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An Interdisciplinary Revolving Door Enrichment Model: Chances and Challenges of Involving pre-service Mathematics Teachers[1]

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The design of learning environments which encourage students to work in a creative manner on mathematical problems is a creative process in itself. The concept of the *Saturday University* program is described in which pre-service teachers are guided at teaching students in extra-curriculum activities on interdisciplinary topics. In the process of the didactical reconstruction of mathematical problems, the pre-service teachers go through the stages of a revolving door model *y*.

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WORKING WITH INTERESTED HIGH SCHOOL STUDENTS IN EXTRA-CURRICULUM ACTIVITIES

Extra-curriculum activities for interested high school students are often believed to be an uncomplicated task for teachers: No learning disabilities have to be considered, a lack of interest is said not to be expected from students who participate voluntarily, and a certain knowledge is assumed to be a reasonable foundation for problem solving and divergent thinking. While the challenges of differentiating classroom activities have been studied from various points of views (Winebrenner 1992), the mathematics education

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community has not payed that much attention to revolving door models (Renzulli, Reis & Smith 1981).

The classical revolving door model will not be explained here in detail; very roughly, it can be summarized as follows: the gifted students are selected to leave the regular classroom activities for some time in order to participate in other activities which they bring back later to their schools.

According to a review of Johnson & Ryser (1996) on research on gifted students in regular classrooms, six methods have been established as effective: the use of open-ended questions that require thinking on a higher level, the modelling of thinking strategies, accepting and expending on ideas and suggestions of students, facilitating original problems, guiding students towards an identification of rules, principles and relationships and, finally, enough time to explain how errors come up.

These methods are usually applied in an ordinary classroom situation where a teacher is confronted with one or a couple of gifted students within a group of students sharing several levels of ability and proficiency in mathematics. In an extra-curriculum activity, the situation is certainly different. Here, it is meant to fulfil the following criteria:

- The learners take part voluntarily without any immediate rewards.
- The activity is of mathematical character or related to mathematics, *e.* g., as an application.
- Students of different classes or even different schools join the group because of some interest in a specific topic. In particular, we do not focus on courses intensifying regular teaching and private tutoring.

It can be expected that in an extra-curriculum activity students with learning disabilities in mathematics are unlikely to find. If, however, a certain topic is used to promote the course, the level of proficiency can be quite diverse.

Looking at the numbers of participants in mathematical competitions, in Europe, the level of attendance from grade 5 to grade 12 is declining continuously. Some reasons for this might be of sociological origin. Gifted students are often interested in several areas and devote time in a lot of projects. Also, distractions from leisure industry, turbulences during puberty, jobbing, and intensive hobbies might contribute to this effect.

Therefore, it is not an easy task to find participants in regular extra-curriculum activities in mathematics in secondary education. Trainers often have to work hard to build up a group of students devoting their leisure time on mathematics.

Extra-curriculum activities offer interested students the opportunity to break out of everyday school life and make friends with peers sharing their interests. Young people of that age have to make a choice among the various offers given to them. A teacher building up a group of interested students, on the other hand, is confronted with a variety

of challenges:

- The students are demanding, curious and ask questions rigorously.
- There is the imminent threat that students might leave the group which, of course, competes with a wide range of offers.
- A rigorous mathematical background is necessary for the conception and for the realization of an extra-curriculum activity in mathematics. The importance of this point increases with the age of the participants.
- There is still a lack of learning material in mathematics worked out for interested high school students, leave alone an elaborate, systematic curriculum.

Given these difficulties, mathematical problem solving with questions of competition type play a major role in gifted education of adolescents. Certainly, the use of problem question of competition type has its merits; however, the concentration on these are a somewhat monotonic way of learning which addresses a special audience and tend to accommodate students to problems of that pattern, in particular with a clearly defined aim of what is to show (Halverscheid 2004). The concept and its realization are based on the assumption that gifted students need varying, challenging, but doable tasks (Roehr-Sendlmeier & Neitzke 1992).

ORGANIZING EXTRA-CURRICULUM ACTIVITIES

A teacher organizing extra-curriculum activities has to consider several aspects, such as characteristics of the students, the parents' wishes, and the requests of the colleagues. The pre-service teachers at the *Saturday University* program were closely involved in the planning and making contact with the schools in order to get some experience in respect to the organization of similar activities later in their profession.

The relationship to colleagues may change when one starts an extra-curriculum activity. Some colleagues consider themselves in a position in which they are forced to offer, often unpaid, extra-curriculum activities. More openly, the following requests are spoken out:

- The students are hoped to learn in addition to the curriculum rather than to anticipate parts of the curriculum. The latter would simply mean to find challenging tasks for the students today at the cost of seeing them unchallenged at a later time.
- The enrichment program should be demanding but not excessively in order to prevent the students from becoming underachievers in the regular school.

The idea of a revolving door model is in particular to create a new environment for gifted students with problems on which they can work off. This additional program is designed in such a way that it is easy to turn back to classroom activities and to add to the school lessons with these experiences. For the didactical choice of the topics this means in particular that anticipations of the classroom curriculum are to be avoided and that the regular courses are not devaluated in any other way either.

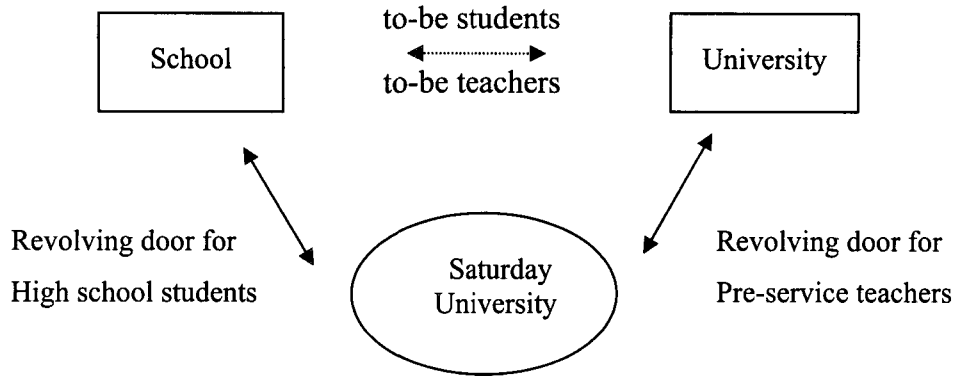
THE SATURDAY UNIVERSITY: A REVOLVING DOOR ENRICHMENT PROGRAM FOR STUDENTS AND PRE-SERVICE TEACHERS

As sketched above, the tasks for teachers to initiate an enrichment program for interested high school students are manifold and quite demanding. Many teachers, if never confronted with a teaching situation in front of a whole group of brilliant students, might never have the courage to get such a program started. The main idea of the *Saturday University* is to connect an enrichment program for high school students with a course for pre-service teachers. The structural opportunities of a university can be used extensively in this approach. In our particular program, interdisciplinary activities in joint projects with different faculties were initiated.

The aims of the program do not differ from those for regular classroom courses except for the fact that advertising was needed: No direct selection of the students was undertaken — mainly for the reason that it was difficult to find a significant number of students willing to turn up at the University on Saturday mornings. Therefore, the aims are described in the best way by some set out by the NCTM (1991), some of which with a certain impact on the education of the gifted are re-formulated here:

- The students should value mathematics, should learn to reason and to communicate mathematically, should become confident of their mathematical abilities and they should become mathematical problem solvers.
- The pre-service teachers who want to work with interested high school students should know, preferably experience themselves, how these learn mathematics, what the influence of the students' abilities is.

The *Saturday University* concept aims at a double revolving door effect: The revolving door for high school students is accompanied by a revolving door for pre-service teachers. It should be underlined that the pre-service teachers in the program were in their last year at the university. It is hoped that their experience with interested and gifted students and with the interdisciplinary learning environments is distributed among other pre-service teachers and future colleagues.



ESSENTIAL FEATURES OF THE SATURDAY UNIVERSITY CONCEPT

A *Saturday University* unit takes place at several Saturdays in a row on a certain topic[3]. The preparation for the pre-service teachers starts approximately half a year earlier with a reading course on the topic, a seminar on the work with interested and gifted students and with individual tutoring by university lecturers.

Each Saturday starts with a lecture explaining the main points of the topic. The lecture is held by a university lecturer, but is prepared jointly with the pre-service students who give courses in small groups (8 to 12 participants) of the participating high school students. The courses are prepared individually by the pre-service students on a certain aspect of the lecture. This forces them to think independently and to work out themselves an appropriate concept for the course. At the same time, the diversity of the courses makes it easier to appeal to the individual interests of the students.

The lecture at the beginning of the day is scheduled between 60 and 90 minutes, the courses by the pre-service teachers are scheduled between 75 and 120 minutes.

After that, all participants, pre-service teachers and lecturers reconvene in a general assembly in which topics of the day are discussed with a specialist. For this, researchers as well as alumni working in industry in the area kindly spent their Saturday morning with us.

THE CHOICE OF SUITABLE TOPICS

From the introductory remarks, the following criteria are derived from a topic being suitable for interested students in secondary education. The formulation of these reflects

[3] The choices of topics are dealt with in the next section.

the format of the *Saturday University* program.

- The topic allows a variety of mathematical problem solving activities.
- It follows the curriculum in that its contents are doable with the knowledge the participants built up at school.
- It does not anticipate (essential) parts of the school curriculum.
- The topic is not treated in books for high school students.
- It offers a broad range of possible further studies in mathematics but also in sciences and computer programming.
- For advertising purposes it should be in the focus of recent developments in science or society.

We developed the following topics for students of the 11th and 12th grades:

- Digital image compression: How are pictures for the internet recorded?
- Markov chains: Biological and economic models based on the repetition of probability experiments.
- Dynamical systems in the plane: The mathematics of billiard games.
- Monte Carlo methods: Gambling as a scientific strategy.
- Opinion polls: The planning and the carrying out of a professional poll in a project work.

THE SOCIAL FORMS OF LEARNING AND THE USE OF COMPUTERS

A variation of the social setting in which learning takes place has been considered important from the beginning of the project. An important social goal has been to give the participants the opportunity to meet other students of different high school of the region.

The use of computers was considered normal by all participants; however, the degree to which they wanted to work with these differed. Some high school student's preferred courses stressing rather a programming side of the topics whereas others chose problem solving with significantly less use of computers.

EVALUATION

During the courses, the number of participants varied. Most advertising was done for the parts on digital image compression (6 Saturdays at the Ruhr-Universität Bochum) and on Markov chains (3 Saturdays at the Dortmund University), where we had fifty

participants in each of the topics. In the first run, the number of participants dropped to thirty. Some participants mentioned that they did not manage to catch up with the course anymore once they had missed one Saturday.

The participants were asked to evaluate the sessions. Interestingly, the attitude towards mathematics changed positively even though the interdisciplinary aspect was stressed. Besides, it also might indicate that the assignment of pre-service teachers, who were accepted by the high school students as partners rather than authorities, contributes to it. To measure the learning progress from the courses designed and carried out by pre-service teachers is a difficult task and would have surpassed our forces. We asked the students to evaluate the change of their attitude on mathematics after the course on image compression:

Table 1. How the attitude towards mathematics developed

Very positively	20 %
Positively	54 %
It did not change	13 %
Negatively	13 %
Very negatively	0 %

In the image compression session, about 30 students said that they came to the course because of its impact on mathematics, 20 students said they were merely interested in sciences and 10 students liked it above all because they could get some impression of university life.

BY-PRODUCTS

Although slightly out of the main stream of this paper, some by-products of the concept should be mentioned briefly:

- Certainly, the universities (Ruhr-Universität Bochum and the Universität Dortmund) involved intended to do some advertising for studying mathematics, statistics or engineering, where the faculties involved in the realization of the concept.
- Between some high school students and pre-service teachers a tutee-tutor relationship developed in the course of the project. The high school students seemed to appreciate the combination of scientific, social, and educational skills.
- Interdisciplinary work is more than just an eye-catcher en vogue: many jobs in business and in research demand interdisciplinary abilities. Both in the area of

education of the gifted and in teacher education, interdisciplinary concepts are neglected. The development of interdisciplinary learning environments which might be appropriate also for ordinary high school courses is another by-product of the concept.

- Several high school students worked out expository papers on the subjects for which they had to learn basics of scientific writing — often with the help of the pre-service teachers after the official part of the course.
- The most rewarding by-product from the point of view of the university is the high intensity of communication between different groups: lectures learnt very directly from the pre-service teachers about their needs, their existent and missing abilities, and they had to design their lectures by taking various perspectives. The interdisciplinary approach made it necessary to work jointly and to discuss across the faculties. The contact to alumni and their involvement in the *Saturday University* initiated new activities, too.

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