LINKING PRE-SERVICE AND IN-SERVICE TEACHER TRAINING: CO-OPERATIVE DESIGN OF WORKING ENVIRONMENTS FOR PRIMARY MATHEMATICS

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Abstract. *We specify a concept of co-organising teacher training and school related research, which supports in-service teachers practising in primary school and asking for support to develop new ways of teaching with constructivistic orientation, which further gives teacher students a chance of praxis oriented investigative learning, and which attains research results by specifically organised teaching experiments. Teachers in primary schools need specific support particularly with regard to teaching geometry. The concept to develop working environments for geometry discussed here is based on a special co-operation between university and school, which is anchored as a special topic in the school program and is based on a specific concept of teacher training by the university. Geometry as a topic in the school program leads to a specific resource bundling model of training and development.*

[Within this framework among others the working environment "strip templates" was developed, an activity-oriented and discourse-oriented working environment concerning congruence and similarity for the primary grades.]

Design of working environments as a concept of teacher training – Co-operation of institutions and superposing of activities

We start with the option to develop working environments for active-discovery and social learning (Wittmann 1997): In demand are working environments related to geometry for the primary grades which give the pupils activity-oriented access to substantial geometric concepts. These activities are to be realised as manipulation options of suitable materials. These manipulable materials should model the basic concepts of the topic in an adequate way.

We follow the empirical findings that generally the constructing and discovering of language follows the constructing and discovering of action patterns related to material rather than precedes them. According to this, we require that out of the child's action experiences an issue-related language has to be developed.

We frequently observe in German classrooms that the competencies in literary language and partly also in verbal language are very different with respect to schools and pupils and are often not qualified to describe mathematical contexts. Mathematics as well as the language education has to contribute to the development of suitable communication. Activities on mathematical topics should not happen without documenting them in an appropriate way. This does not mean documenting the individual pupil's performance for the teacher but rather documentation which contributes to the communication among the pupils about the topics they worked on.

Only by this, different ways of working become exchangeable among the learners: *Variety demands correspondence.*

Therefore we postulate that from the outset the forms of documentation are developed simultaneous to the development of the working environments also. This means especially that the constructions, which are articulated by certain materials (paper, cardboard, pencil, computer, etc.) are accompanied by descriptions of the constructions. From the very beginning these documents are purpose-focused and addressee-specific: They have to elicit the individual way of construction to a partner in a similar working environment. Individual ways of working will only pass *"from the singular to the regular"*, *"from the I to the You and then to the We"* (Gallin & Ruf 1999) if they are communicable by applicative documents. In our geometric working environments the documents are mostly material-iconic texts generated by the pupils in form of posters showing sequences of working steps in a special way.

In geometry the procedures and symbols generally are not fixed as early as in arithmetic. If a classroom culture intends to lead from the individual procedures to procedures which are classroom standard, then geometry seems to be a suitable field for this.

The design and analysis of substantial working environments require forms of co-operation among persons and institutions which are not given a priori. Within the university a co-operation of teacher students and lecturers is profitable which integrates research, teaching an investigative learning and is essentially characterised by *design*, *empirical investigation* and *product oriented examinations* (Wittmann 1995, Hengartner 1999, Wollring 1999). However, even a broad and intensive co-operation within the university system remains imperfectly and single-edged without systematic co-operation with schools. It is in the school where a newly designed working environment has to pass the tests. In our project we found a way of co-operation which on the one hand is sufficiently flexible and on the other hand is sufficiently institutionalised. It yields an efficient concept of developing and teacher training and is characterised by the features *geometry in the school program* and *resource bundling co-operation*.

Geometry in the school program

The *laboratory for didactic of mathematics for the primary grades* at the university of Kassel managed by the author, started a long-ranging co-operation with the primary school "Grundschule am Jungfernkopf" in Kassel. Although usually names of schools and teachers are not mentioned explicitly in research cooperation and reports in this case the situation is different, as the special school and the university here cooperate like in a "joint venture".

This is formally anchored in the official school program in respect of the content. In the school program, the principal Mrs Becker, as a working partner of the author, notes the following in a section titled *"Revisiting geometry with children"* (status: may 2002):

"Innovations are also necessary in the field of mathematics which appears to be so clearly structured. The facts are familiar to us. We quickly agree on what and how much the children should learn.

We also know that active discovering learning bolsters, fosters self-determined learning and succeeds by insight and real understanding. Communication and exchange, trying, judging, deciding to accept or to refuse are standing at the beginning of children's learning in this concept and rules rather at the end. Challenge, problem posing and productiveness in the field of exercises are indispensable.

Within our domain of experience, however, we also need the chance to rediscover fields like *geometry* and also suitable methods and forms to organise working.

In *co-operation with the university of Kassel* we set out on a 'path of educational discovery'. This centres on the school practicals which for the past three years has been regularly conducted at our school by the department of mathematics under the direction of Prof. Wollring.

One or two classes together with their mathematics teachers benefit from this special opportunity at a time.

So the pupils experience special ways of learning for themselves and communicate them to others. On the spot, the teachers of our school get a directly realisable training in geometry and in addition the valuable chance to observe classroom interaction undisturbed.

Our medium term goal is that all teachers of our school will directly benefit from this form of in-service teacher training.

Within the scope of this concept the following working environments were put to the test in our school and made available for our use:

- From the geometry of paper folding: *folding of Sonobe cubes* and documenting the folding process by *folding posters*.
- From the geometry of paper folding: a course in axial symmetry by *creating folded starlets* consisting of two pieces symmetric to each other.
- From the geometry of congruence and similarity: Creating a picture story *"The Tangram Magician"*, testing an approach to create the pictures illustrating a story with given theme by various self-made types of Tangrams
- From spatial geometry: Creating bricks, cubes and buildings by the *"vertex-edge-clips-technique"* and documenting the constructions, including a exhibition in our school
- From congruence geometry: Project *"Strip templates"* to create tilings and mosaic pieces for mosaic pictures.

Both, the school and the university deliberately wish to continue this co-operation for the benefit of both partners."

The role of research in this cooperation

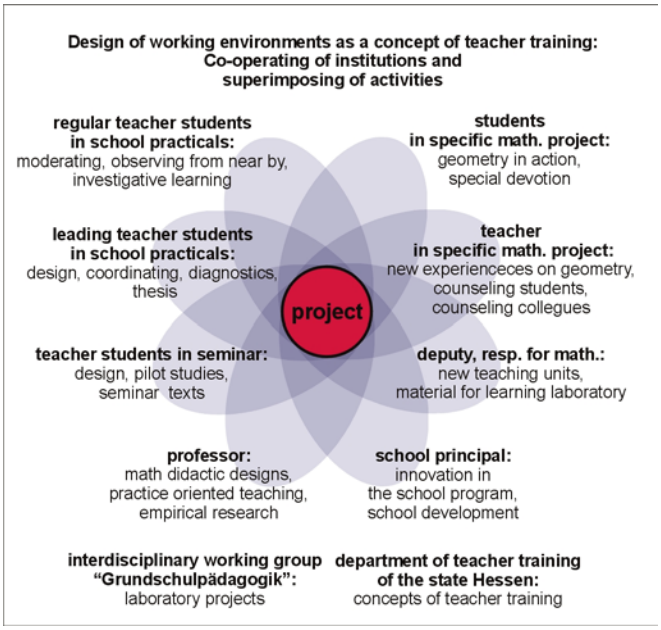
In most of his research projects the author investigates pupils activities and interactions in learning environments by qualitative empirical analysis. The goal is to describe and to predict pupils behaviour in new learning environments the teachers are not yet familiar with. The organisational concept with respect to the participants consists in including the student teachers as *semi-professionals* and as *co-researchers*. The data collected in form of observation recordings, video documents and *eigenproductions* are analysed in university laboratory by the author and the leading student teachers mentioned below. So the concept essentially includes an *extension of the laboratory* in combination with a special *multi-rage dissemination of the results*.

A concept of resource bundling co-operation for teacher training and school related research

An essential element of this co-operation is the co-ordinated organisation of different courses and lessons, whose participants contribute to the actual project and produce a concentrated effect. The core consists in a *product oriented form of school practice studies*.

In traditional math related school practicals, which are a common element in pre-service mathematics teacher training in Germany, the teacher students conduct a series of lessons in a mathematics classroom. Every student teacher conducts one lesson. In most cases teacher centred instruction ("chalk and talk") dominates. Legally, the teacher is fully responsible for the topic of the lessons and also responsible for the training and supervision of the student teachers. In general the student teachers do not receive a report but only a written acknowledgement for their participation. Such traditional approaches to school practicals may have weaknesses: If they do not have an analytic conceptual design, the student teachers are drawn into a "routine" which is not always desirable and which as a rule generates little innovation but rather "innovation resistant tradition". University lecturers often view these practicals as not efficient.

The traditional school practicals in mathematics are re-designed within our project as *school practice studies*. They constitute the interface in the co-operation of the school and the university and are redesigned to a developmental instrument for working environments. Thus they become very efficiently utilisable and the weaknesses mentioned above are widely removed.



A shared starting point for the school principal and the author as organisational partners is the position, that geometry teaching needs new impulses. According to the observation of the principal, geometry is usually taught in short time sections or skipped completely. However, there is a potential to motivate the teachers to revisit geometry by providing hands-on material and organisational support. Geometry in the primary grades, so the position of the author, is difficult to organise in a sensible way by teacher centred whole class instruction. Special working environments are required and thereto systematically attained experiences and empirical knowledge about how primary school children work on the geometric topics and problems in these working environments. Formal representations do not have the same status in early geometry as in early arithmetic, so there is a special focus on the development of a natural geometry related language which starts from "eigen-produced" (individually produced) notations and develops to standardised notations.

Starting from these positions the following organisation was conceived: School and university co-operate by *bringing together different participants and superimposing different types of activities: lectures, seminaries, school practice studies and school lessons*.

- The *principal of the school* creates a topic in the school program which fixes developmental objectives in respect to the mathematics classroom, ensures a long-ranging systematic co-operation with the university and gives her space for investigative and developmental work. In exchange the principal expects innovative possibilities for the teachers to gain experience with respect to geometry and effective developmental impulses for the school as a whole.
- An *authorised representative for the teaching of mathematics at this school*, in our case the deputy principal of the school, makes the contact to the teachers, in whose classes the special school practice studies related to geometry will

take place. She is the partner to be addressed in the school both for the student teachers engaged in the school practice studies and for single teacher students who deal with special analyses. She may introduce special demands for single colleagues or classes into the co-operation including the formulation of specific developmental tasks. She expects a successive building up of the learning laboratory in the school by new materials for geometric working environments.

- The *teacher* does not have to make preparations for the school practical. During the practical s/he is widely unburdened – if required s/he supports the student teachers with specific information and advice. Primarily, s/he gains new experience with respect to geometric working environments and may later pass them to other colleagues. The teacher is no longer in the role of a teacher-educator and thus, these school practicals rather have the character of special in-service teacher training (see school program). An important point of this agreement is that after the completion of the practical the complete material and logistic structure of the working environment remains in the school. Thus, for other colleagues a material fund is collected from which they can organise similar lessons.
- The *pupils* work in the working environments moderated by the student teachers in a situation which they notice as a specific one, characterised by different demands but also by different scopes for development and different personal devotion compared to the classroom routine. They are conscious that they are important partners not only in their material work but also in their critical feedback to the student teachers and to the lecturer.
- A *lecturer*, in this case the author, develops the design of geometric working environments together with student teachers in a special methods class until a status is reached where further development is not possible without empirical studies following Wittmann's (1995) approach of "didactics of mathematics as *design-science*". These are then realised in the special math related school practicals. In this way, the design of working environments, classroom related teacher education and empirical research are linked. This research is linked with the research of colleagues. With this project, the author participates in a larger research and developmental project of the *„Interdisciplinary Working Group Elementary Education"* at the University of Kassel. The goal of this project is the development of modules for learning laboratories in primary schools outside of university towns.
- *Teacher students in seminars on didactic of mathematics* prepare the development of a working environment and partly run first empirical tests related to it. This work is assessed and credited in the sense of a product oriented exam. Continuing this they may write the thesis for their masters degree on this topic. In this case they have to elaborate the design of a geometric working environment and related qualitative empirical research in detail. The data basis emerges by systematic observations in the school practice

studies, completed by clinical interviews with pupils single or in pairs. These student teachers are very early aware of the general orientation of their work and co-operate in pairs on this developmental task on a long-term basis in the sense of a product oriented exam. Our experience shows that high quality working environments require this effort.

- *Student teachers playing a leading role in the school practicals* have a special position which the lecturer can offer only to few of the students working on the design and the diagnostics related to a geometric working environment as part of their masters thesis. Two top students per semester get this chance. In shared responsibility with the lecturer they are personally responsible for the contents and the logistics of the current unit for the period of one semester. They pre-arrange the working program for the pupils and the regular teacher students (see below), they moderate central sections in the lessons and they document the eigenproductions of the pupils. Thus these school practice studies become a special *design-diagnostic-instrument* with greater potential than individual persons could raise. Leading students here get the task and the chance to use and to manage the school practice studies as a *temporarily arranged didactical laboratory* to reinforce their investigative potential.
- *Regular student teachers in the school practicals*, usually about eight persons, constitute the student working team guided by the leading students. As new working environments have to be tested and the co-operation of the children has to be observed intensively, pairs of regular student teachers care for stable groups of up to six pupils at "table islands". The role of the regular student teachers on the one hand is to moderate the work of the pupils in their group as attentively as possible and on the other hand to observe the work of this group by prepared guidelines intensively from a position very close to the children. Their elaborated observations are given to the leading students as empirical material. Instructions to the whole class are only given by the leading students and only on a small scale. The regular students do not address the class as a whole, this experience they may gain in different forms of school practicals. But they have the rare opportunity to observe pupils working on mathematics from a position close-by. So this way of moderating teams by the student teachers yields a form of work combining support of self-active learners and observing active children as in a clinical interview. Thus we intend to compensate the instructional orientation of many traditional forms of school practicals. So our school practicals are not designed to compete with but to complement other forms. The main working goal for the regular student teachers is *to gain diagnostic competence by investigative learning*, if possible before they are responsible to give instructions. Some of the regular students participated in the design of the working environments by their seminar assignment. The leading students always participated as regular students in previous school practice studies.

Thus, this combined concept of teacher training and product development consists of temporary bundling of as many resources as possible in one project, to design and evaluate a working environment and to achieve this by superposing different forms of activities. In doing so we intend that *all participants gain a personal benefit* from this co-operation: The school gains a substantial innovation. The teachers gain a specific training on the job and a field-tested logistic. The regular teacher students gain necessary credits in connection with a developing task related to practice, combined with an observational task. The leading teacher students gain experience in conducting a working group. Moreover they gain the substance for their masters thesis and material which they may later use in their classrooms. Finally, the lecturer fgains school related research results through which s/he participates in national and international exchange.

Concluding remarks

It is not always possible to bundle so many resources as described here to develop a working environment. In our experience though, the quality of the products and of the teacher training is definitely higher than it would be by investing less energy.

Our example affirms that substantial mathematical concepts and contexts from the field of geometry can be transferred into working environments which make them accessible by activities for primary school children. As mentioned before, one should aim at a balance between the "own ways" of activities and the communication on these individual ways among the learners in these environments. This general goal is valid far beyond the mathematics classroom. It refers to one of the main deficits of the present mathematics classroom and to the problem of how the learning of mathematics can be better linked to other fields and how to maintain or to improve its quality.

With regard to the concept of teacher training and material development, the working environment "strip templates" mentioned here plays the role of an exchangeable carrier of higher-ranking ideas. On a higher level, it is a matter of literacy with respect to mathematics and other fields. In connection with the PISA study a "more discursive" mathematics classroom is demanded. This especially applies to the mathematics classroom in the primary grades and is not a new insight but still current. Producing own strategies and own ways is not possible without the simultaneous constitution of an adequate subject-specific communication. To make this communication sustainable is one of the principal duties of classroom culture in primary schools.

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