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Training of student teaching assistants and e-learning via math-bridge – Two projects at the German Centre for Higher Mathematics Education

Rolf Biehler[1], Axel Hoppenbrock[1], Juliane Klemm[1], Michael Liebendörfer[2] and Thomas Wassong[1]

[1]*Institut für Mathematik, Universität Paderborn and* [2]*Institut für Mathematik, Universität Kassel*

Abstract

We introduce the German Centre for Higher Mathematics Education and briefly explain its structure and aims. Then we present two research projects from our Centre: firstly we look at a training programme for student teaching assistants organizing small learning groups as support to large scale lectures. Secondly we refer to the math-bridge project providing e-learning material for mathematical bridging courses and student support centres including tools for assessing mathematical competence.

1. The Centre

The German Centre for Higher Mathematics Education (khdm, www.khdm.de) was founded in late 2010 and was funded after a successful application in a national competition for innovative projects in university education. It is established as a joint institution of the Universities of Kassel, Lüneburg and Paderborn.

The main objectives of the khdm are the development of a scientific foundation for research in higher mathematics education as well as the implementation of teaching innovations and their evaluation corresponding to scientific standards. A further aim is building a network for higher mathematics education both nationally and internationally. In our work, we (especially) focus on bridging courses before the first semester and on the first study year since problems show up very early throughout all programs that have mathematics as content.

On the one hand, our research concentrates on how to understand more deeply students' problems with university level mathematics. We include problems with understanding mathematical concepts, problems with proving and mathematical writing, deficiencies in learning strategies and problem solving strategies as well as with the specificities with the university mathematics culture that is much different from school mathematics. Moreover, we run some intervention projects, where we foster the use of learning strategies and working techniques and where we improve the small group teaching carried out by student teaching assistants, enabling them to give more individual advice and support. The curricula are enhanced by 'interface modules' where the relationships between the new university mathematics and the students' major subjects such as engineering, economy and mathematics teaching are explicitly drawn. We also develop tools for competency diagnostics, teaching evaluations and reusable e-learning modules for blended learning scenarios in bridging courses and in first year university courses.

The research and development projects are organized in four working groups (WGs) referring to different study subjects:

- WG 1: Mathematics for primary/secondary school teachers
- WG 2: Mathematics for bachelor and gymnasium (grammar school) teachers
- WG 3: Mathematics for economics

- WG 4: Mathematics for engineering

These make up the pillars of the Centre (see Figure 1) and are connected via Cross Working Groups (CWGs) dealing with overall issues:

- CWG 1: Methods in empirical teaching/learning research
- CWG 2: Didactical analysis of mathematical content
- CWG 3: Innovations in teaching/learning
- CWG 4: e-learning

The working groups are complemented by a team of associated scientists (e.g. educational psychologists) that support the centre in special research projects (e.g. CWGs). Management of the daily operations and a directorate for the more forward-looking decisions form the head of the centre.

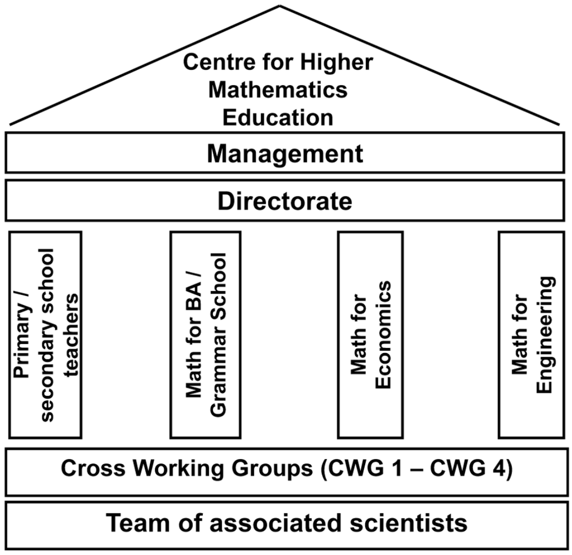

Figure 1: The structure of the centre

In the future, we plan to develop a web portal for information services and exchange of teaching resources and offer courses for professional development for university teachers in mathematics. Community building is also done through organizing annual conferences. The 2011 conference focussed on mathematical bridging courses.

2. A training programme for undergraduate teaching assistants in mathematics

Lectures in university mathematics are often attended by several hundred students. Individual support by the lecturer is impossible. Weekly tutorials given by undergraduate teaching assistants play a central role in directly supporting students' learning. In these tutorials homework assignments and students' questions concerning the lecture are discussed. Moreover, tutorials should offer opportunities for collaborative work in small groups. Teaching assistants are urged to support the learning process on a minimal basis, just intervening when absolutely necessary. Apart from their role as a teacher in the tutorials, teaching assistants are required to do additional tasks: correcting and even grading homework assignments or advising students on mathematical or personal questions.

Obviously, the competences and the beliefs of the teaching assistants have a great influence on the students' learning. Teaching assistants in Germany are usually successful students of mathematics at the end of their studies without further educational qualification or experience. They do not receive any training at all because programmes are seldom available. Some universities offer training programmes for teaching assistants from all faculties [9], [12], however, these do not fit the specific needs of mathematics' lectures. "It is interesting but not applicable for us" is often expressed by the assistants after such workshops. Little effect on teaching habits can be observed. As a result, specific training programmes for teaching assistants of mathematics have been developed in the last years [13]. Compared to the general programmes offered by the faculty of pedagogy, these mathematically orientated programmes focus on specific methods and exercises used in mathematical tutorials. However, most of these mathematical training programmes still focus a lot on the general topics of pedagogy, which often complicates the application of content to actual situations in tutorials. A different approach to training teaching assistants in mathematics can be found in [5]: there a programme is developed that concentrates on the tasks of the teaching assistants and uses simulations to practice typical situations.

Based on this idea, a training programme orientated on the specific needs of mathematical teaching assistants was developed by the Centre's LIMA project (Learning Innovations in Mathematics for pre-service teachers, http://www.lima-pb-ks.de/, [5], [6], [8]). In order to identify the needs of our teaching assistants, we developed a theoretical competence analysis and observed teaching assistants during their work in the tutorials. We analyzed the feedback on the students' homework assignments given by the teaching assistants. We were able to identify several areas of difficulty: the feedback provided in the tutorials and on the assignments was usually too general and did not apply to the specific difficulties of the students. Presentations of solutions to exercises often did not fit our expectations in form and content, or flaws in time and group management prevented an effective learning atmosphere. Based on these and further information, we defined our list of tasks a teaching assistant should be able to accomplish:

1. Pedagogically reflected content knowledge: Certainly, we expect teaching assistants to know the mathematical content and its representation in the lecture. Additionally, they must be informed about the didactical intentions of the lecturer and connect the content of the current lecture to the exercises given to the students.
2. Group management: Teaching assistants must create an atmosphere that facilitates learning. Therefore, they should be able to define and encourage rules for the tutorial, moderate discussions and implement social conventions of communication.
3. Presenting solutions: By presenting solutions to exercises, teaching assistants should discuss difficult parts of the solution and unfold the problem solving process. Additionally, the solution should be structured and presented in a manner that facilitates students' understanding.
4. Organizing collaborative group work: Apart from being able to introduce and end with collaborative group work, teaching assistants should function as moderators having a spectrum of intervention types at their disposal (content-related, strategic, etc.).
5. Commenting on students' assignments: Teaching assistants should not only be able to identify mistakes and alternative solutions, but also give constructive feedback which provides insight into the nature of mistakes and ways to overcome them.

Based on these tasks, we developed a specific training programme consisting of a pre-term workshop, in-term assistance & feedback as well as an evaluation meeting at the end of the term. The pre-term workshop lasts two full days for discussing and practicing the tasks described above. Special attention is paid to the specific conditions and requirements of the respective lecture. Exercises, which might become student assignments later in the term, are used as workshop material for practicing the presentation of the solution or the correction of homework. In this way, the participants see the direct connection of the workshop content to their actual work. Furthermore, the trainer gets a first insight into the mathematical knowledge of the teaching assistants and can discuss difficult topics in the workshop if necessary. On the whole, the pre-term workshop aims at unfolding the standards set for the teaching assistants and giving a first feedback on their strengths and weaknesses.

The LIMA training programme pays special focus to the in-term assistance. On the one hand, teaching assistants receive extra material, e.g. planning devices or solutions with didactical and mathematical comments, on the other hand, they get individual feedback. At least once a term, they are observed in their tutorial session by the trainer. The session is videotaped, in order to be able to view and discuss interesting scenes in the feedback session. Additionally, the teaching assistants visit each other in their tutorials and exchange experiences afterwards. Lastly, the teaching assistants meet with the trainer and lecturer every week to talk about the mathematical content and plan the next tutorial together.

After the first term we interviewed the teaching assistants who took part in our programme. We have adjusted and improved specific elements in response to their feedback and repeated the programme with teaching assistants from a different university. The response in further interviews was positive, especially complimenting the in-term assistance. However, teaching assistants were also thankful for the opportunity to better understand what is expected of them and how they can fit these expectations. Comments on the programme such as "it is interesting but not applicable for us" have not yet been recorded, probably due to the close linking of our training concept to the actual setting of their work.

3. Math-Bridge

3.1. The Project

When looking at existing bridging courses all over Europe you will find several problems: most of the projects are not networked either nationally or internationally, most of the content is not multilingual and interoperable, and in addition the content of most projects is not adaptable to the special needs of an individual learner. The project Math-Bridge (http://project.math-bridge.org) tries to give a solution for these problems. The targets of the project are supporting multilingual, European-wide usable content, enhancing the adaptive and adaptable system ActiveMath (http://www.activemath.org) for the special needs of bridging courses and presenting tested bridging course scenarios for the use of the content and the system. One product of the project is the system Math-Bridge, which includes all of the content and the features concerning the needs of bridging courses.

Math-Bridge is founded by the EU within the eContentPlus programme (ECP-2008-EDU-428046-Math-Bridge).

3.2. The Content

3.2.1. Structure of the Content

Several universities from all over Europe (Austria, Finland, France, Germany, Hungary, Spain and The Netherlands) are partners in the project. Most of them have experiences with bridging courses in their countries and also support content for bridging courses. These contents had to be integrated into ActiveMath. For this purpose, the content needs to be sliced into learning objects and annotated with different metadata. This is necessary for the system to choose the right content for the special needs of the individual learner. Moreover, course designers can pre-allocate contents for a course. Currently Math-Bridge provides 9713 learning objects, 1514 of them are examples and 4200 are exercises. This is the largest repository of mathematics related learning objects, at least European-wide.

The learning objects have to be annotated with two different types of metadata: structure metadata and pedagogical metadata.

The **structure metadata** defines the type of the learning object (axiom, definition, theorem, proof, example, exercise, text) and also the content related relationship between the learning objects: on one hand we defined an ontology of topics [1, pp. 22]. These are possible topics in bridging courses, based on the Core Taxonomy for Mathematical Sciences Education (http://people.uncw.edu/hermanr/mathtax/), the experiences of the project-partners and the SEFI-Curriculum [11]. Each learning object is linked to a topic in the ontology. On the other hand, the structure metadata define the connection between different learning objects concerning one topic. For instance, a proof is assigned to a theorem or an example/exercise is a assigned to a corresponding definition. Some learning objects need more information to be displayed in the right context. For instance, there are exercises that can only be solved by knowing a specific example. For these and similar dependencies between learning objects we introduced so-called 'complex learning objects' that combine several learning objects in a predefined order.

For the **pedagogical metadata** we defined a competency model for bridging courses with the following: *technical competency*, *mathematical problem solving competency*, *modelling competency* and *communication and reasoning competency*. [10, p 18]. Besides the competencies we also defined three achievement levels for each competency (reproduction, connection, reflection) [1, p. 19] and five levels of difficulty (very easy, easy, medium, difficult, very difficult) [1, p 20].

3.2.2. The Interactive Exercises

One important feature of Math-Bridge is the exercise system. Math-Bridge has a large number of more than 4200 exercises. The Math-Bridge exercise system has a comfortable functionality: The built-in exercise system supports multistep interactive exercises with an automatic evaluation of the students input, supported by a computer algebra system. Also included are non-interactive exercises with self-evaluation based on a sample solution. Math-Bridge also integrates several external exercise systems, for instance STACK (ttp://www.stack.bham.ac.uk/wiki/index.php/Main_Page) and domain reasoners like IDEAS (http://ideas.cs.uu.nl/www/).

The integration of different exercise systems increases the opportunities of pedagogical scenarios for the use of exercises, like assessment, diagnosis, learning and practicing with exercises.

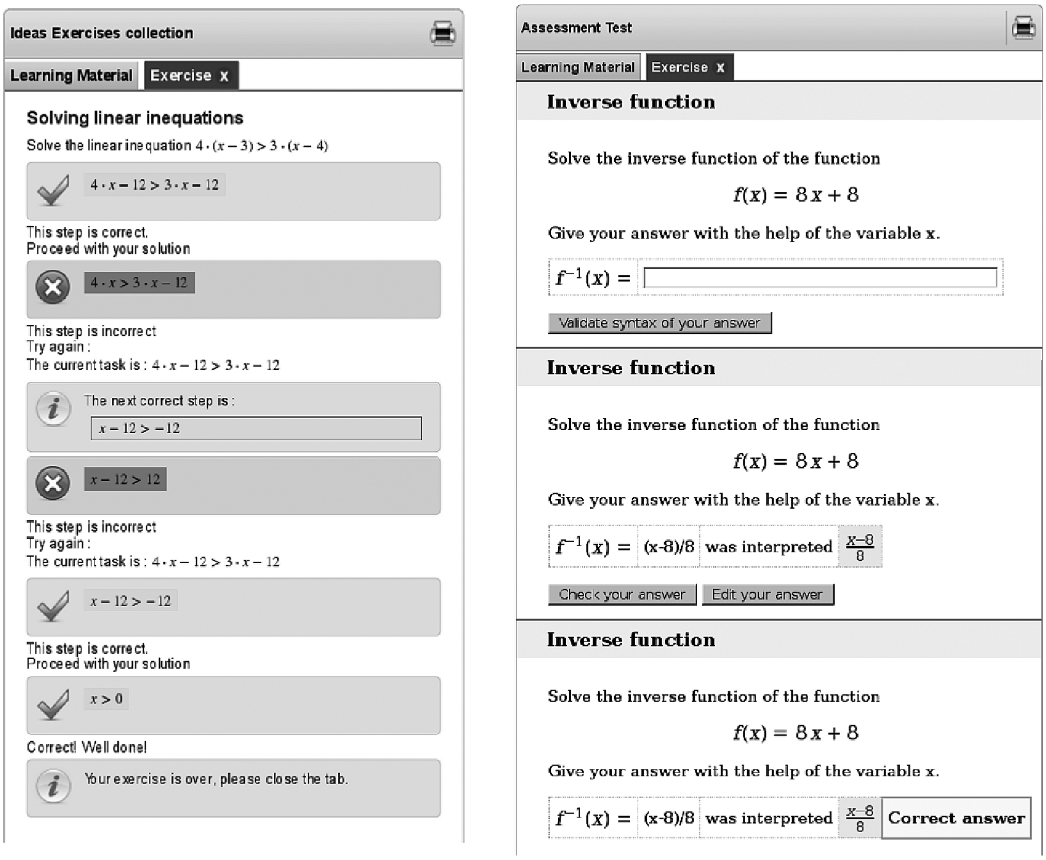

Figure 2: IDEAS exercise (left) and STACK exercise (right)

Another important aspect of the exercise system is the recording of degree of correctness of the learners' answers. The system uses the scoring to estimate the competency of the learner against the competency model of Math-Bridge [7].

3.2.3. The Remedial Scenarios

Math-Bridge provides the possibility to create automatic generated books that fit learners' individual needs. The system uses the learner's estimated competencies to select the adequate learning objects.

The learner first has to choose her/his type of book, the so-called remedial scenarios: *Improving your knowledge*, *Exploring new topics*, *Training a Competency*, *Taking an Exam* and *Using pre-structured Courses* [2, 3]. In a second step the learner has to choose the topic she/he wants to learn about.

The remedial scenarios are based on a scheme of orchestrating different learning objects. The system uses this abstract scheme to create the book and choose the learning objects, the exercises and examples based on estimated competencies.

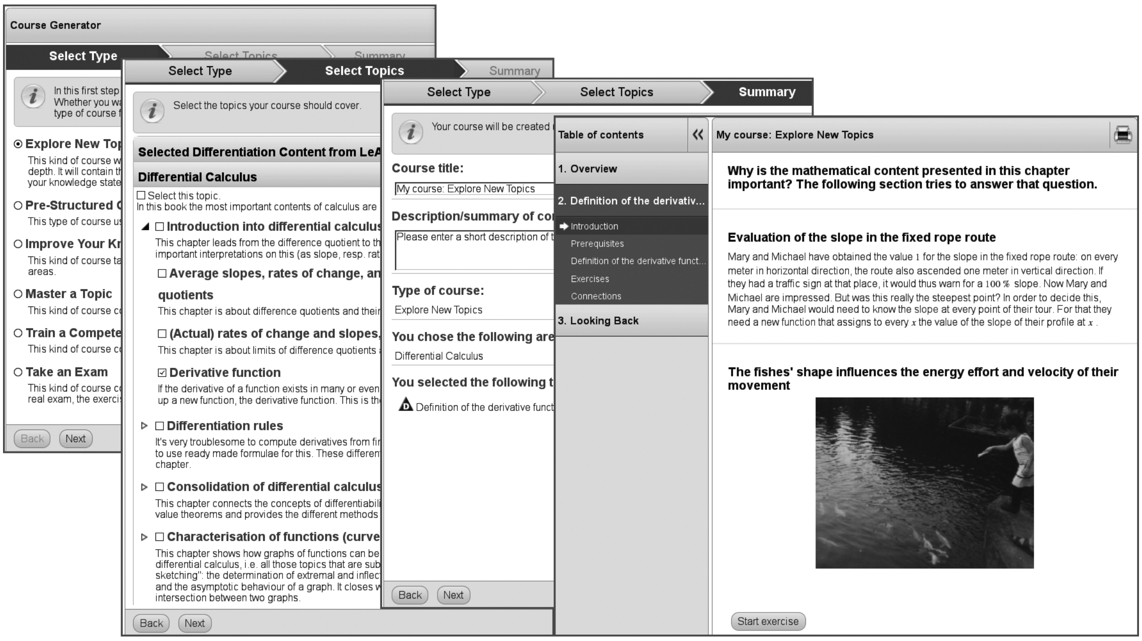

Figure 3: Steps to create an individual automatic generated book

3.3. The Use of the Content

3.3.1. The Composition of the Content

For the bridging courses in Kassel and Paderborn, where we used Math-Bridge in 2011 for the first time, we started with our content from the project VEMA [4] that we provided for Math-Bridge with one pre-recorded book for each topic. We analysed the content based on this from the other partners and enriched our content with several learning objects. In doing so we increased our number of interactive exercises and added some visualisations to increase our students' understanding of the topics. We added a large number of IDEAS-exercises in order to support the technical competencies of our learners..

3.3.2. The Use of the Content in the Lecture

During the bridging courses in Kassel and Paderborn we used the learning management system moodle as main platform to structure the content and to communicate with our learners. The moodle course for the bridging course provides opportunities for synchronous (chats) and asynchronous (mail, forum) communication, diagnostic tests for each topic, a link to the dialog for automatically generated books and links to the different pre-defined books.

The bridging courses consisted of three days of attendance a week and two days for individual learning. The days of attendance are structured with three hours of lecture in the morning and two hours of tutorials in the afternoon.

During the lecture the lecturer included at some points several learning objects, mainly (interactive) visualizations. For individual learning, the lecturer assigned tasks to the learners to structure their learning. Examples are tasks for individual learning of specific topics, the use of IDEAS-exercises for training in technical competencies and the use of the remedial scenario for specific purposes.

3.4. Evaluation

An important part of the use of Math-Bridge for the bridging courses in Kassel and Paderborn was an evaluation with more than 1900 learners. The evaluation contains pre and post tests to measure learning gains and pre and post questionnaires to measure the usability for learners and their attitudes towards mathematics. The analysis of the data is currently in progress and will be published in further publications.

4. Future perspectives

The training programme for student assistant teachers will be used and adapted for the courses accompanied by all other working groups of the centre. Moreover it will become the object of a research study where we will empirically observe and analyze the emerging competencies of our student tutors. Math-Bridge and our VEMA material will be extended and integrated for use not only in bridging courses but also in the first year study programmes for remedial purposes.

References

1. Biehler, R.; Hochmuth, R.; Fischer, P. & Wassong, Th. (2009): *Target Competencies*. ECP-2008-EDU-428046, Math-Bridge, European Remedial Content for Mathematics. Deliverable D-1.1. Accessed via http://mathbridge.math.uni-paderborn.de/publ.html (29 November 2011).

2. Biehler, R; Fischer, P.; Hochmuth, R. & Wassong, Th. (2010): *Pedagogical Remedial Scenarios*. ECP-2008-EDU-428046, Math-Bridge, European Remedial Content for Mathematics. Deliverable D-1.3. Accessed via http://mathbridge.math.uni-paderborn.de/publ.html (29 November 2011).

3. Biehler, R.; Hochmuth, R.; Fischer, P.; Jeuring, J. & Wassong, Th. (2010): How to support students learning in mathematical bridging courses using an ITS? Remedial scenarios in the European project Math-Bridge. *Student Mobility and ICT: World in Transition*. Accessed via http://www.cs.uu.nl/research/techreps/UU-CS-2010-023.html (29 November 2011).

4. Biehler, R.; Fischer, P.; Hochmuth, R. & Wassong, Th. (2011). Self-regulated learning and self-assessment in online mathematics bridging courses. In: Juan, A.A.; Huertas, M.A.; Trenholm, S. & Steegman, C. (eds.): *Teaching Mathematics Online: Emergent Technologies and Methodologies*. Hershey, PA: IGI Global. pp. 216-237.

5. Biehler, R., Hochmuth, R., Klemm, J., Schreiber, S., Hänze, M. (2012). Fachbezogene Qualifizierung von MathematiktutorInnen – Konzeption und erste Erfahrungen im LIMA-Projekt. In: *Hochschuldidaktik – Mathematik und Informatik. Symposiumsband zum Symposium „Verbesserung der Hochschullehre in Mathematik und Informatik"*. Submitted.

6. Biehler, R., Hochmuth, R., Klemm, J., Schreiber, S., Hänze, M. (2012). Tutorenschulung als Teil der Lehrinnovation in der Studieneingangsphase „Mathematik im Lehramtsstudium" (LIMA-Projekt). In: *Hochschuldidaktik – Mathematik und Informatik. Symposiumsband zum Symposium „Verbesserung der Hochschullehre in Mathematik und Informatik"*. Submitted.

7. Faulhaber, A. & Melis, E. (2008). *An Efficient Student Model Based on Student Performance and Metadata*. European Conference on Artificial Intelligence.

8. Klemm, J., Schreiber, S., Biehler, R., Hochmuth, R. (2011) Qualifizierung von MathematiktutorInnen im LIMA-Projekt. In: *Beiträge zum Mathematikunterricht 2011*.

9. Knauf, H. (2007): *Tutorenhandbuch: Einführung in die Tutorenarbeit.* 3. ed., Bielefeld.

10. Liese, R. (1994): Unterrichtspraktische Übungen für Übungsgruppenleiter in Mathematik. Ein Beitrag zur Verbesserung der Lehre durch Ausbildung und Training von Fachtutoren. Preprint Nr. 1674. TU Darmstadt.

11. Mustoe, L.; Lawson, D. (2002): *Mathematics for the European Engineer - A Curriculum for the Twenty-First Century*. Brussels

12. Reimpell, M. & Szczyrba, B. (2007): „Studierende als Dozierende - Kompetenzentwicklung durch ein Tutorenzertifizierungsprogramm." In Berendt, B., Voss, H.-P. & Wildt, J. (eds.): *Neues Handbuch Hochschullehre*. Berlin Stuttgart.

13. Siburg, K.F. & Hellermann, K: (2009). Mathematik lehren lernen – Hochschuldidaktische Schulungen für mathematische Übungsgruppenleiter. *DMV-Nachrichten*, Vol. 17: 174-176.