IS GRADE 7 TOO LATE TO START WITH BILINGUAL MATHEMATICS COURSES? AN INTERVENTION STUDY

Lena Wessel, Susanne Prediger, Alexander Schüler-Meyer, & Taha Kuzu

TU Dortmund, Germany

Bilingual mathematics courses have proven to be beneficial for multilingual learners because activating home languages can facilitate the access to mathematics, especially in the early years of schooling. But does this argument also apply to older multilingual students who have not received an opportunity to develop their home languages in the academic and mathematical technical register? Or do language barriers in these registers hinder the mathematical learning process? The presented intervention study explores the realizability of bilingual mathematics courses in Grade 7, for German-Turkish speaking immigrant students in German schools without prior formal mathematics education in their Turkish home language. The randomized control trial shows that even in the short time (5 x 90min.), students can equally profit from bilingual learning opportunities as from monolingual German learning opportunities, although some time and effort is required for overcoming initial barriers in the home language.

BACKGROUND AND RESEARCH QUESTIONS

Building upon the home languages of multilingual learners has been promoted as a beneficial way for facilitating the access to subject matter learning (Barwell, 2009 for mathematics). Even if the meta-analysis of Reljić, Ferring, and Martin (2015) reports only few randomized control trials that provide empirical evidence for the increase of mathematical competences in bilingual courses, several qualitative case studies show a higher intensity of mathematical learning processes when home languages are activated (cf. Barwell, 2009 for many examples). Hence, the Council of Europe (Beacco et al., 2010) has pleaded for including students' home languages in subject matter courses. However, most European school systems are still reluctant to open their mainly monolingual classrooms for home languages (Gogolin, 2011; Meyer, Prediger, César, & Norén, 2016).

This also applies to German schools, in which the rate of multilingual learners has grown rapidly (to over 25 % percent in a few years) due to immigration and demographic changes. Although an increasing awareness for language diversity results in enhancing *second* language learning in the academic and technical register (cf. Prediger, Clarkson, & Bose, 2016), limited efforts have been developed for including home languages in German math classrooms. We focus on the most frequent of those home languages, Turkish, and investigate a Turkish-German bilingual course.

An often mentioned obstacle for including the home language Turkish is that Turkish-German students (mostly born and schooled in Germany) often develop only their Turkish *everyday* register, but have limited access to the Turkish *academic* and *mathematical-technical* register due to limited formal language learning opportunities in Turkish (cf. Beacco et al., 2010; Prediger et al., 2016, for the three registers). As a result, bilingual mathematics courses in secondary schools need to also invest time into teaching the academic and technical register. Since most bilingual school trials have started in primary schools (cf. Reljić et al., 2015), it is an open question whether bilingual math courses can also be started in Grade 7 with an additional need of learning Turkish in the academic and technical register, depending on students' Turkish language proficiency:

Q1. Is there a benefit for Turkish-German-speaking seventh graders without formal education in the Turkish academic and technical register participating in a bilingual mathematics course, compared to participating in a monolingual German mathematics course?

Q2. To what extent does the benefit depend on the students' Turkish language proficiency?

DESIGN OF THE BILINGUAL INTERVENTION

Two forms of intervention

The German *monolingual intervention* for fostering conceptual understanding of fractions was developed and positively evaluated by Prediger & Wessel (2013). It is based on design principles of macro-scaffolding and relating registers, i.e. connecting graphical, symbolic and verbal registers (everyday, academic school, and technical register, cf. Prediger et al. 2016, cf. Wessel, 2015).

The *bilingual intervention* included the same program, and additionally three Turkish registers: working with students' everyday resources and extending their academic register and technical register in Turkish with the help of the bilingual teacher and bilingual teaching material (developed by Kuzu, 2014). Sometimes, students were obliged to speak and write Turkish and sometimes German, but mostly, they were free to code switch or speak in the language of choice.

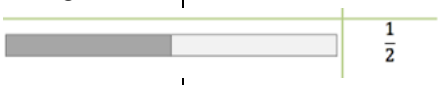
Design principles for the bilingual intervention

Culturally sensitive contexts for activating Turkish language and everyday resources. Activating students' multilingual out-of-school resources does not only require the language, but also a culturally sensitive way of mobilizing students' everyday experiences. It has been shown that culturally sensitive everyday contexts which refer to students' everyday experiences enable the students (1) to activate their first language cultural background, (2) to discuss mathematical ideas, and (3) to solve problems cooperatively (Moschkovich, 2015). In our bilingual intervention, we referred for example to the traditional Turkish narrative Nasrettin Hoca, baklava pieces, or leblebi as particular Turkish contexts.

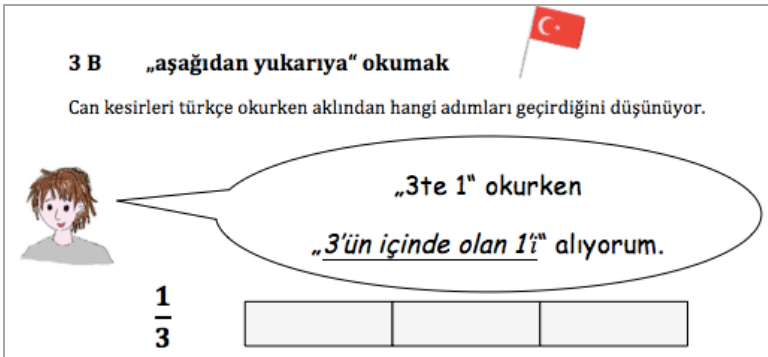
Macro-scaffolding. In order to sequence students' intended learning trajectories from their everyday resources towards the more formal mathematics, each topic starts with a culturally sensitive everyday context and a graphical representation for constructing mathematical meanings of mathematical concepts. These conceptual trajectories are supported by offering meaning-related lexical means (words and phrases) in German and Turkish academic register (Wessel 2015; similar for percentages in Prediger & Pöhler 2015). Table 1 shows selected steps in the conceptual learning trajectories in the five intervention lessons. Some decisions about Turkish meaning-related expressions had to be discussed with Turkish-speaking linguists as the Turkish textbooks mainly provide words for the formal expressions, but not for expressing meanings.

Reflecting languages as a resource for conceptual understanding of fractions. The Turkish and German languages differ in the way fractions are conceptualized. While the German expression "3 4-tel" for ¾ resembles the English way, e.g. "3 4-ths", the Turkish way is closer to the part-of-whole-interpretation by "3-te 1", literally translated "4, therein 3", setting a focus on the referent whole. In different tasks in the intervention, we asked students to explicitly reflect on the different conceptualizations of fractions (see Fig. 1) with the aim to activate further bilingual resources for a conceptual understanding.

Table 1. Conceptual learning trajectory and lexical means for five lessons of intervention

	Conceptual learning trajectory (cf. Prediger & Wessel 2013)	**Main graphical representations**	**Examples of lexical means in German and *Turkish***
1	• Meaning as part-whole models in graphical representations, verbally given everyday situations and symbolic fractions; • Investigating systematic variation of fractions in bars; • Assigning technical terms and phrases as well as contextual meanings to symbolic fraction.	Fraction bar 	• ¾: *"3 4-tel"* = "3 4-ths": In Turkish *"4te 3"*. Specific Turkish conceptualization of the fraction as "4, therein 3"; • „Anteil" = "share": In Turkish „*düşen pay*". "Anteil" as specific German word for thinking „part-in-a-whole" - share. The Turkish expression was constructed of the word "düşen pay" due to multiple allocated and missing translation options; • "Teil" & "Ganzes" = "part" & "whole": In Turkish "*parça*" & "*bütün*".
2	• Equivalent fractions: Meaning of equivalent fractions with fraction bars and everyday situations of scoring; • Finding equivalent fractions by computation within the symbolic register.	Fraction bars in the bar board 	• "gleichlang" = "as long as": In Turkish "*aynı/ eşit uzulukta*"; • "vergröbern" & "verfeinern" = "dividing in smaller / bigger pieces": In Turkish „*iri taneli yapmak*" & "*ince taneli yapmak*". Focus on meaning-related vocabulary instead of formal expression "reducing or expanding a fraction".
3	• Ordering fractions in different registers; • Investigating systematic variation of fractions and reflecting on order relations for fractions with same numerator/ denominator • Comparing strategies for different "part-in-a-whole" relations in fraction bars of varying lengths.	Bar board	• See lesson 3 plus vocabulary for comparison: • "kleiner / größer als", "der kleinere / größere Anteil" = "smaller / bigger than", "the smaller / bigger share"): In Turkish "*daha büyük/ daha küçük*", "*daha büyük / küçük düşen pay*".
4	• Fractions as operators (x/y of sets of discrete objects); Unitising of quantities and specifying fractions as operators in concrete and graphical register; • Computing fractions as operators within the symbolic register.	Bar board, set of cards and discs 	• Typical construction "x/y von … ist …" = "x/y of … is …": In Turkish "*…'ün/nın/in xde y'u/ü/ı …*", having a different sequence of sentence elements and suffixes (due to the suffix-vocal harmony) when translated ("of … x/y is …").
5	• Determining and representing parts and part-whole relationships for given quantities in graphical representation (arrays) and word problems.	If necessary: see lesson 4	• Repetition of basic lexical elements

Coordinating languages. In the beginning of the intervention, the teachers where instructed to use Turkish extensively in order to establish Turkish as a language of instruction. Furthermore, in order to counteract the danger of Turkish being just an 'addition' to the language of instruction (Garcia, 2009), we gave the students both Turkish and German worksheets. Over the course of the intervention, the teacher handed over the initiative for language use to the students. In sessions 4 and 5, the students were free to use Turkish or German. We assumed that if students acquire the technical or academic register in Turkish, they are able to transfer this to German, and vice versa.



English translation:

When I read "3-te 1", I take 3, in it 1.

What does Can mean? What does it mean to think 3, therein 1?

Figure 1. Task with explicit reflection of Turkish conceptualization

RESEARCH DESIGN AND METHODS

A randomized control trial was conducted with conceptual understanding for fractions as dependent variable for comparing the two forms of intervention and a control group.

Data gathering

Sampling and background factors. The sample consisted of n = 139 multilingual students with low German language proficiency and varying Turkish language proficiency from 12 schools in North Rhine Westphalia. The students were randomly assigned to three groups "monolingual intervention", "bilingual intervention" and the control group (with no specific intervention, only regular math classes), serving as independent variable. These groups were controlled to be comparable with respect to socio-economic status, general cognitive abilities, as well as math and German and Turkish language proficiency. Language proficiencies were assessed by two C-Tests, offering economical and highly reliable measures, the German C-Test with Cronbach's Alpha α = .774 (N = 1122), and the Turkish C-Test with α = .874 (N = 254).

Dependent variable students' performance in dealing with fractions was measured by a pre- and a post-test on conceptual understanding of fractions, standardized in a prior project (Prediger & Wessel, 2013). With α = .834 for the pre-test (28 items, N = 1120) and α = .754 for the post-test (29 items, N = 417), both tests showed a satisfactory internal consistency.

Hypotheses for analysis

Providing learning opportunities for improving the proficiency in the academic and technical registers in a restricted course of 5x90 min, the bilingual intervention had a reduced time-on-task for the conceptual understanding of fractions. Although bilingual education has proven to be beneficial in the long run, this might especially cause initial barriers for students with low Turkish language proficiency. These considerations suggested investigating the following hypotheses.

H1. As the time for acquiring proficiency in the Turkish academic and technical registers reduces the time-on-task for fractions, the five sessions of bilingual intervention are less effective for increasing students' conceptual understanding of fractions than the monolingual intervention.

H2. Students with lower Turkish language proficiency profit less from the bilingual intervention than students with higher Turkish proficiency, as they have to overcome more initial barriers.

Data analysis

For testing hypothesis H1 in the randomized control trial, a repeated measures analysis of variance (one-way ANOVA) was used to test for significant differences in the fraction pre-post-difference with group and time as main factors, and group by time as an interaction factor. *For testing hypothesis H2*, an ANOVA was conducted separately for students with low and high Turkish language proficiency (groups T+ and T- built on the basis of the Turkish C-Test by median split). In addition to inter-group effect sizes measured by partial eta squared (η^2) in the variance analysis, the intra-group effect sizes d were measured, reflecting the differences of means within each group as a percentage of a standard deviation. In general, $d < 0.2$ counts as low and $d > 0.8$ as high. A qualitative analysis of the videotaped intervention sessions is currently conducted.

RESULTS OF THE QUANTITATIVE ANALYSIS

As the means of pre-test and post-test in Table 2 suggest, all groups have a significant increase in their fraction test scores over time, but the increases of the intervention groups are much higher than the one of the control group. This result is reflected by the effect sizes: Whereas the control group only has a medium effect of $d = 0.4$, both intervention groups have strong effects ($d = 1.08$ in the monolingual and $d = 0.94$ in the bilingual intervention). These effects are confirmed by the significance of the main factor "time" in the ANOVA and its high effect size of $\eta^2 = 0.41$. The difference between the groups is confirmed by the significant interaction effect of groups x time with $\eta^2 = 0.09$. Hence, the three groups develop significantly unequally over time. But the post doc test does not show significant pairwise differences, especially not between the monolingual and the bilingual intervention. Hence, hypothesis H1 cannot be confirmed, the bilingual intervention is comparably effective for mathematics achievement as the monolingual one.

For the hypothesis H2, we see a confirming tendency that students with high Turkish language proficiency (TLP) profit more from bilingual education: Due to the small group sizes, the ANOVA with post hoc test does not show significant group differences in the average increase of achievement ($F_{(time)} = 92.63$, $p<0.001$, $\eta^2 = 0.41$; $F_{(group)} = 0.64$, $p = 0.67$ (n.s.), $\eta^2 = 0.005$; $F_{(group\ x\ time)} = 3.07$, $p<0.05$, $\eta^2 = 0.1$). However, comparing the average difference Δ of scores in pre- and posttest and effect-sizes d shows a tendency that students of high Turkish language proficiency ($\Delta = 3.47$, $d=1.15$) profit more from the bilingual intervention than students with low TLP ($\Delta = 2.28$, $d = 0.75$) (also see Table 3).

Table 2. Effects of two forms of intervention and control groups in Pre-and Post-test

	Achievement in Pre-Test m (SD)	**Achievement in Post-Test m (SD)**	**Intra-group effect-size d**
Monolingual intervention (n=46)	7.46 (3.34)	11.15 (3.48)	+1.08
Bilingual intervention (n=43)	8.02 (2.60)	10.88 (3.49)	+0.94
No intervention (n=50)	8.30 (2.83)	9.62 (3.69)	+0.4
Inter-group and time effect	$F_{(time)} = 93.13$, $p<0.001$, $\eta^2 = 0.41$; $F_{(group)} = 0.37$, $p = 0.69$ (n.s.), $\eta^2 = 0.005$; $F_{(group\ x\ time)} = 6.83$, $p<0.01$, $\eta^2 = 0.09$		

Table 3. Comparison of students with high and low TLP in Pre-and Post-test

	Achievement in Pre-Test m (SD)	**Achievement in Post-Test m (SD)**	**Intra-group effect-size d**
Monolingual intervention for high Turkish LP (n=24)	7.75 (2.95)	11.21 (3.92)	+ 1.01
Monolingual intervention for low Turkish LP (n=22)	7.14 (3.77)	11.10 (3,01)	+ 1.17
Bilingual intervention for high Turkish LP (n=21)	8.24 (2.51)	11.71 (3.55)	+ 1.15
Bilingual intervention for low Turkish LP (n=22)	7.82 (2.72)	10.10 (3.32)	+ 0.75
Inter-group and time effect	$F_{(time)} = 92.63$, $p<0.001$, $\eta^2 = 0.411$; $F_{(group)} = 0.64$, $p = 0.67$ (n.s.), $\eta^2 = 0.023$; $F_{(group \times time)} = 3.10$, $p<0.05$, $\eta^2 = 0.012$		

FIRST INSIGHTS INTO THE QUALITATIVE ANALYSIS

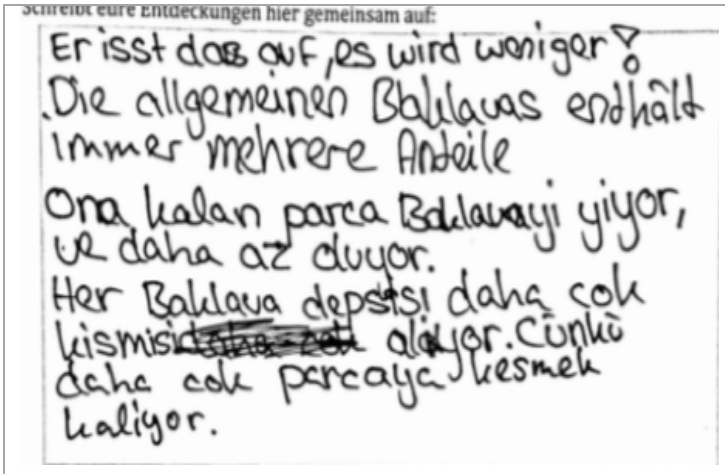
Academic and technical register in Turkish as an obstacle that can be compensated

The assumption that students still need to acquire some proficiency in the Turkish everyday register and academic / technical register for the concept of fractions was confirmed at various points during the intervention. Initially, some students could not express for example “multiply” and “divide” in Turkish, as they had never talked about mathematics in their home language before. This led to obstacles in the learning processes: students could lose track in a discussion when the teacher spoke too quickly or in a too elaborated way. But remarkably, by employing strategies like coordinating languages between the Turkish and German worksheets and by borrowing words from German, the students could overcome these obstacles. Furthermore, students adopted some Turkish expressions from the teacher and the peers, like those mentioned in Table 1 (similarly in Planas, 2014).

Students’ bilingual resources as a starting point for conceptual development

Meryem’s written bilingual explanation in Figure 2 gives an insight into how bilingual students can profit from activating their Turkish resources. In the first lesson, students are required to give written explanations for their task solutions, which is known to be an effective strategy for student-student scaffolding (de Guerrero, 2010). The task was to explain how they would divide a baklava (a Turkish cake, usually served on a rectangular shaped plate) with 2, 3, 4 and 5 friends. Five fraction bars were given as a representation for the baklava. Lexical scaffolding was offered by providing some lexical phrases for dealing with fractions, here „kısım“ (part) and „parça“ (piece).

Meryem started her written explanation in German and continued in Turkish (Fig. 2). In the German text, she describes the context of the task, referring to the amount of baklava one would get (“it is getting less”). In German, conceptually oral words are used (“that”, “it”) (Schleppegrell 2004). In Turkish, the explanation becomes more elaborate, explicit, and detailed. By using the everyday context of sharing a baklava, the student is able to better explain how the pieces change when more children share a baklava. For that, she invents a word based on her everyday experiences (“serving tray baklava”). This is in line with research showing the positive effect on everyday contexts on the students’ abilities to participate in rich discourse practices (Moschkovich, 2015), in this case the practice of explaining.



Translation of the German beginning:

"He eats it all, it is getting less! The general baklavas contain always more parts."

Translation of the Turkish continuation:

"He eats the piece ["*parca"*] of baklava that remains for him, and it becomes less. Every serving tray ["*depsisi*"] baklava gets more parts ["*kismisi*"] because one has to cut more remaining pieces."

Figure 2. Meryem's explanation for the task: "Can divides a baklava with 2, 3, 4 and 5 friends – What happens with the share that Can gets of the whole baklava? Why does Can's share change?" (in Turkish slightly different order of sentence elements: "Can's share is changing how and why?")

This short document illustrates that at least some of the bilingual students are able to engage in mathematical explanations from the very beginning of the intervention, when they can activate their everyday experiences. When the offered lexical phrases are in the horizon of the students' everyday experiences in culturally sensitive familiar contexts, they can be adopted and used in the explanation, such as "kısım" (part) and "parca" (piece) which are used in "daha cok kismisi" (more parts) and "parca…daha az oluyor" (piece … it becomes less). In contrast, the German word "Anteil" (part in a whole or share) is not used with the correct meaning. Possibly, Meryem used "Anteil" because it is signified as relevant in the task, but not for its mathematical meaning. Such an idiosyncratic use of unfamiliar words can occur when students have not yet appropriated a word in dialogic communication and in familiar contexts (Bakhtin, 1981).

DISCUSSIONS

As the randomized control trial has shown, Grade 7 is not too late for starting bilingual mathematics courses. Although the multilingual Turkish-German students in our study had only limited proficiency in the academic Turkish register and nearly none in the technical register, the initially required investment was quickly made: within three sessions, nearly all students caught up and gained confidence in their Turkish as a language of learning. Hence, already the first five sessions of the bilingual intervention were equally effective for acquiring conceptual understanding of fractions as the monolingual intervention, although the latter provided more time-on-task for training fractions. This empirical finding even applies for students with low (academic) Turkish language proficiency, although the students with high Turkish proficiency profited more.

First insights into the learning processes of the bilingual intervention give hints that in a longer run, the bilingual intervention might even be more successful than the monolingual intervention. Here, we illustrated a case where a student, by connecting to a culturally sensitive familiar context, is able to use her Turkish language resources and adopt the presented lexical scaffolding to give a more

elaborate explanation than in German. Of course, further deep qualitative analyses are necessary to better understand the initiated bilingual learning processes.

We conclude that bilingual subject matter courses should not be afraid of the *necessary, but manageable initial investment into the home language academic and technical register*. These results are very encouraging for bilingual mathematics courses to be installed even in later years, which of course, in their practical realization, should be longer than five sessions.

Acknowledgment. The project "MuM-Multi: Fostering Language in multilingual mathematics classrooms – effects and conditions of a content- and language integrated intervention" is funded by the German ministry BMBF (grant 01 JM 1403 A). We thank our partners Angelika Redder, Jochen Rehbein, Meryem Celikkol, and Jonas Wagner for the excellent interdisciplinary cooperation on the design of the bilingual intervention.

References

Bakhtin, M. M. (1981). *The Dialogic Imagination. Four Essays*. Austin and London: University of Texas Press.

Barwell, R. (Ed.) (2009). *Multilingualism in Mathematics Classrooms*. Bristol: Multilingual Matters.

Beacco, J.-C., Byram, M., Cavalli, M., Coste, D., Egli Cuenat, M., Goullier, F., & Panthier, J. (2010). *Guide for the development and implementation of curricula for plurilingual and intercultural education*. Strasbourg: Council of Europe. http://www.coe.int/lang. [Retrieved January, 4, 2014].

Garcia, O. (2009). *Bilingual Education in the 21st Century: A Global Perspective.* Hoboken: Wiley-Blackwell.

Gogolin, I. (2011). Bilingual education. In J. Simpson (Eds.), *Routledge Handbook of Applied Linguistics* (pp. 229-242). London: Routledge.

De Guerrero, M. (2010). Activating the ZPD: Mutual Scaffolding in L2 Peer Revision. *The Modern Language Journal*, 84, 51-68.

Kuzu, T. (2014). *Aufbau inhaltlicher Vorstellungen von Brüchen mit Erstsprache Türkisch. Designexperimente in Klasse 7.* Unpublished Master-Thesis, supervised by S. Prediger. TU Dortmund.

Meyer, M., Prediger, S., César, M., & Norén, E. (2016). Making Use of Multiple (Non-shared) First Languages: State of and Need for Research and Development in the European Language Context. In R. Barwell, et al. (Eds.), *Mathematics Education and Language Diversity* (pp. 47-66). Dordrecht: Springer.

Moschkovich, J. (2015). A Sociocultural Approach to Academic Literacy in Mathematics for Adolescent Englisch Learners. In D. Molle, et al. (Eds.), *Multilingual Learners and Academic Literacies* (pp. 75-104). London: Routledge.

Planas, N. (2014). One speaker, two languages: Learning opportunities in mathematics classroom. *Educational Studies in Mathematics,* 87, 51-66.

Prediger, S., & Wessel, L. (2013). Fostering German language learners' constructions of meanings for fractions. *Mathematics Education Research Journal*, *25*(3), 435-456.

Prediger, S., & Pöhler, B. (2015). Intertwining lexical and conceptual learning trajectories – A design research study on dual macro- scaffolding towards percentages. *Eurasia Journal of Mathematics*, 11(6), 1697-1722.

Prediger, S., Clarkson, P., & Bose, A. (2016). Purposefully relating multilingual registers: Building theory and teaching strategies for bilingual learners based on an integration of three traditions. In R. Barwell et al. (Eds.), *Mathematics education and language diversity. The 21st ICMI study* (pp. 193-215). Cham, Heidelberg, New York, Dordrecht, London: Springer.

Reljić, G., Ferring, D., & Martin, R. (2015). A Meta-Analysis on the Effectiveness of Bilingual Programs in Europe. *Review of Educational Research, 85*(1), 92-128.

Schleppegrell, M. J. (2004). *The language of schooling: A functional linguistics perspective*. Mahwah, NJ: Lawrence Erlbaum.

Wessel, L. (2015). *Fach- und sprachintegrierte Förderung durch Darstellungsvernetzung und Scaffolding*. Heidelberg: Springer Spektrum.