integration. Through the additional MOOC students should experience that their mathematical ability has increased and they should evaluate their own performance in a positive way.

## Evaluation and reflections

In this section I will try to give some provisional answers on the research questions raised in the previous section and reflect on these answers. Furthermore, we will share some of our experiences. Not all information is available yet since some data is still being processed and individual student answers are still pending.

### Technical Details

On the technical side, the data on access have not been evaluated yet. However, during the course I was able to get an impression of how the widgets were accessed. First, there were some students that complained about not being able to access the entire online space. The online team of the university did its best to help these students and after two days no student complained about this problem anymore. Still, it may be the case that some students just took the traditional course and skipped the additional **MOOC**. Unfortunately, some students had problems accessing specific widgets, such as the videos made by the lecturer. Students that used Internet Explorer as a browser did not have a start button for the video. The university's online team was able to relink the videos through the online platform of the university so that these students were also able to see them on their home computers. In other cases the problem of not being able to see the video was fixed by changing the DivX-setup of the computer. If problems could not be fixed by the online team, students were advised to access the spaces from one of the computers of the university. In theory, each student should have had the opportunity to work on the **MOOC** course.

In class, students stated that the most common widgets used were the online videos and the PDFs with exercises and solutions. Also, Internet links providing further videos or additional reading material were used quite often. The additional helping devices, like for example calculators, functions plotters or the activity recommender were hardly used by the students. When asked why these widgets were hardly used the most common answers were that students had the specific function of one of the widgets on their calculators or that they did not need these functions. For future **MOOC**s on the **ROLE** platform students expressed the wish to have more learning videos and widgets that are explicitly designed for the different topics of the course. Most of the actual widgets are general mathematical applications, which can just be used for the introductory course. However, for future **MOOC**s, it would be better to design widgets with which the students can control and test their results of the exercises instead of auxiliary exercises. It should be mentioned that this would increase the workload for the lecturer and the members of the ROLE team significantly, as these new widgets would need to be programmed.

### Participation and final test

In total, 279 students signed up for the course. 229 participated in the final exam. Even though the final exam was mandatory, a lot of students did not attend it. During their first year of studies these students will have the opportunity to take the final exam. Thus, their results are not included in the diagrams below. In comparison to the previous year the results of the final exam improved tremendously even though the test had the same questions (see Figure 2a and 2b for the results; on the horizontal axis there is the result of the test (in percentage), and on the vertical axis there is the number of students).

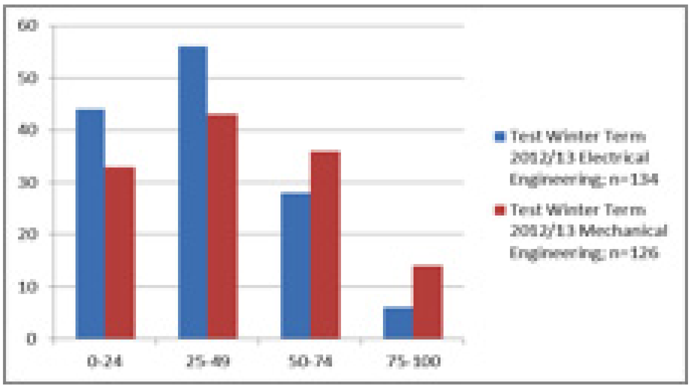


Figure 2a: Results of the finals exams in percentages

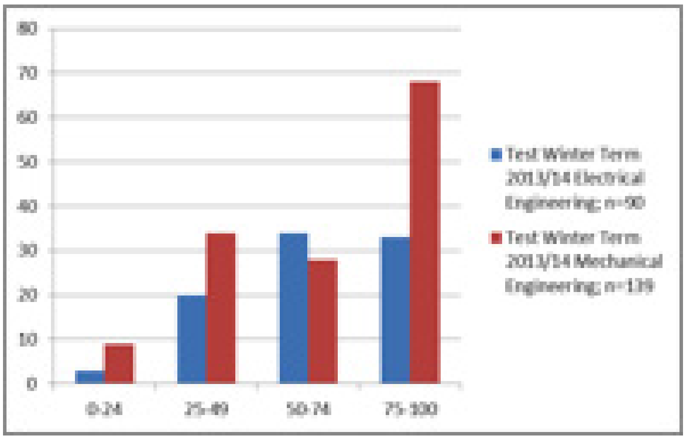


Figure 2b: Results of the finals exams in percentages

Unfortunately, this year's test was written online whereas last year's test was written under supervision at the university. Thus, students were able to use books, calculators and the course material during the exam. Additionally, they were able to work in groups. Nonetheless, there were no simple calculation exercises and the students did not have much time for each task of the exam, so that it can at least be said that students performed better in finding approaches that led to the solution. Furthermore, there were no consequences if students did not pass the test. The test served only as a classification of their pre-university knowledge and I explicitly explained that they would just betray themselves if they cheated on the students. While talking to the class after the test, I got the impression that most of the students tried to work on their own. Since we do not have the staff capacity to correct all the finals exams in two days in person, and in order to ensure more significant comparisons, the test will be performed again online next year.

One particular student retook the course and was able to compare the MOOC experience to the regular course of the previous year. He stated that the widgets on the online spaces were of great help. This student had deficits because some topics were not taught during his school education. When attending the course in the first year, he had problems following the lecture and solving the tasks provided. With the MOOC, he was able to watch individual videos again and test his knowledge on easier exercises. In the event of problems, he thought that the forum, provided on the online space, was of great help. He had a lot of questions that he was afraid to ask in class in front of his fellow students, so he used the individual message function of the online space to ask for help. He stated that not being exposed to the scrutiny of his fellow students made him more comfortable when asking his questions.

## Online evaluation

134 students completed the online evaluation of the course. In total, 113 students stated that the MOOC explicitly supported their understanding, and that the self-regulated learning on the spaces helped them gain the knowledge needed for their studies. 18 students said that the MOOC was only partially helpful and one person considered the MOOC to be useless. Students in class stated their appreciation for the opportunity to repeat exercises, watch the videos and get additional information. One of the main reasons they considered the MOOC to be useful is that during orientation, students do not go to the library of the university and pick a book that might help them. Some of them did not even have a library card at that point of their orientation. In the online spaces, additional information and course material selected and structured by the lecturer is made available. The positive effect of this is that students who skip searching for books after a short period of time when they are not able to find the material needed, and students who do not have access to the library are now able to work directly with the texts and exercises provided. This way these students work at home for the class instead of skipping this process. On the other hand, there is the negative effect that the lecturer takes more and more responsibility into his or her own hands. Thus, the experience of searching for literature is curtailed and students lose some of their learning autonomy.

Despite this fact, more than 80 percent of the students mentioned that the MOOC fostered their learning autonomy. They stated that the search engines and the possibility of selected their own level of difficulty on the online spaces made challenging experiences possible. Individual learners, mostly those with deficits resulting from incomplete school mathematics, told me that they needed the opportunity to take a closer look at the material. Hence, students' motivation definitely increased (more than 87 percent) and the reception of the MOOC course is very positive. The students think that they gained the knowledge, but one has to keep in mind that students often misjudge their own mathematical understanding. Even though they think that they have gained the knowledge, they are not always able to solve the tasks provided.

Their positive feeling after the course was supported by my experience during the first weeks of the current winter term. Despite the fact that a lot of elementary problems are still caused by a lack of knowledge, deficient accuracy or inattention, the overall impression of this year's course is much better than that of the last winter term. This may also depend on the individual learners of the course, but especially when it comes to the topics of the introductory course, the students of the current class perform a lot better than last year's students. During the repetition course, which is held during the winter term, we discuss current problems rather than spending a lot of time repeating the fundamentals.

Finally, when students were asked if the MOOC could replace the traditional course, they stated that they feel there is still a need for in-class elements. They appreciated the existing structure with a basic course and lots of presence elements. Among other reasons they mentioned that they like the direct contact with the lecturer, that questions can be discussed in the plenum and that there is a direct student-student interaction, which is important for forming peer groups during orientation. Despite the fact that some students had technical problems with the online spaces and could barely participate, nearly all students stated that the MOOC played an important role in deepening their knowledge and bridging existing gaps. In class, they could get a glimpse of the necessary topics and an idea of their personal deficits. At home they were able to work on these deficits with their own speed. Exercises that they did not understand in class because the speed of the lecture and the tutorial was too fast could easily be repeated at home. They could watch the videos that explained the topics discussed in the morning if they had not fully comprehended each step. If the exercises of the traditional course were too simple, students could pick more advanced tasks or search for continuative literature.

In the survey, ten students stated that just a MOOC would be enough to gain the mathematical knowledge during orientation. 14 students stated that there was no need at all for an additional MOOC. The remaining 113 participants in the survey stated that they would keep the subdivision into a traditional course and a MOOC, as was the case in this year's orientation.

In summary, both the students and I were satisfied with the way the additional MOOC worked. Despite technical problems, and the necessity for selection of the widgets to be better adjusted to the topics of the introductory course, a further MOOC will be held during orientation at the Bonn-Rhein-Sieg University of Applied Science.

For the structure of this year's MOOC, a university would need access to the ROLE platform. Once this is set up, the online spaces can be linked to the universities' own online platform. ROLE spaces are available for many different subject matters. For additional information, please contact the Frauenhofer Institute FIT. Examples of different spaces and a widget search engine can be found on the web page: www.role-project.eu

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