BARRIERS AND MOTIVATIONS OF PRIMARY TEACHERS FOR IMPLEMENTING MODELLING IN MATHEMATICS LESSONS

Rita Borromeo Ferri and Werner Blum

University of Kassel, Germany

Mathematical modelling is one central competency within the German education standards in mathematics for primary schools (from grade one to grade four). However, a lot of primary teachers do not know how to deal with modelling in the classroom, what can be often recognized during in-service teacher training or classroom observations. To get more insight into reasons for this reserve, a quantitative study was developed with the aim to investigate central barriers and also motivations of primary teachers for implementing modelling in mathematics lessons. The results show three essential barriers for primary teachers: 1. lack of material; 2. time pressure; 3. Assessment. In the paper we will go deeper into these and further results.

INTRODUCTION AND RESEARCH QUESTION

The national and international research area of mathematical modelling at the secondary and tertiary education levels is rather well established and a lot of modelling problems, materials and practical ideas for teachers are available. Although mathematical modelling in primary schools is discussed within the international debate as well, there are still rather few research studies. In Germany in particular, there are only very few studies focusing on this topic, and the development of modelling problems for primary classrooms did not really start until the national education standards for mathematics at the primary level (in which modelling is one of five competencies that pupils ought to achieve in grades 1 to 4) became compulsory in 2003. But there is still a big gap between the demand that modelling really starts in primary school and is an essential part of mathematics, on the one hand, and the experiences from everyday school practice where many teachers do not like to deal with this topic since it seems to be "too complex and too hard for young kids". Adequate starting points for avoiding this mismatch are, in particular, modelling seminars with practical elements for future primary and secondary teachers at university. We have a lot of experiences with these seminars (see Borromeo Ferri & Blum, 2009) and we think that these teachers will have another view on teaching modelling when they are in school. The biggest problem is to convince those teachers who have taught mathematics for a long time in the same way and have heard about modelling, but do not know what it really means and how it can be implemented in their daily mathematics lessons. This special situation with primary teachers in Germany has led us to investigate barriers and motivations for teaching mathematical modelling in primary school more deeply and more systematically.

In the international literature, there are no quantitative findings concerning these aspects for primary teachers (grades 1 to 4). So our central research question was:

What are the main reasons which hinder primary teachers to implement modelling in mathematics lessons?

THEORETICAL BACKGROUND

A lot of research studies have revealed positive effects of modelling problems in elementary school (Bonotto, 2004) with examples such as shopping in the supermarket or timetables for trains. Also Verschaffel (2002) emphasizes the possibility of modelling activities in primary school, in particular in the context of arithmetic operations (see also Usiskin, 2007). Especially the research of English (2002, 2006) concerning modelling activities of 10- and 11-year-olds are impressive. Young students created, for example, a shopping-guide in the context of a modelling problem (see Mousoulides & English, 2008). Starting with Modelling Eliciting Activities (MEA) already in kindergarten and subsequently in primary school is in Lesh's sense (see e.g. Lesh & Doerr, 2003) the basis for effective modelling in upper grades. A lot of Lesh's case studies show that primary kids are actually able to deal with modelling problems and to get remarkable results, in particular if the teachers themselves like modelling, have knowledge of how to communicate it in the classroom and have stimulated so-called "thought-revealing-activities". We also have used one of Lesh's examples (the "Big Foot" problem) successfully in grade 4. Summarizing existing studies about teaching and learning mathematical modelling, the crucial role of the teacher becomes evident. So modelling can only be learned effectively if there are teachers who have appropriate competencies in this field (Borromeo Ferri & Blum, 2009).

Besides the above-mentioned aspects, our main hypotheses are based on further results of empirical research. Within the LEMA project (**L**earning and **E**ducation in and through **M**odelling and **A**pplications, project director: Katja Maaß) questionnaires, mainly for secondary teachers, were developed concerning beliefs (Maaß & Gurlitt, 2009) and also concerning the question which obstacles and motivations the teachers have for integrating modelling in their mathematics lessons (Schmidt, 2009). The main results of Schmidt's quantitative study with more than 50 secondary teachers in a pre- and post-test design have revealed three main barriers for teaching modelling: 1. The time needed for working on modelling problems; 2. Lack of materials (no access to suitable modelling problems); 3. Assessment (teachers do not know how to give marks for modelling activities). More generally, the following six categories of obstacles for the implementation of modelling in mathematics classrooms have been identified in the educational debate (compare, e.g., Blum, 1996, 2011; Kaiser-Meßmer, 1986; Burkhardt, 2006; Maaß, 2004; Ikeda, 2007): 1) organisational obstacles (such as the time needed to deal with modelling problems in the classroom); 2) student-related obstacles (lessons become more demanding and less predictable); 3) teacher-related obstacles (non-mathematical competencies and broader beliefs are needed, lessons become more demanding and less predictable, assessment becomes more complex); 4) material-related obstacles (are there enough suitable examples?); 5) systemic obstacles (such as expectations of parents, scientific associations and other pressure groups, or regulations in examinations); 6) research-related obstacles (are there reliable empirical results as a basis for teaching modelling?)

METHODOLOGY AND DESIGN OF THE STUDY

Questionnaire development

The empirical study of Schmidt (2010a, 2010b) was particularly interesting for us because she developed a questionnaire on the basis of findings from those empirical studies in mathematical modelling which have reconstructed relevant obstacles and motivations for teaching modelling (see the end of the previous section). So the construction of her questionnaire can be described as an inductive and deductive procedure. The developed "inductive" items came from theory and the "deductive" items from interviews with experts. This questionnaire was the basis for our own questionnaire development, but we modified items and scales for the purpose of applying it with a sample of primary teachers. A central theoretical background for our questionnaire was "The offer-and-use model" (Figure 1) according to Helmke (2006), because the categories of this model (teacher, education, context etc.) were the basis for the structure of our scales (see below).

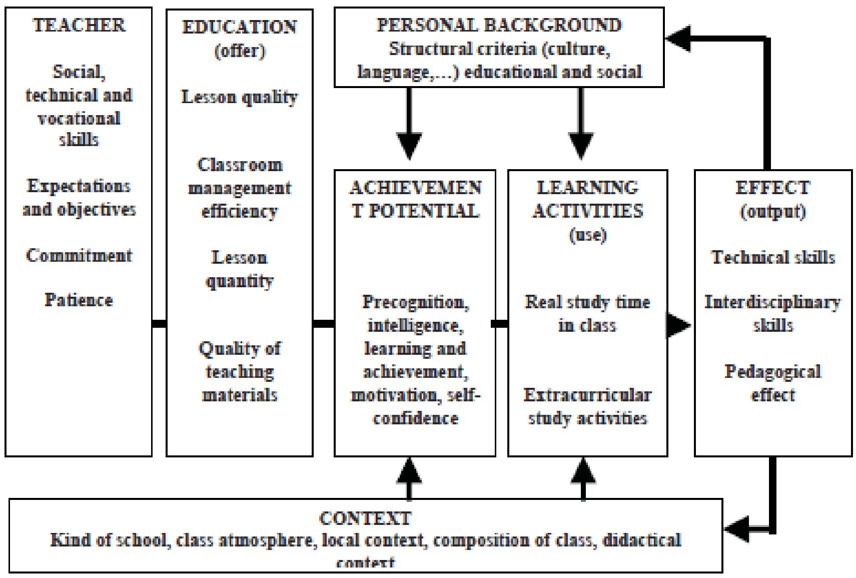

Figure 1: "The offer-and-use-model", Helmke (2006)

Altogether our questionnaire comprised 14 scales with 43 items and additionally one open item asking for personal comments and experiences with mathematical modelling. Besides demographical questions concerning age, years of teaching, experiences with modelling and subjects studied at university, the scales are labelled as follows: “*context*” (sample item: The parents of the pupils in my class do not like if I teach modelling problems in mathematics lessons), “*differentiation*” (sample item: modelling problems support stronger and weaker pupils at once), “*time*”, “*role of the teacher*”, “*lesson planning*”, “*motivation of the pupils*”, “*material*”, “*creativity*”, “*independence*” (sample item: pupils are able work on their individual solution processes), “*excessive demand*”, ”*assessment*”, “*long-terms effects in mathematics lessons*”, “*applying mathematics in real life*”, “*long-term effects beyond mathematics lessons*”.

The answer format corresponded to a 3-level Likert scale (Rost 1996) from “strongly agree” to “do not agree” (see Figure 2). The numbers of items per scale differ (from 2 to 6). Of course, only scales with a satisfactory reliability (see below) were used for further analyses. It is important to keep in mind that this questionnaire is focusing on teacher’s personality and so gives only feedback about subjective ideas and attitudes concerning the topic of modelling. The questionnaire was discussed with several primary teachers before using it in the sample.

Hypotheses: On the basis of the theory and of the results of Schmidt’s study within the LEMA-project, in combination with the research on modelling in primary school as well as experiences from teacher education, we assumed the following six scales as examples of barriers for modelling: “context”, “time”, “lesson planning”, “material”, “excessive demand” and ”assessment”. On the other hand, we supposed the following eight scales as motivations for teachers to include modelling: “differentiation”, “role of the teacher”, “motivation of pupils”, “creativity”, “self-dependence”, “long-terms effects in mathematics lessons”, “applying mathematics in real life” and “long-term effects beyond mathematics lessons”.

Design of the study and sample

The study was mainly *quantitatively* oriented, because on the basis of experiences in in-service teacher training we knew some of the barriers and motivations, but we still had no empirical knowledge about, for example, a comparison between teachers who studied the subject or not, and so we wanted to get more generalizable results. Because the questionnaire was only used once with test persons belonging to one group our study has a non-experimental-design. The data collection started in March 2012 and was completed in April 2012. Our sample comprised 71 primary teachers (female: 64, male: 7) from 8 of the 16 German states and was a convenience sample. Often two or three teachers from the same school got the questionnaire. We were glad about the relatively big sample for this study, having in mind how hard it is to get teachers, particularly teachers who did not study the subject, to spend time for working on such a questionnaire. The schools were in suburban regions respectively in smaller cities. The mean age was 44. Most of the teachers (43 in total) have studied mathematics as a subject at university, but 28 did not. The indicated frequency of integrating modelling was (in total): never: 20; seldom: 37; monthly: 9; weekly: 5. So we can say, as a first result, that for the majority of the teachers, modelling is not an essential part of mathematics lessons.

Data analysis

The underlying theory for the data analysis is the so-called Expectancy Theory or VIE-Theory (Vroom, 1964) which itself is based on the concept of Instrumentality (Peak, 1995) coming from motivation research. Vroom has built his theory on three variables which influence the motivation of a person (see Brandstätter 1999, p. 351ff): Expectancy, Instrumentality, and Valence, whereas we not focus on Expectancy in our questionnaire. *Instrumentality* is the belief that a person will receive a reward if the performance expectation is met. *Valence* is the value that the individual places personally on the rewards based on his/her needs, goals, values and sources of motivation; In order for the valence to be positive, the person must prefer attaining the outcome to not attaining it. Expectancy Theory of motivation can, for instance, help managers understanding how individuals make decisions regarding various behavioural alternatives. The model below shows the direction of motivation when behaviour is energized: Motivation = Instrumentality **x** Valence

The following example of our study shows the procedure:

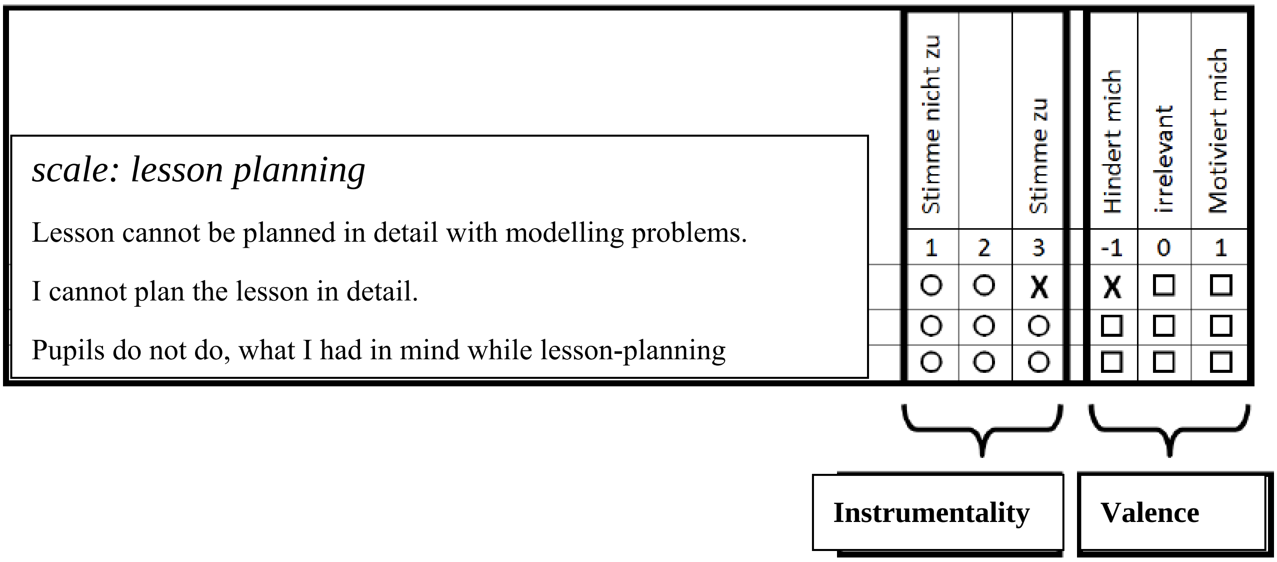

Figure 2: Example of data analysis (scale: lesson-planning)

The figure shows values from 1 to 3 in the first dimension and from -1 to 1 in the second. For the product of Instrumentality and Valence we get: 3 x (-1) = -3 Overall the parameter values may range from -3 to 3. In this way, all the data were coded and the software SPSS was used. The reliabilities of 12 of the 14 scales were satisfying, with Cronbach's α in the range between .65 and .84. Only the two scales "context" and “motivation” had smaller reliabilities; hence these two scales will not be contained in the following diagrams.

EMPIRICAL RESULTS

Relevant aspects from teachers’ perspective – an overview

Very briefly we will first show how strong the test persons agreed to the statements in these scales, so we look at the left part of the rating scale (Instrumentality) of the questionnaire (see above; 1-3). The higher the level of agreement, the more relevant is this aspect for the teachers. In the following boxplot, those scales are shown which can be interpreted as *barriers* (see our hypotheses):

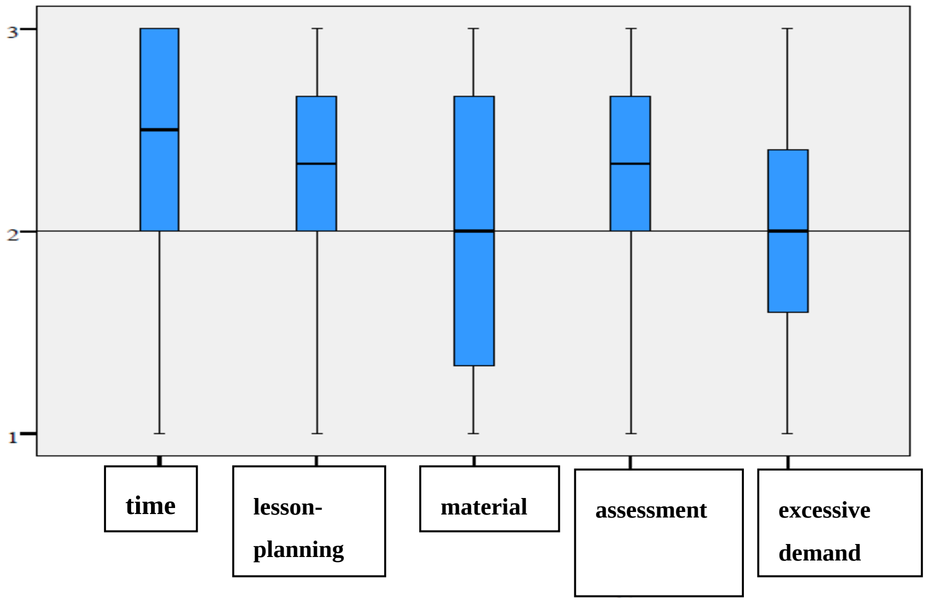

Figure 3: Relevant aspects from teachers’ perspective

The values between 1 and 2 show a tendency towards rejection by the teachers, whereas the values between 2 and 3 show a tendency towards agreement concerning these aspects. In particular the scales “*time*”, “*lesson planning*” and ”*assessment*” have high relevance for the teachers. Regarding “*material*” and “*excessive demand*” different attitudes of teachers become visible. For the scales that can be interpreted as *motivations* from the teachers’ perspective, the scale “*independence*” got the highest agreement from nearly all teachers. But also the other aspects (“long-terms effects in mathematics lessons”, “applying mathematics in real life”, “long-term effects beyond mathematics lessons”, “creativity”, “role of the teacher”) show a surprisingly high level of acceptance. Summarizing the first rating scale in more detail, the highest agreement came from the category “*learning activities*”: 87% of the teachers have the opinion that their pupils could be more creative mathematical thinkers when working with modelling problems, and 85% think that the level of self-dependence will be better. The highest value within the category “effects” was received by the aspect “relevance for everyday life” with 78%. The above-mentioned aspects only show the level of agreement. In the following it is interesting to see whether this agreement is more a barrier or a motivation for integrating mathematical modelling.

Barriers and motivations: For investigating the expected barriers or motivations both dimensions in the questionnaire (Instrumentality and Valence) were multiplied and so linked in the sense of the Expectancy Theory. Regarding to our hypotheses we expected barriers concerning all five scales. Analyzing this results in more detail, for 50% of the teachers’ “*time*” is seen as a barrier; only 28% are indifferent and for 22% it seems to be motivating. The aspect “*material*” is also a barrier for 42% of the teachers, 41% are indifferent and 17% are motivated. Concerning “*assessment*” the opinions of the teachers were different. Against our expectations the aspects of “*excessive demand*” and “*lesson-planning*” were rather stimulating for the teachers.

Expected reasons of motivation: For seven scales of the questionnaire, answers were expected that tend towards teachers’ motivation to integrate modelling. Especially the aspect of self-dependence was evaluated very positively: 91% of the teachers voted to be influenced positively, 6% were indifferent and only 3% saw a barrier for it. Concerning the “long-term effects beyond mathematics lessons” even 96% of the teachers are motivated, only 6% voted for indifference and for 1% it is a barrier. Only the scale “differentiation” did not show such high positive effects: 69% rated it as positive, 17% were indifferent and 14% it was regarded as a barrier. Looking at the other scales, also “*creativity*” and “*applying mathematics in daily life*” had similar positive values. Looking at the scale “*context*”, which comprises the sub-scale “*difference in assessment of pupils*”, 61% of the teachers see a motivation, because modelling can support weaker and stronger learners.

Differences between teachers who studied mathematics as a subject or not: In Germany not all primary teachers studied mathematics as a subject; it depends on the particular state. 28 of 71 teachers have not studied mathematics. The analyses show no big discrepancies concerning the aspects of “*time*” and “*lesson-planning*” and the aspect “*material*” seems for both groups of teachers realize substantial obstacle. However the aspect “*assessment*” illustrates considerable differences: teachers who did not study mathematics see here a barrier to teach modelling and for the other teachers "*assessment*” is a strong motivator.

Influence of experiences in teaching mathematical modelling concerning barriers and motivations: A small part of the sample (14 teachers) often uses modelling problems in class, 37 persons only seldom and 20 never. This was a good basis for analyzing differences in the attitudes of the teachers with respect to who often they do modelling activities. Already the aspect “*time*” made it clear that there are substantial differences: Experienced teachers do not see a barrier, but for inexperienced teachers time is a strong argument against modelling. Very similar results concern the aspect “*material*”. Experienced teachers also show a strong motivation concerning the material. A reason is, of course, that they often use such problems and know where to get these. Regarding the expected reasons of motivation, the scales "*long-term effects in mathematics lessons*", "*applying mathematics in real life*" and "*long-term effects beyond mathematics lessons*" were a stronger motivator for the inexperienced teachers. We think that experienced teachers recognized the positive effects of these aspects for modelling, too, but for them these aspects were less relevant compared to others.

SUMMARY AND DISCUSSION

Although mathematical modelling is a central competency in the German education standards for mathematics and should thus be a compulsory part of mathematics lessons, a lot of primary teachers still do not have these aspects in their mind and a lot of them are afraid of integrating modelling in their classrooms. For this reason we wanted to investigate barriers and motivations of primary teachers more systematically. The three essential barriers are *material*, *time* and *assessment*. For teachers experienced with modelling, *time* was not such a strong barrier as it was for the inexperienced teachers. One can suppose that the problem of time is rather a prejudice concerning modelling problems and their possible complexity. Probably different teachers set different priorities, because some are willing to invest time for modelling and others do not like to use this kind of tasks. The aspect of *assessment* was a barrier for many teachers. For teachers who did not study mathematics it seemed to be a much stronger barrier than for those who studied the subject. This could be related with their professional education. While teachers who did not study mathematics are fine with tasks which have unique results (right or wrong solution), the specialized teachers are able to asses pupils who work on open problems and so produce multiple solutions. The aspect *material* could not be allocated to a group, but was rated as a barrier for the main part of the sample. Besides the barriers a lot of motivating reasons for modelling could be found, in particular *self-dependence* of the pupils, creativity, *long-terms effects in mathematics lessons, applying mathematics in real life, long-term effects beyond mathematics lessons*. Also the changing *role of the teacher* was rated very positively.

The results of the study gave new insight into attitudes and opinions of primary teachers for implementing mathematical modelling in their lessons. All answers of the teachers made clear that they have recognized the benefit of modelling problems and modelling activities in general. All the barriers mentioned before can of course be eliminated or at least reduced by suitable professional development activities. With our results, we have now a better basis for meeting the needs of the teachers in such activities.

REFERENCES

Blum, W. (2012): Can Modelling Be Taught and Learnt? Some Answers from Empirical Research. In: Kaiser, G.; Blum, W.; Borromeo Ferri, R. & Stillman, G. (Eds.) Trends in Teaching and Learning of Mathematical Modelling, Springer, New York, p.15-30.

Blum, W. (1996): Anwendungsbezüge im Mathematikunterricht. Trends und Perspektiven. In: Kadunz, G. et al (Eds.): *Trends und Perspektiven. Beiträge zum 7. internationalen Symposium zur „Didaktik der Mathematik*“. Wien: Hölder-Pichler-Tempsky. p. 15-38.

Bonotto, C. (2004). How to replace the word problems with activities of realistic mathematical modeling. In H. W. Henn & W. Blum (Eds.) Proceedings of the ICMI Study 14: Applications and Modelling in Mathematics Education Pre-Conference (pp.41-46). University of Dortmund.

Brandstätter, V. (1999): Arbeitsmotivation und Arbeitszufriedenheit. In: Hoyos, C. G. (Eds.): Arbeits- und Organisationspsychologie: ein Lehrbuch. Weinheim: Psychologie Verlags Union. p. 344-357.

Borromeo Ferri, R.; Blum, W. (2009). Mathematical Modelling in Teacher Education - Experiences from a Modelling Seminar. In: European Society for Research in Mathematics Education (Eds.). *Proceedings of CERME 6,* Lyon , France, p. 2046-2055.

Burkhart, H. (2006): Modelling in Mathematics Classrooms: reflections on past developments and the future. –In: *ZDM* 38 (2) p. 178-195.

English, L. D. (2002). Development of 10-year-olds’ mathematical modelling. In: A. Cockburn & E. Nardi (Eds.), Proceedings of the 26th International PME Conference (pp.329-336). Norwich: University of East Anglia.

English, L. D (2006). Mathematical modelling in the primary school: Children’s construction of a consumer guide. Educational Studies in Mathematics 63, p. 303-323.

Helmke, A. (2007): Unterrichtsqualität: erfassen, bewerten, verbessern. 5. Aufl. Seelze: Krallmeyer

Ikeda, T., Stephens, M. & Matsuzaki, A. (2007). A teaching experiment in mathematical modelling. In: Haines, C., Galbraith, P., Blum, W. & Khan, S. (Eds): *Mathematical Modelling (ICTMA 12). Education, engineering and economics*. Chichester: Horwood Publishing, p. 101-109.

Lesh, R. A. & Doerr, H. (Eds.). (2003). Beyond constructivism: A models and modeling perspective mathematics teaching, learning, and problem solving. Mawwah, NJ: Erlbaum.

Maaß, K. (2007). Modelling in class: What do we want the students to learn? In: Haines, C., Galbraith, P., Blum, W & Khan, S. (Eds): *Mathematical Modelling (ICTMA 12). Education, engineering and economics*. Chichester: Horwood Publishing, p. 65-78.

Maaß, K., & Gurlitt, J. (2009). Designing a Teacher Questionnaire to Evaluate Professional Development in Modelling. In: European Society for Research in Mathematics Education (Eds.). *Proceedings of CERME 6,* Lyon , France, p. 2056-2064.

Mousoulidis, N. G. & English, L. D. (2008). Modeling with data in Cypriot and Australian primary classrooms. In O. Figueras & A. Sepulveda (Eds.), Proceedings of the 32nd International PME Conference (pp. 423-430). Morelia, Mexico: PME.

Peak, H. (1955). Attitude and motivation. In M. R. Jones (Ed.), Nebraska symposium on motivation. Lincoln, NE: University of Nebraska Press.

Rost, J. (1996): Lehrbuch Testtheorie, Testkonstruktion. Huber, Bern.

Schmidt, B. (2010a): Modelling in the Classroom – Motives and Obstacles from the teacher’s perspective. In: European Society for Research in Mathematics Education (Eds.). *Proceedings of CERME 6,* Lyon , France, p. 2066-2075.

Schmidt, B. (2010b): Modellieren in der Schulpraxis. Beweggründe und Hindernisse aus Lehrersicht. Hildesheim & Berlin: Franzbecker.

Usiskin, Z. (2007). The arithmetic operations as mathematical models. In: W. Blum, P. L. Galbraith, H.-W. Henn & M. Niss (Eds.), Modelling and Applications in Mathematics Education (p. 257-264). New York: Springer.

Verschaffel, L. (2002). Taking the modelling perspective seriously at the elementary school level: Promises and pitfalls. In A. Cockburn & E. Nardi (Eds.), Proceedings of the 26th International PME Conference (pp. 64-80). Norwich: University of East Anglia.

Vroom, V. H. (1964): Work and motivation. New York: Wiley.