A QUESTIONNAIRE FOR SURVEYING MATHEMATICS SELF-EFFICACY EXPECTATIONS OF FUTURE TEACHERS

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Because of traditionally high drop out rates in mathematics courses students often expect to fail also. This results in a low motivation for learning mathematics and a low mathematics self-efficacy expectation. However, self-efficacy beliefs of a person have been identified as an important factor for performing tasks successfully. Higher self-efficacy expectations can lead to better results and therefore increase the motivation for learning mathematics. This is especially important when these students are future mathematics teachers. In order to determine the mathematics self-efficacy expectations of students and to measure the influence of pedagogical interventions on self-efficacy, an adequate instrument is needed. This paper describes the development and validation of a scale for measuring the mathematics self-efficacy expectations of future teachers (MaSE-T).

INTRODUCTION

For many 'non-mathematicians' mathematics is incomprehensible or inaccessible. Some even get scared when they see mathematical formulas or they have to solve a mathematical problem, even if they use mathematics subconsciously in everyday life. For example, some have problems when to determine the length of the diagonal in cuboids. In an everyday situation, when they have to decide whether a box is large enough for packing an object, they solve the problem by using approximations. Hence some kind of mathematics is often done without even recognizing it.

Negative attitudes and expectations towards mathematics are mostly founded in low performances at school or bad experiences in math classrooms. This leads to an expectation of not being able to handle mathematics in general. The belief in one's own mathematical competence (skills and knowledge) is an important factor for being a successful problem solver. Increasing mathematics self-efficacy will get 'non-mathematicians' to dare more mathematics in everyday life, e.g. computing the reduction of prices on goods or read statistics about every day issues. In general, it can influence their behavior and attitudes when they are faced with mathematical tasks. For these reasons a learning scenario which increases the mathematical self-efficacy besides the content knowledge should be more valuable than a course which "only" increasing the knowledge.

This means that the success of mathematical learning scenarios, e.g. at school or at university, should not only be measured by knowledge tests. Pre- and post-testing the mathematics self-efficacy expectations during a course in mathematics will provide information whether the learners' mathematics self-efficacy expectations have increased.

Especially for future mathematics teachers it is important to possess adequate self-efficacy beliefs in mathematics. On the one hand, even as a teacher, they have to be able to read mathematical publications on some levels. On the other hand, teachers should set an example for students concerning their mathematical beliefs and serve as a model. Teachers with low self-efficacy expectations will hardly motivate students to do mathematics and to believe in their own competence. This is one of the reasons why we focus on the higher mathematical education of future teachers in our research.

Measuring the mathematics self-efficacy expectations of future teachers demands an adequate instrument for measuring the right level. Existing instruments in German are either on middle school level or focus on engineering students and do not meet the requirements of German mathematics teacher education. Thus, a new instrument has been developed and validated.

In this article we first give a review of the theoretical basics of (mathematics) self-efficacy. After that we describe the development of an instrument for measuring the mathematics self-efficacy of future teachers. Finally we validate our 15-item mathematics self-efficacy questionnaire (MaSE-T) in an adult student population. Additionally the relationships between MaSE-T and gender, preparation for primary or secondary schools, as well as the level of specialization in mathematics (major, ‘middle’ or minor) are investigated. The paper ends with concluding remarks and an outlook on future research.

SELF-EFFICACY AND MATHEMATICS SELF-EFFICACY

Self-efficacy can be defined as the judgement of one’s capabilities to successfully perform a particular given task (Bandura, 1977; Bandura 1997; Zimmerman, 2000). These expectations and beliefs influence whether somebody starts working on a task and the intensity of the performance (Pajares & Kranzler, 1995). As a consequence people with low mathematical self-efficacy will avoid mathematical tasks or situations.

Self-efficacy beliefs are a main factor in someone's decision making process, e.g. the choice of academic courses or career decisions (Hackett & Betz, 1981; May & Glynn, 2008). Especially low self-efficacy beliefs lead to negative decisions in the related domain. Successful learning scenarios – at school or at university – should increase learners’ self-efficacy expectations as well as their skills and knowledge. A main source of self-efficacy expectations is one's own successful performance. If a student completes a task autonomously with more or less feedback, s/he develops positive expectations to handle new and unknown situations or problems. However, the effect could be weaker due to the non-existing own performance if learners only ‘consume’ information about how to solve the task.

In general, self-efficacy expectations “are task and domain specific” (Pajares & Miller, 1995, p.190). For that, measurements of self-efficacy expectations should be always fitted to the related domain or task. For example, questionnaires have been proposed to measure self-efficacy expectations in the field of computer usage (Compeau & Higgins, 1995; Cassidy & Eachus, 2002; Barbeite & Weis, 2004) or mathematics (Betz & Hackett, 1981; Pajares & Miller, 1995; May & Glynn, 2008). Mathematics self-efficacy expectations indicate the belief of a person in his/her own competence to solve mathematical problems and tasks successfully. Mathematics self-efficacy is positively related to math performance (Pajares & Miller, 1994; Kabiri & Kiamanesh, 2004; Liu & Koirala, 2009). This means that the higher a person rates on mathematics self-efficacy scales, the better this person performs on solving mathematical problems. There are also gender differences in mathematics self-efficacy expectations. Males are usually scoring higher in mathematics self-efficacy questionnaires than females (Betz & Hackett, 1981; Randhawa & Gupta, 2000). It can be assumed that gender effects are based on social and cultural roles and the masculine image of mathematics.

The survey proposed by Betz and Hackett (1981) and the revised version by Kranzler and Pajares (1997) have widely been used in research. These surveys mainly consist of three kinds of items: math problems, math tasks used in everyday life, and performance in college courses. However, these surveys have several drawbacks: (1) Some items are formulated on a level too low for students studying mathematics at German universities, for example: "Fred's bill for some household supplies was $13.64. If he paid for the items with a $20 bill, how much change should he receive?" It is important that questionnaires for measuring mathematics self-efficacy expectations require an adequate level of mathematical content knowledge. (2) Math problems and real-world math tasks are not clearly separated. For example, the item mentioned before is included in the "math problem" scale, but could also belong to the scale with real-world math tasks if Fred wants to buy additionally a $6.80 item. (3) It would be interesting to see whether there is a difference between the expectation to solve a mathematical problem and a corresponding task which is contextualized in a real-world setting. In the existing surveys, there is no link between mathematical problems and real-world tasks. Therefore we decided to construct an own questionnaire described in the next section.

THE MATHEMATICS SELF-EFFICACY SCALE FOR SURVEYING FUTURE TEACHERS (MASE-T)

The first version of the questionnaire consisted of 25 items: mathematical problems without contexts (10 items), real-world mathematical problems (10), and reasoning problems (5). In contrast to the scales by Betz and Hackett (1981) and Pajares and

Miller (1997), each mathematical problem was related to a real-world mathematical problem. In table 1 there are some example items for math-problems (Xa) of the questionnaire with their corresponding real-world math problem (Xb). In addition, a third scale has been included with 5 reasoning problems, for example "I am confident in proofing that the square root of 2 cannot be represented as fraction.". All items were arranged randomly and had to be rated on a 5-point Likert scale ranging from 1 ("I am not at all confident.") to 5 ("I am totally confident.").

Table 1. Example items of the questionnaire.

item	
1a	"I am confident in determining the approximation formula of a somewhat cuboidal geometric body's diagonal."
1b	"I am confident in estimating whether a 2.5 meter long board can be transported in a van."
2a	“I am confident to solve the systems of equations with $x + y = 7$ and $x \cdot y = 30$.”
2b	“I am confident in calculating the length and width of an rectangle, if the perimeter counts 72 cm and the area is 288 cm² large.”
3a	“I am confident in calculating the side length of a perpendicular triangle by using a trigonometric function.”
3b	“I am confident in calculating the covered difference of height by knowing the incline of the street.”

EMPIRICAL STUDIES

In a first study, the 25-item questionnaire has been tested aiming to reduce the number of items. In a second study, a reduced questionnaire (15 items) has been tested for reliability and validity.

Study 1: 25-item mathematic self-efficacy scale

Sample

831 university students of future teachers at the German universities of education in Ludwigsburg (526 students), Schwäbisch Gmünd (126), and Weingarten (179) participated in the study. The sample consisted of 215 males and 615 females (one missing) with a mean semester count of 1.33 (*SD*=0.86; range 1-8). The overrepresentation of female students is normal in study courses of future teachers in Germany.

Procedure

All students were asked to complete the questionnaire anonymously and voluntarily during a mathematics lecture at the beginning of the winter semester in 2008/2009. The participation was voluntarily and without any reward.

Results

Internal reliability over all items was very good (Cronbach's alpha = 0.89). This value indicates a high degree of internal consistency of the items. Despite having a three-dimension scale (mathematical problems, real-world mathematical problems, and reasoning problems), each item contributes to the measurement of a single construct (mathematics self-efficacy expectations).

Factor and item analyses conducted on the collected data lead to a four factor model (PCA method, 50.7% of total variance). All items loaded on the first factor, which suggests that all items are related to mathematics self-efficacy. Hence, the remaining three factors can be the considered to be related to the three mathematical dimensions. As a result, based on reliability coefficients and factor loadings, the 25-item scale was reduced to a 15-items scale[1]. Therefore now each of the three dimensions consists of 5 items. As a consequence, some of the former corresponding mathematical problem items and real-world problem items have been removed. Thus, for a few items the corresponding items are missing.

Study 2: 15-item mathematics self-efficacy scale

The second study aimed at testing the psychometric properties of the reduced 15-item scale. In addition, the validity of the questionnaire had been tested by correlating the mathematics self-efficacy score with the grades of the 'Abitur', the final high school exam.

Sample

The total sample (*N*) of the main study consisted of 1318 participants (320 males, 995 females). Participants were again first year students (*mean* semesters 1.43, *SD*=0.97; range 1 to 9) of future teachers at the universities of Education in Ludwigsburg (493 students), Schwäbisch Gmünd (166), Weingarten (174), Heidelberg (165), and Karlsruhe (320).

Additionally, the sample can be divided into different groups with regard to two dimensions. On one hand it can be separated into four groups of students by their study course specialization. Therefore the first group were future teachers for primary school (*n*=640; 90 males, 550 females). Further groups are future teachers for secondary general school (*n*=189; 58, 181), future teachers for intermediate secondary school (*n*=362; 145, 217), and future teachers of schools for special needs

[1] The reduced 15-item questionnaire can be downloaded on www.sail-m.de in a German and English version. This article is based on the German version, the English one hasn't been validated yet.

children (n=120, 26, 94). It can be assumed that teacher students for secondary schools perform best on the MaSE-T scale. On the other hand the sample can be divided by the students' level of specialization in mathematics for study. In Baden-Württemberg, Germany, future teachers can choose whether they take mathematics or not (n=237; 37, 200). If mathematics is chosen as a subject it can be studied as major (n=401; 88, 313), 'middle' (n=396; 116, 280) or minor (n=275; 78, 197) subject.

Procedure

Students from the participating universities were again asked to complete the questionnaire anonymously and voluntarily during 20 minutes of their mathematics lecture at the beginning of the winter semester in 2009/2010.

Results

After the reduction of items the internal reliability, measured by Cronbach's Alpha, was nearly to the same as in the first study (*alpha*=0.84, n=1273) and indicates a high internal consistency. The alpha values of the three dimensions of the scale are still acceptable (see table 2).

The validity of the questionnaire was tested by relating the MaSE-T scores to different variables such as grades in the final high school exam, gender, chosen school type, and the level of specialization of mathematics.

First, mathematics self-efficacy scores were correlated with the grades in the final high school exam. At a first sight marks in exams don't give information about the belief in one's own mathematics self-efficacy expectations. At a closer look mathematics self-efficacy can be seen as a predictor for mathematical academic outcomes (Multon et al., 1991; Betz & Hackett 1983). And it can be hypothesized that the final exam grade in math can also be a predictor for mathematics self-efficacy expectations. A correlation between the two scales was significant (r=0.47, p<0.01, n=345). This means that students with higher grades in their final school exam rated higher in the mathematics self-efficacy scale.

Second, gender differences have been investigated in order to test whether male subjects have higher mathematics self-efficacy scores than female subjects. Gender differences have been reported in earlier studies (Betz & Hackett, 1981; Randhawa & Gupta, 2000). Table 3 shows the total score of mathematics self-efficacy and the mean scores of the subscales separated into males and females. Males scored significantly higher in total MaSE-T and the subscales "real-world mathematical problems" and "reasoning problems" than females.

Table 2. Reliability of the MaSE-T scale.

dimension	*n*	Cronbach's Alpha	items
total MaSE-T	1273	0.84	15
mathematical problems	1309	0.77	5
real-world mathematical problems	1302	0.70	5
reasoning problems	1294	0.74	5

Table 3. Gender differences in MaSE-T scores.

	males (*n*=319)		females (*n*=992)		test of significance
scale	*Mean*[2]	*SD*	*Mean*	*SD*	t
total MaSE-T score[1]	52.1	9.7	49.5	9.1	<0.001
mathematical problems	18.5	4.3	18.4	4.1	0.812
real-world mathematical problems	19.3	3.6	17.9	3.5	<0.001
reasoning problems	14.3	4.1	13.1	4.0	<0.001

[1]) Higher scores in mathematical self-efficacy indicate a greater confidence in the ability to accomplish the mathematical task.

[2]) Minimum score 15 / maximum score 75.

Comparing the MaSE-T scores of the groups aiming for different school types (table 4), also significant main effects for groups (F=7.80, $F_{(3,14)}$<5.56, p<0.01) were identified. A post hoc analysis reveals that future teachers for intermediate secondary schools have a significantly higher MaSE-T score (p<0.01) than the other groups. Lowest MaSE-T scores had future teachers for schools for children with special needs, which were significant lower than the scores of the other groups[2] (p<0.05).

Comparing groups according to students' with different levels of specializations in mathematics with the MsSE-T score (table 5), an ANOVA revealed a significant main effect of the factor *group* (F=33.24, $F_{(4,14)}$<9.73, p<0.001). Post hoc tests showed that students who didn't choose mathematics as a subject had significantly (p<0.001) lower MaSE-T scores than students who have chosen mathematics, as

[2] This group contained a relative high number of students which didn't choose mathematics as subject. A closer look at the data showed that the mean of the major subject students is similar to the mean of intermediate secondary school students.

predicted. In addition, students who have chosen mathematics as minor have significant lower MaSE-T scores ($p<0.001$) than the major and 'middle' students (see Table 5).

These two results between groups, study course specialization as well as the subject choice of mathematics, are covered by the findings of Hackett and Betz (1989). They found that mathematics self-efficacy beliefs are predictive for the choice of major. On the one hand, students with low self-efficacy expectations in mathematics avoid studying mathematics or don't choose mathematics as their major (table 4). On the other hand, in the group of students who have chosen mathematics as a subject, the students with the highest MaSE-T score are future teachers for intermediate secondary school. In contrast, students with low mathematics self-efficacy beliefs often choose to be primary school teachers because they often think that only basic arithmetic skills are needed. Secondary school teacher students know they'll have to do some 'real' math, consequently the group of future teachers for intermediate secondary school score the highest at MaSE-T.

Table 4. Mean MaSE-T scores of different study course specializations

Group	*n*	*Mean*	*SD*
Primary school	640	49.3	9.1
Secondary general school	189	49.2	9.7
Intermediate secondary school	362	53.3	8.5
School for handicapped children	120	46.4	9.9

Table 5. Mean MaSE-T scores for different levels of specializations in mathematics.

Group	*n*	*Mean*	*SD*
major subject	401	53.0	8.3
'middle' subject	396	52.6	8.5
minor subject	275	49.0	8.3
math not as a subject	237	42.7	9.2

DISCUSSION

In this paper, a questionnaire for measuring mathematics self-efficacy expectations of future teachers (MaSE-T) has been introduced. The refined 15-item MASE-T scale achieved a suitable level of internal reliability (*alpha*=0.84). Validity of the scale was indicated on one hand by producing significant gender differences. On the other hand, a positive correlation between MaSE-T and the final school exam grade has been found. The differences between samples grouped according to their chosen school type and to the different levels of specializations in mathematics also indicate the validity of the MaSE-T scale. While students with higher MaSE-T score chose mathematics as their major subject, students with lower scores avoided mathematics as field of study.

In future studies, the change of students' mathematics self-efficacy in different learning scenarios for future teachers can be measured. By this, lectures and tutorials can be evaluated regarding to the change of the mathematics self-efficacy.

ACKNOWLEDGMENTS

Work described in this article is funded by the German Federal Ministry of Education and Research.

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