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ENABLING TEACHERS FOR ANALYSING AND FOSTERING LEARNING PROCESSES OF SECOND LANGUAGE LEARNERS: Design of and research in a preservice teacher education course

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Mathematics teacher education must prepare prospective teachers for multilingual classrooms. For analysing and fostering learning processes aiming at conceptual understanding of students who learn mathematics in their second language, teachers need didactic and linguistic knowledge on typical resources, challenges and learning pathways, but also interpretative awareness, cultural sensitivity and self-confidence in their own capacities to analyse and foster the learning processes in mathematics classrooms. The paper presents the conception of an interdisciplinary teacher education course with its theoretical background, the design of the course and selected findings on its effects.
Key Words: Preservice Teacher Education - Language Diversity - Analysing Learning Processes

CONTEXT: NEED FOR NEW TEACHER EDUCATION COURSES IN GERMANY

German schools have only recently become aware of the increasing percentage of students whose home language is not the German language of instruction (currently 20%, in five years 30 %). Most of these students are immigrant students in the second or third generation with well developed basic communication skills in German, but restricted cognitive academic language proficiency (in the sense of Cummins, 1979). Large scale assessments show that the German school system has failed to support these second (or third) language learners adequately (Heinze et al., 2009). To a higher degree than in other countries with comparable economic and immigration situations, students' success in German mathematics classrooms depends on the language background and the socioeconomic background (OECD, 2007, p. 120; Burns & Shadoian-Gersing, 2010, p. 20).

As migration and the disadvantages of students with a non-German home language was politically disregarded for many years, German mathematics teachers (most of them being monolingual Germans) have only developed a restricted sensitiveness to the specific resources and challenges of second language learners so far. This has for example been testified by Hachfeld et al. (2010): When asked to predict the frequency of solutions in mathematical test items, German mathematics teachers hardly distinguish different language backgrounds although they have enormous effects on test results. But without the teachers' sensitiveness for specific resources and challenges of second language learners, disadvantages cannot be reduced and students cannot be sufficiently supported.

Starting with the assumption that *teacher education is the main field of activity* for changing these documented systematic disadvantages (Burns & Shadoian-Gersing, 2010; Chitera, 2011), we explore how the topic can be embedded in the university teacher education of middle school teachers. For this, we developed the course "Analysing and Fostering Mathematics Learning Processes of Second Language Learners" in an interdisciplinary cooperation between the faculties of second language education and mathematics education (Prediger, Tschierschky, Wessel, & Seipp, 2012).[1]

The paper reports on the content, design and effects of the course and intends to contribute to the theoretical discussion on teacher education for multilingual classrooms.

CONTENT: RELEVANT ATTITUDES, KNOWLEDGE AND COMPETENCE FOR TEACHING SECOND LANGUAGE LEARNERS

Attitudes. A lot has been written about important *intercultural attitudes* of teachers, especially on the necessary openness to use multiple languages in classrooms in general (e.g. Chitera, 2011). Although these attitudes are essential conditions for understanding and fostering the mathematics learning of second language learners, they are not sufficient on their own. In our course concept, we also focus on teachers' *knowledge* on mathematics learning in a second language (Muzaffar, Halai, & Awan, 2011), teachers' *diagnostic competence* (Prediger, 2010; Thompson & Kersaint, 2011) and teachers' *repertoire of instructional practices* for fostering the learning (Secada et al., 2011).

Knowledge. For accompanying second language learners on their learning pathway to develop conceptual understanding, teachers' necessary *professional knowledge* refers to four areas and their mutual interplay in particular:

- typical *linguistic challenges and resources* of second language learners in mathematics classrooms
- *instructional strategies* to foster the acquisition of language that is relevant for mathematics classrooms
- *typical mathematical challenges and resources* that are connected to the specific language resources of second language learners
- *instructional strategies* to foster especially the conceptual understanding of second language learners in mathematics.

[1] The development of and research on the teacher education course is conducted within the larger project dortMINT (2009-2012). The project is funded by the foundation "Deutsche Telekom Stiftung" and investigates ways for enabling preservice teachers for analysing and supporting learning processes in different subjects and areas. Erkan Özdil and Susanne Prediger lead this part of the project, Lena Wessel and Kristine Tschierschky have given the courses, and Bettina Seipp has conducted the quantitative evaluation.

Knowledge and Attitudes. This knowledge is a prerequisite for a flexible repertoire of instructional practices, but must be accompanied by prospective teachers' *self-confidence* that they are able to apply their knowledge and capacities. For this reason, we decided to concentrate the monitoring of attitudes on this specific point: the self concept on knowledge and competences.

Competence. For enabling prospective teachers to analyse the mathematics learning processes of second language learners, it is crucial to develop their sensitiveness in terms of *diagnostic competence*. Diagnostic competence was conceptualized by Prediger (2010) as being composed of

(1) an interest in student thinking without a deficit-oriented perspective;
(2) an interpretative attitude of understanding students from an inner perspective;
(3) general theoretical knowledge on resources, obstacles and learning pathways;
(4) domain-specific (here mathematical and linguistic) pedagogical content knowledge with a focus on conceptual understanding.

Knowledge and Competence. Whereas the first three points apply to mathematics learning situations with all learners, the forth point requires specific knowledge about mathematics learning in a second language. Besides some general knowledge on language acquisition and for example the difference between BICS and CALP (Cummins 1979), we especially focus on those linguistic aspects that impact the construction of mental objects needed to construct meaning for mathematical concepts (Freudenthal 1983).

DESIGN OF THE COURSE

Participants, time and design principles

The course "Analysing and Fostering Mathematics Learning Processes of Second Language Learners" encompasses 6 ECTS (i.e., 180 h workload in a 13 x 180 min course plus empirical investigations in schools and individual work for reading, documentation etc.). It is designed for prospective mathematics middle school teachers in their second or third year of university education.

Whereas knowledge alone could simply be developed in theoretical courses on pedagogical content knowledge, the development of diagnostic competencies, instructional practices, self-confidence and supportive intercultural attitudes requires practical experiences and their systematic reflection (similar to inservice courses by Secada et al., 2011). As Breen (2003) has carefully shown, these experiences should follow the *principle of action and reflection*.

In order to sensitize for linguistic aspects in mathematics learning (Burns & Shadoian-Gersing, 2010), we followed the *principle of integrating mathematical and linguistic aspects* in the pedagogical content knowledge.

Design experiment as integrating core of the course

For implementing these two principles, all prospective teachers in our course conduct a *design experiment* with a pair of pupils (of 10-12 years) that is based on the mathematics- and language-integrated instructional strategy of relating registers (Prediger & Wessel, 2011). In a think-pair-share-setting, the pupils are given a linguistically challenging text on hit rates in a soccer kick competition. The pupils are asked to compare the hit rates of four groups that were represented in the text by different expressions: “7 goals among 10 kicks”, “50 %”, “4 of 6 kicks”, and “every forth kick was a goal”. One possible solution is to mathematize all expressions by fractions and order them. For this, some pupils translate the information given in different verbal representations into symbolic representations and use the symbolic technique of ordering fractions. Other pupils draw graphical representations or find alternative mathematizations.

In a second step, the pupils are asked to draw the hit rates in fraction stripes, i.e. to translate from verbal or symbolic to a graphical representation (see Fig. 1) and to decide on the best hit rate in the graphical representation.

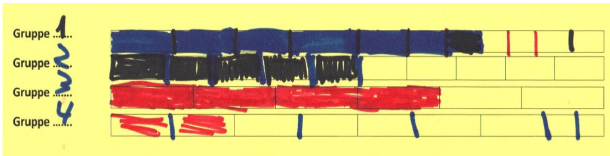

Fig. 1: *Representing hit rates graphically*

Within these design experiments, prospective teachers can observe typical phenomena:

- Some pupils interpret the different expressions as different structures which do not all refer to rates or fractions, for example, “every forth kick” is often interpreted alternatively (frequent interpretation: every forth kick = 4 out of 4 kicks are a goal).
- Pupils offer a creative diversity of alternative mathematizations like considering only the number of goals (absolute frequency) or the difference between kicks and goals. This diversity provokes mathematically rich discussions among the pupils.
- Many second language learners are challenged by expressing their ideas in German and make use of drawings or their home language in order to support their speech. Linguistic restrictions sometimes imply difficulties in constructing necessary mathematical relations, like for ordering fractions (Prediger & Wessel, 2011).
- The order relation we consider to be inherent in the stripe representation in Fig. 1 (a fraction is smaller if its stripe is shorter) is not at all the only interpretation of the graphical representations. Instead, pupils extensively negotiate how to read the fraction stripes. These negotiations are an excellent opportunity for language learning.

- The graphical representation of the situation in the fraction stripe helps to develop a language for discussing the different mathematizations ("Look at this, this is longer", "You count the fields and I look how long the stripes are.")

In the teacher education course, prospective teachers analyse the videotaped and transcribed scenes of the design experiments and reconstruct the pupils' resources and obstacles to express their ideas and to develop their conceptions on the meanings of verbally, graphically or symbolically given representations. During these activities, the prospective teachers learn how deeply the linguistic and mathematical aspects of learning are connected in conceptually challenging learning situations.

For deepening this analysis, the prospective teachers receive different theoretical inputs and opportunities to apply them to their own cases (see Prediger et al. 2012, for details). At the end of the course, the prospective teachers plan different instructional strategies to foster the pupils' learning on fractions and on the language of rates and fractions.

SELECTED FINDINGS ON EFFECTS OF THE COURSE

The effects of the course have been evaluated in three different dimensions:

1. How does the diagnostic competence of prospective teachers develop?
2. How does the knowledge of prospective teachers grow (compared to control group)?
3. How do the self concepts of prospective teachers grow (compared to control group)?

The development of diagnostic competence was investigated qualitatively within the intervention group. The growth of knowledge and self-concept (question 2 and 3) was measured in a quasi-experimental pre-post-test-design with a control group and intervention group by a questionnaire with different instruments (for n=88). The control group also participated in a language education and a mathematics education course, but not in an integrated course like the intervention group.

Finding 1: Deepened diagnostic competence

Methods. For investigating the diagnostic competence of the prospective teachers in the intervention group, the participants received a rich diagnostic task at the beginning and the end of the course in which a document of two pupils had to be analysed. 2 x 14 prospective teachers' texts on the pupils' document were analysed with respect to the components (1)-(4) above. Whereas developments of components (1)-(3) could be expected according to earlier similar projects (Prediger 2010), most crucial was component (4): How could the prospective teachers widen their repertoire of mathematical and linguistic categories for analysing pupils' utterances?

Results. As shown in the detailed analysis (in Prediger et al., 2012), 13 of 14 prospective teachers widened their repertoire of didactic categories for analysing pupils' utterances. Those who gave only rather global evaluations in the pre-test ("student has general reading difficulties and should get help in reading"), learned to apply differentiated categories in the post-test, for example reconstructing specific mental models for fractions, problematizing the change of representations, stating specific differences between BICS and CALP, etc. This finding is promising since the wider repertoire of categories reflects the theoretical input of the course as well as the prospective teachers' experience in the design experiment for which the interplay of linguistic and mathematical aspects is crucial.

Finding 2: Significant growth of knowledge

Methods. With open questions in the questionnaire, 88 participants of the intervention and the control group were asked to describe typical difficulties that pupils generally meet in dealing with fractions (mathematical challenges), typical linguistic difficulties of second language learners in mathematics classrooms (linguistic challenges) and to explain instructional strategies for fostering their linguistic resources (language learning) and the development of mathematical insights (mathematics learning).

The quality of answers was operationalized by comprehensiveness, relevance and conciseness of the analysed texts. As these criteria partly reflected individual writing styles, not knowledge, we only coded individual change of quality by comparing pre and post test answers of each individual prospective teacher. The codes were: 1 (weaker), 2 (equally good), 3 (better or equally good on a high level in the pretest).

The coding procedure reached a high interrater reliability with Cohen's Kappa = .74. The coding procedure puts the data on an ordinal scale of measurement, hence it was treated by a non-parametric Kruskal-Wallis one-way analysis of variance by ranks to account for significant differences between the groups.

Results. As Table 1 shows, significant differences in the change of knowledge could be found for three out of four aspects. Only instructional strategies for enhancing mathematical understanding were learned equally well in the control group (who took part in other, non-integrated language and mathematics education courses).

Table 1. Significance of differences between intervention and control group (n=77) in the change of quality of the open items about knowledge…

… on mathematical challenges	$H= 8.99$, $p = .011$
… on linguistic challenges	$H= 6.16$, $p = .046$
… on instructional strategies for language learning	$H= 15.25$, $p \leq .0001$
… on instructional strategies for mathematics learning	$H= 1.37$, n.s.

Finding 3: Significant growth of self concepts

Methods. The development of individual self concepts on knowledge and competences to analyse and foster students in mathematical and linguistic issues was assessed on a 4-point Likert scale with three subscales, two of them addressing isolated aspects, the third adressing the integration between linguistic and mathematics aspects (see first column of Table 2 for exemplary items). An analysis of variance (ANOVA) with repeated measures was conducted.

Results. As shown in Fig. 2, the intervention group had the highest effect sizes on all subscales and significant growth on all subscales. Also the control group (who visited isolated language education and mathematics education courses) reached comparable growth on the isolated subscales. In contrast, the growth of self confidence on integrated mathematical and linguistic aspects was minimal for the control group and significantly higher for the intervention group.

We conclude that it is not sufficient to learn about language learning and mathematics learning in isolated courses. Instead, the integration is needed to be addressed within the course; otherwise, the prospective teachers do not feel confident enough to apply their linguistic knowledge to mathematics classrooms.

Table 2. Self concepts on knowledge and competence to analyse and foster students learning growth from pre test to post test. (1=low, 4=high).

Subscale (exemplary item)	Reliability of subscale (Cronbach's α)	Effect size of growth pre-post in intervention group	Significance of group differences
Subscale Mathematics Learning (e.g. "I can evaluate teaching materials re their didactic quality.")	α= .75	+ 0.57 (medium)	$F_{(group)} = 2.53$, n.s. $F_{(time)} = 11.39$, $p \leq .001$ $F_{(group\ x\ time)} = 1.98$, n.s.
Subscale Language Learning (e.g. "I know how to assess the linguistic resources of second language learners.")	α= .70	+ 0.99 (high)	$F_{(group)} = 3.57$, n.s. $F_{(time)} = 40.52$, $p \leq .001$ $F_{(group\ x\ time)} = 3.09$, n.s.
Subscale Integration of Linguistic and Mathematical Aspects (e.g. "I know instructional strategies for fostering language learning in math classrooms.")	α= .78	+ 1.64 (very high)	$F_{(group)} = 7.50$, $p = .001$ $F_{(time)} = 81.01$, $p \leq .0001$ $F_{(group\ x\ time)} = 9.06$, $p \leq .0001$

CONCLUSION

Although the evaluation was only restricted to n=14 and n=88, resp., and therefore cannot be generalized to all prospective teachers, the findings justify the hypothesis that the designed teacher education course could enhance prospective teachers' diagnostic competence, knowledge and self-confidence in these competencies with a considerable effect size.

We conclude that it seems to be possible to change the teachers' prerequisites to work in multilingual classes with a quite restricted amount of learning time (6 ECTS). The comparison to the control group shows that the integration of all relevant aspects must be an important part of the work because prospective teachers cannot be expected to integrate isolated learning contents on their own.

Therefore, we must also enhance the research that integrates linguistic and mathematical didactical aspects in order to increase our knowledge about the best strategies for analysing and fostering mathematics learning of second language learners (Prediger & Wessel, 2011).

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