SELF-GUIDED AND CO-OPERATIVE LEARNING – scenarios and materials

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ABSTRACT

What can scenarios of self-guided and co-operative learning look like? How can knowledge be consolidated by means of intelligent practice? How can new media make the teaching and learning of mathematics more exciting? These are three main questions that the German pilot study 'SelMa - self-guided learning in mathematics in senior high schools' tries to answer.

Teachers of the pilot study have created different scenarios of self-guided learning. They describe the role of new media for mathematical exploration (e.g. CAS) as well as for presenting the topic to be learned (e.g. hypermedia). They focus on co-operative working and point out the teacher's role in each learning arrangement. Up to now suitable classroom material for some scenarios has been developed and systematically tested by other schools (evaluators) to determine if it is suitable for everyday use.

This paper presents the following learning arrangements and materials: a learning caroussel, an electronic learning environment for constructive learning and a jigsaw-puzzle. How learning diaries, mindmaps and communication via email and world wide web can support the individual learning processes will also be demonstrated. Results of first evaluations are included.

The current state of affairs is documented online (http://www.selma-mathe.de). This site (in German) offers a wide range of material that can be tried out and adapted to the teacher's individual needs. It is intended to be a platform for communication and co-operation between teachers working in the field of self-guided learning of mathematics as well.

Keywords: self-guided learning, learner-centred teaching , innovative pedagogical methods, changing role of tutors, learning environment, learning caroussel

1. A pilot study: organization, aims and evaluation

The four-year pilot project "**Se**lf guided **l**earning in **ma**thematics in senior high schools" -called **SelMa** started in early 1999. Its aim is to analyse the interdependencies and interactions between mathematics, learning in general and the use of new media.

Main questions focussing upon learning, mathematics and the use of media are

- Which mathematical topics are suitable for the idea of self-guided learning?
- How should classroom material be arranged and presented? In particular: online or offline?
- How should students and teachers be supported?
- How can the progress of learning be 'assessed'?
- How can new media improve the quality of learning (mathematics) and stimulate life-long learning?
- How can knowledge be consolidated by means of intelligent practice?
- How can telecommunication (platforms for collaborative learning or a "teacher-on-demand" via email) support the learning of mathematics?

A team of 3 to 4 teachers from 5 schools in North Rine-Westphalia, called '*authors*', began - addressing the issues mentioned above - to create scenarios of self-guided learning and develop suitable classroom material.

A second group of 10 schools, so called '*trial-schools*' were incorporated in the pilot study, when the first projects had been finished and successfully tested by the authors in their own classes. The trial-schools are to evaluate the material and to systematically test whether it works in everyday use. To analyse the materials and concepts from an educational point of view, suitable evaluation tools are created. Monitoring is done by academics and experts of mathematical departments of the universities. Furthermore, authors and evaluators are going to disseminate their practice in in-service-teacher-training, in order to build up networks of schools in the different regions. As the project takes place in an "open workshop" on the internet (www.selma-mathe.de) other schools can participate at an early stage. A wide range of materials that can be tested and adapted to the teacher's individual needs is offered. The aim of the 'SelMa-website' is to be a platform for information, communication and co-operation between teachers. Including *publishers* in our project leads to effect high-quality media (offline and online), for the work in the periods of self-guided and co-operative learning of mathematics.

2. At a glance: different scenarios and concepts

The first projects were based on rather different ideas of self-guided learning. The authors could not base their work on concrete concepts or learning arrangements because in German mathematics education there is still a severe lack of comprehensively documented research material so that ideas could be transferred to other fields within mathematics education.

In one scenario of self-guided learning, **electronic learning environments** are intensively used. Students use these environments in longer periods in mathematics lessons as well as at home. The material consists of a **hypertext** with exercises, contextual aid, a glossary, solutions and general ideas how to optimize individual and collaborative learning in school and at home. Another group of authors established an **independent learning centre** (for all subjects) at their school. Some parts of our mathematics curriculum have been set aside for self-guided learning, that means that these topics are not taught collectively in mathematics lessons but outside the framework of the school timetable. The students have to study them on their own without any support from the teacher. These learning environments consist of a course with a rather linear structure - with graded aid, suggested solutions and a collection of problems, in particular real-life problems of different categories. It provides opportunities for simulation and visualisation of mathematics. It acts as a tool in order to free the students from laborious calculations, which often distract from the actual problem.

Other authors tried to describe a scenario with a systematic change between instruction, self-guided learning by the **group-jigsaw-puzzle-method** (see Figure 3). In the initial phase, several groups work on different problems. They solve the problem, discuss and clarify anything that is still unclear. These 'experts' have to transfer the knowledge gained during a second phase when new groups with experts for different problems are formed. Schools that evaluated the material and this method stated that it worked well on topics that can be seen from different perspectives. Classes which worked on this method for the first time had problems in the beginning of their work because weaker students feared failing as teachers in the second part of the jigsaw-method.

Another means for increasing student activity and self-guided learning is the method of the **'learning carousel'**. Ten to twenty different stations (exercises, real-life problems depending on the subject) are offered to the students. Some stations deal with a special task, a new mathematical context, others invite students to exploration or investigation of mathematical problems using handheld computers. Each station offers special aids on how to approach the task and other hints suitable to the students' needs and a paper with a complete solution. All students receive a 'to-do-list', which informs them about all the stations (number; title; topic; obligatory or additional station; individual, pair or group work, media). Students can choose the order of tasks and might individually (or in groups) choose their learning pace.

These learning arrangements carry certain dangers. During periods of self-guided learning teachers automatically change their roles from acting as instructors to being supporters of individual learning processes. Usually teachers cannot exactly measure how much has been learned by the groups and the individual students. Students must be capable of monitoring their learning progress on their own, but this ability has to be acquired in a similar way as subject matter has to be learned. **Additional tools** like learning diaries, mindmaps and electronic communication tools might support this process of self-assessment (*see 3.3*).

3. Scenarios, material: use in the classroom and evaluation

3.1 Learning environments and evaluation of material

The pilot study 'SelMa' offers two examples of learning environments, '*linear programming/optimization*' and '*matrices*'. Educational research tells us that learning and understanding mathematical concepts and using problem solving strategies work better if there are various approaches with real-life problems of various levels accommodating different types of learners. So we drafted hypermedia-learning environments with some interactive parts concerning visualisation or intelligent practice. As different details, conclusions and relations between single mathematical topics (that are required to understand a mathematical topic) are presented in a linked-up, not a linear structure, the learners are facilitated to create their individual mental network of mathematical knowledge.

'Linear optimization': This learning environment has been created for the revision of concepts around linear functions. The students choose one out of a range of problems (on the basis of brief descriptions of the problems), which make up the 'heart' of the learning environment, and then they are guided through the important steps to solve a mathematical optimization problem. At the same

time they revise what they have learned about linear functions at lower secondary level. The learning unit links new contents and mathematical concepts with topics that the students acquired in previous mathematics lessons (and possibly have forgotten in the meantime). One part of this learning environment deals with the learning process and the monitoring by the students themselves. In the learning environment students find, e.g., advice for self-assessment and hints how to optimize group work and their study at home.[9]

'Matrices': In this learning environment students are offered several real-life problems related to the same mathematical topic of the subject 'matrices'. They choose one problem that they are interested in, then they are 'guided' through the problem (which is posed rather openly) not step by step but by more general questions concerning strategies of problem solving, by a glossary or by questions that prepare the formation of the mathematical theory behind the problem. New definitions and theorems etc. will be discussed in whole-class teaching. Students can see that different problems lead to the same mathematical concepts. They can easily built up the theory of matrices with a minimum of help from the teacher. Fundamental operations on matrices are found and correctly defined by using technology for exploration or as a black-box (Derive or handheld TI 89/92 or built-in java-applications).[7]

Both learning environments, intended for the use in the classroom and at home, offer details that support orientation and self-guided learning in hypermedia:

- survey of the subject to be learned
- table of contents
- glossary and review of the topic
- some recommended paths
- different modes of representation and visualization and interactions (as often as possible)
- some interesting historical facts of the subject and real-life applications
- exercises with contextual, graded help
- a chapter concerning learning strategies, problem solving and self-assessment of the learning process.

The material includes practical advice for the teacher, who becomes an *individual adviser* when students work with this learning environment. He acts as *moderator*, when the results of the group work are presented and general methods to solve problems are discussed by the whole-class.

The **results of first evaluations** show that it works very well if the teacher chooses some of the problems leading to the same mathematical topics. If the students are working on different problems, they will often not solve them because they lack parts of the theory that are required for the chosen task. Periods of self-guided learning do not have to be too long. Whole-class-teaching is necessary to deepen theory. As the material is based on HTML, some teachers modified some of the problems, added or reduced hints and solutions or integrated documents, links to websites and interactive visualizations.

3.2 Learning Carousel and its evaluation

The project "Geometry of Circles" consists of two parts. In the first part the students investigate the equation of a circle and then create - using CAS or a graphing calculator - a mathematical description of a logo, a window of a church, a pattern or a model of an existing object containing several circles. Here, students can see the importance of geometry in real life. The students work in groups of two or three and have to present their results on posters or WORD-documents to the rest of the class.

The second part of the project is based on the method 'learning carousel', often practised in elementary schools. It focuses on the development of new aspects of coordinate geometry and it consists of problems that connect the new geometric object 'circle' with other objects like parabola and lines (tangent, points of intersection, ...).

The problems are presented on worksheets and in files, first with the help of concrete exercises, then by generalizing the solution. Each station consists of the worksheet, some helpful questions and a complete solution. Some stations are more graphically oriented, e.g. including investigations of families of curves or a puzzle in which descriptions, graphs and equations of circles have to be matched.

The fact that small groups of students work on different tasks according to their suitable learning pace enhances individual learning. The complete learning carousel consists of 10 stations. The stations are accommodated to different background levels of learning, different speeds of learning, and different modes of working (individually or in groups of two or three)..

Different media are used at different stations, e.g. the CAS DERIVE or the TI-89 calculator. The tasks are usually activity-oriented. The students normally work in groups of two or three and decide together at which station to work next. At each station the materials lie on a table during the whole lesson. There are 3 or 4 copies of each station so that the students really have a choice of what to do next. During the work the teacher answers questions from each group. In our first evaluation we noticed that students only tentatively used the additional aid, which was put on a table further away from the exercises. First they tried to help each other, then they asked the teacher who had much more time to give individual advice than in traditional lessons. Collaborative work is highly supported by this method. The students did not look at the solution provided without trying to solve the problem on their own.

First **evaluations** show that:

- A convincing structure of the different tasks and items of the learning carousel seems to be very important for the organization and the success of learning.
- Students have to be introduced into this way of working and have to learn to get by in the time provided for this task.
- There must be a summary and/or a test after using the learning carousel.
- Work with more than 10 stations has to be interrupted by short periods of whole-class-teaching to summarize and to see if any support is necessary or not. Most of the teachers admitted that this method required more flexibility and presentation skills than teaching lessons that are more teacher-oriented.

3.3 Mindmaps, "learning logs" and communication tools and evaluations of their use

Many evaluators of the material state that, especially after long periods of self-guided learning, weaker students sometimes did not know whether they had learned all topics and understood all relations between new and old subjects. **Mindmaps** can support the review of the main steps of the learning process in different ways.

First, a mindmap containing only main topics can be completed individually after a period of self-guided learning. So the individual automatically reflects his or her own learning progress. New facts are linked to details of the 'old' individual network of knowledge. Different mindmaps - that means different points of view - can be presented and discussed in class.

Second, a mindmap of the subject matter can be constructed in whole-class teaching and can be used to summarize the topic with all items of the subjects, with definitions, examples and the relations between them, at the end of a learning unit.

Third, mindmaps can accompany the learning unit to show which aspects of a problem/topic have already been examined, what the next steps are and how many different aspects are still to be analysed. The mindmap is completed when the learning unit is finished. When all topics are numbered the mindmap visualizes the outcome of the course as as well its results.

We and the **evaluators** of the study often used electronic mindmapping tools like '*Mindmanager*'[1] or '*Inspiration'* [2] that offer various features e.g., structuring branches on different levels that can be moved to other positions, annotations and links to different documents and websites. Most of the students were rather acquainted with the method of mindmapping. They liked visualizing the topics and relationships between them in their notes. They added formulas, annotations and other documents by links. When asked why they liked this tool, they answered that they automatically discussed relationships in greater detail and became better aware of the structure and relationships between mathematical topics than before.

Learning logs are a means to encourage students to continuously reflect upon their learning progress. In an introductory session students of Year 11 were informed about the aims of this method and the prospective contents of their learning log. A learning log - only read by the student and the teacher - should contain all important facts of a lesson (steps towards a new topic, definitions, proofs, examples) and may include a personal review (What did I learn? What was difficult for me to understand? How can I memorize it?). The diaries were checked (annotated if there were mistakes) and assessed by the teacher every three months. The SelMa-website[6] presents 25 diaries in the following six fields of reflections: lessons, aha-effects, individual explanations, self-assessment, analyses of mistakes, and further issues. Most of the students who kept a diary with a lot of personal annotations stated that they felt better prepared for the tests in comparison with the beginning of the school year because they had paid more attention to their weaknesses (see: www.learn-line.nrw.de/angebote/selma/foyer/projekte/lerntagebuecher/index.htm)

We have also started to gather experience with **collaborative online tools** like **BSCW**[1] or **Web-CT** that are used in longer periods of self guided learning. Using these we hope to encourage encourage students to share information, to help each other and initiate discussions with experts.

All students had access to the internet at school, most of them at home, too. At the beginning of the first longer period of self-learning we invited students of Year 11 (40 students) to use a workspace in the internet. We prepared a forum with FAQs to post individual questions concerning the topics of the previous lessons. There, students got answers first from the 'teacher on demand', then later from other students as well. Weaker students could find intelligent practice, links to interactive online-tools and visualizations, brighter students sometimes (!) used worksheets with more demanding tasks and experiments e.g. with CAS instead of the given homework.

First evaluations produced different results:

- Groups without any experience with electronic communication (except personal emails) were not convinced of the benefit of this additional teaching aid. They did not like to pose questions in the forum and seldom used the offers for intelligent practice.
- Groups that were acquainted with communication tools used the forum more intensively. They annotated the applets and mathematical online-tools to inform the others whether they were helpful or not.
- The workspace that had been "prepared with different offers" *before* starting was accepted better and more intensively used than a rather waste workspace that had to be filled with FAQ.

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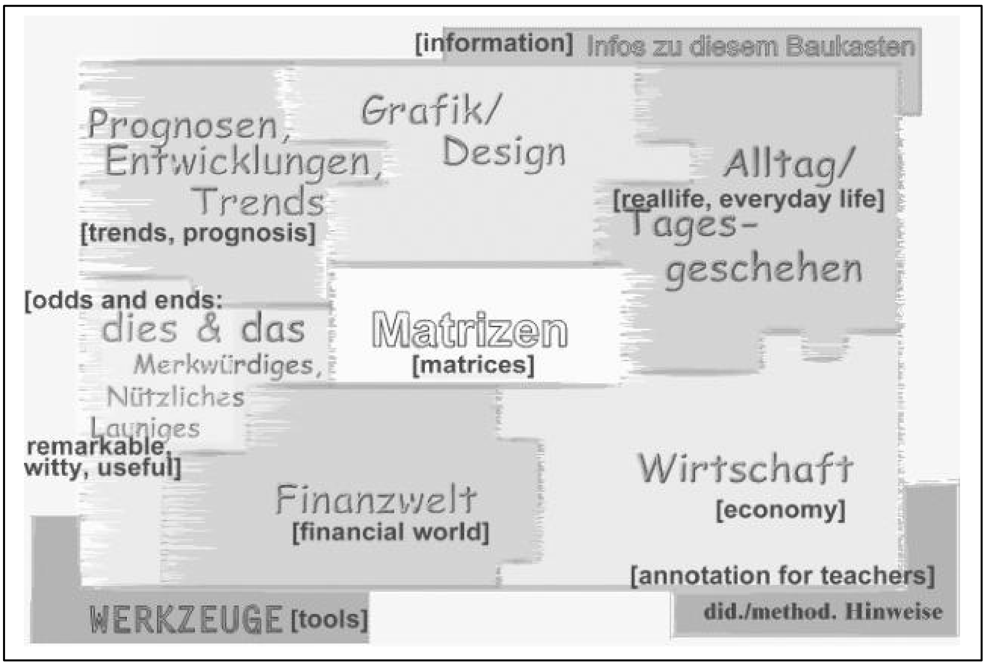

Fig.1: main page of the learning environment 'matrices'.

"To-Do-List" Circles

This is your own "To-Do-List". Please mark the station which you have accomplished, and note questions, which are still open.

Nr.	topic	important to know	how difficult?	o.k.?
1	finding equations of circles	revision	✓	
2	intersection line-circle		✓✓	
3	tangent line		✓✓	
4	points of intersection of 2 circles		✓✓	
5	does every equation fit to a circle?		✓	
6	famliy of circles	additional	✓✓✓	
7	puzzle of circles, equations and descriptions	revision/self-check	✓	
8	circles and lines	Nr.2	✓✓	
9	more complex exercise	last station?	✓✓-✓✓✓	
10	equation of a tangent line, that reminds of the position of the circle	Nr.2 before	✓✓✓	

Fig. 2: "To-Do-List" for the learning carousel about the subject 'circles'

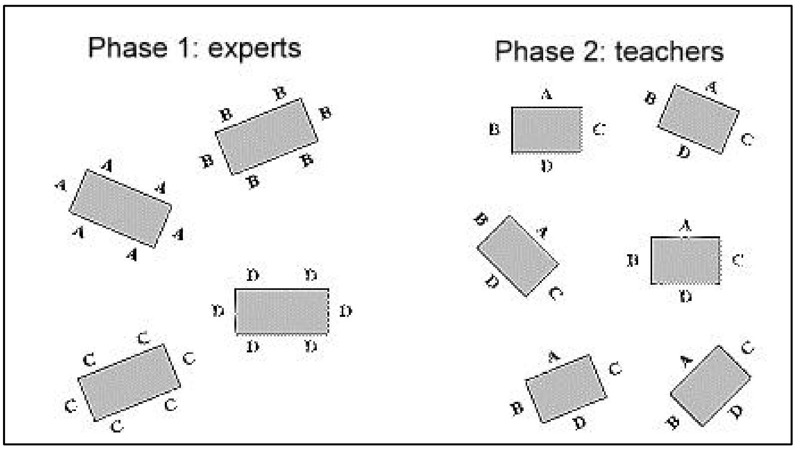

Fig. 3*:* organisation of a jiggsaw group puzzle

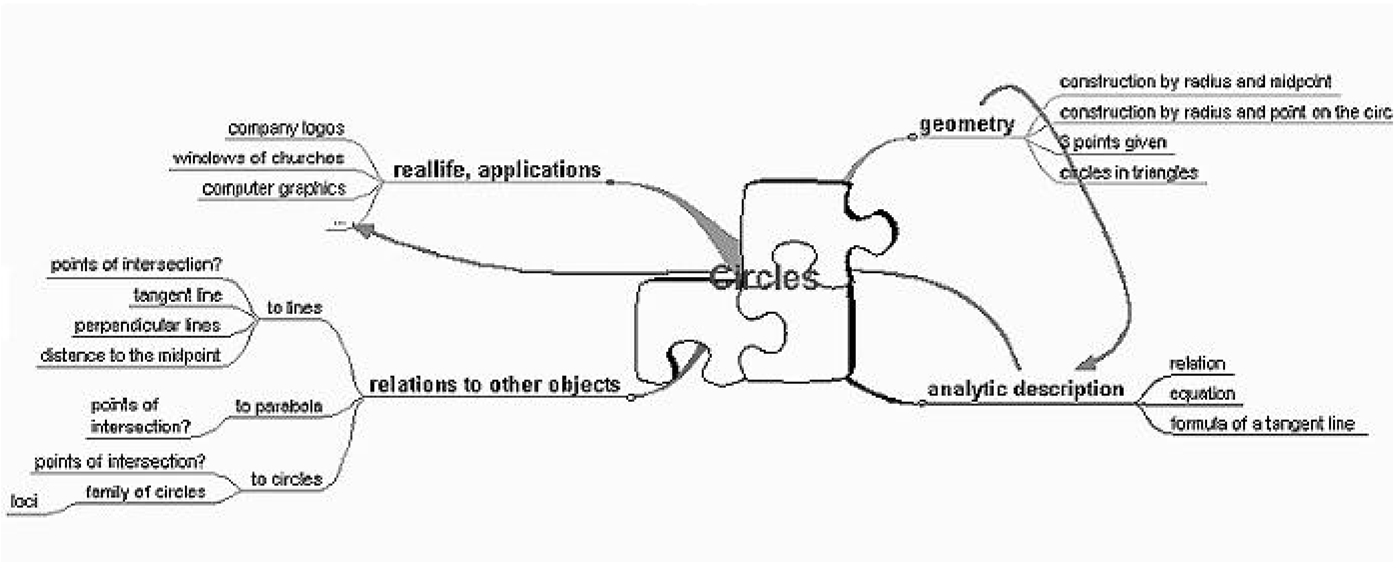

Fig.4*:* Mindmap of the learning subject "circles"
(translated in English, made with the help of the software 'Mindmanager'[5]).