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tmcs@science.unideb.hu
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Self-regulated learning in mathematics lessons at secondary level

Sophie Rusznak and Stefan Götz

Abstract. Self-regulation is a prerequisite to be able to set goals and to find suitable ways to reach them. Furthermore, it is an important ability which affects different areas of every day's life. In educational context, self-regulation is often linked to self-regulated learning. The concept of self-regulated learning as well as key terms related to this topic such as problem-solving and modelling tasks will be discussed, while an emphasis lays on the role of the teacher. In this paper, a study on the attitudes of mathematics teachers towards self-regulated learning is presented. It focuses on teachers' assessment of the possibility and limitations of self-regulated learning in mathematics lessons. It can be observed that most of the surveyed teachers try to incorporate self-regulatory processes in their teaching, but encounter difficulties related to various factors, such as their students, framework conditions, and the time required for such learning processes.

Key words and phrases: mathematics education, self-regulated learning, empirical qualitative research, mathematics teachers' attitudes.

MSC Subject Classification: 97D10.

Introduction

Self-regulation plays an important role in numerous aspects of life. It is fundamental for being able to set goals and find suitable ways to achieve them. The steadily rising importance of lifelong learning (e.g., Bundesministerium für Bildung, Wissenschaft und Forschung, 2021, p. 434) as well as digitalization require students to control and optimize their learning. Studies (Perels et al., 2009;

Zimmerman et al., 2011) show that self-regulating abilities are essential for successful learning. In general, self-regulation is defined as

> an active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate, and control their cognition, motivation, and behavior, guided and constrained by their goals and the contextual features in the environment. (Pintrich, 2000, p. 453)

Self-regulated learning is a component of self-regulation, which includes both subject-related and interdisciplinary skills that can be required in a school or university context, but also in other areas of everyday life. Self-regulation refers not only to learning itself, but also to the ability to manage the learning process. It therefore does not describe an action, but a competence for a process that does not necessarily has to be related to learning but can take place in different areas of life (Stoppel, 2019, pp. 45 et seq.). There are different definitions for self-regulated learning. Götz (2017, p. 146) uses a definition which considers the aspects of self, regulation and learning. He describes learning as a "form of acquiring knowledge and competences, in which the learner sets his own goals and chooses strategies in order to reach this goal". Moreover, the learner modifies his or her strategies according to the difference of his or her present state and his or her goal. Two additional key concepts, which play an important role according to this definition, require clarification: motivation and self-motivation. Motivation refers to the psychological processes that are activated throughout the entire course of an action, including the initiation of a selected behavioural option. The specific motivation for a given action is influenced by both individual characteristics and situational factors. In this context, goals and the feasibility of attaining them are evaluated, and possible courses of action are weighed (Götz, 2017, p. 82). Self-motivation, which is also referred to as intrinsic motivation, derives its value from the action itself. It is characterized by an individual's willingness to engage in an activity because it is inherently satisfying or rewarding, either due to the enjoyment of the activity itself or because the topic is perceived as interesting (Götz, 2017, p. 89).

Recent research shows that students who rely on self-regulated learning strategies tend to set goals independently and generally display better results than students who use traditional learning methods, such as frontal instruction or other teacher-centred approaches. Moreover, studies show that self-regulated learning promotes sustainable learning for all types of learners, while traditional learning primarily caters to certain types of learners (Gardenia et al., 2017, p. 12). A meta-study conducted by Donker et al. (2014), which includes 58 studies performed on self-regulated learning in primary and secondary education, shows that these strategies improve writing skills (Hedges' $g = 1.25$), as well as performance in science ($g = 0.73$) and mathematics ($g = 0.66$). Furthermore, all strategies that were taught proved to be effective, whereby, for example, the cognitive strategy of repetition ($g = 1.39$) or metacognitive knowledge about self-regulated learning showed a large effect (general knowledge $g = 0.97$, knowledge about own learning $g = 0.94$).

Theoretical frame

Self-regulation in mathematics lessons

As stated in the Introduction, self-regulated learning is mainly based on designing one's learning-process. This includes setting goals and choosing strategies (Giger, 2014, p. 26). The right learning-situation is designed in a way that enables personal responsibility and an independent choice of strategies (Gardenia et al., 2017, pp. 10 et seq.). Pintrich (1999) divides these strategies for self-regulated learning into three categories: cognitive learning strategies, metacognitive learning strategies and resource management strategies (see also Azevedo, 2009). Cognitive learning strategies include repetition, elaboration and organisational strategies. The strategies can be used for both simple tasks (such as repeating information, words or lists) and more complex comprehension tasks. Additional to cognitive strategies, metacognitive knowledge and the application of metacognitive strategies can also have an important influence on learners' success. There are two general aspects of metacognition: knowledge about cognition and self-regulation of cognition. Metacognitive knowledge refers to learners' knowledge of how to control and regulate their cognitive activities. Self-regulation subsequently refers to the application of this knowledge and to concrete actions: "[...] metacognition is monitoring and controlling what's in your head; self-regulation is monitoring and controlling how you interact with your environment; and self-regulated learning is the application of metacognition and self-regulation to learning [...]" (Mannion, 2020). Most theoretical models of self-regulatory strategies include three categories: planning, monitoring and regulation. Resource management strategies include techniques that learners use to control their learning environment.

Especially in mathematics didactics, heuristic strategies play an important role. The term 'heuristic' is used to summarise different problem-solving techniques. By practising these heuristic tools and strategies, deficits in problem solving can potentially be compensated for (Gürtler et al., 2002, p. 226; Schoenfeld, 2016). As described by Bruder (2005), self-regulatory strategies have multiple advantages for learners in mathematics lessons. Self-motivation can be increased, pupils become familiar with various heuristic strategies, practice dealing with mistakes becomes natural and taking responsibility for their own learning would become a matter of course. They become familiar with structured learning and develop techniques that help to make their own learning more effective. Bruder (2005) describes how the learning process can be supported by self-regulation: It helps learners to get an overview, to set one's goals and to plan as well as organize the learning process. During learning they choose suitable strategies and ask for help if needed. At the end of the learning process, students use self-regulation to reflect on their learning.

There are numerous approaches to support students in developing self-regulated learning strategies. Many methods focus on subject-specific teaching which is often followed by transfer. Ormrod (2006, p. 356) states that there are different aspects (goalsetting, monitoring, planning, evaluation, motivation and freedom of self-regulation) which can be used as guidelines to encourage students' self-regulated learning abilities.

In mathematics didactics, exercises that involve problem solving as well as modelling tasks play an important role, as they are often related to metacognitive and self-regulatory learning strategies. Learners first set themselves goals and adaptively select the appropriate approach from a repertoire of strategies. The result is then compared with the goal, which may subsequently lead to a change of the goal or of strategy (Sjuts, 2016). These two kinds of tasks have also been considered in the conducted study presented later.

Problem solving and modelling tasks

A problem task is characterised by the lack of ready-made solution schemes or known algorithms for solving it. Working on the task is understood as a process in which problem solving occurs (Herold-Blasius, 2021, p. 83). Problem solving means the application of mathematical knowledge, skills and abilities to problem tasks (Pólya, 2014; Schoenfeld, 1985). On the one hand, solution strategies are developed; on the other hand, it is important to recognize and use known concepts by transferring known strategies to similar situations (Mason et al., 2010). The ability to argue also plays an important role when it comes to metacognition. To be able to tackle problems, learners constantly draw on self-regulatory processes, in particular planning and monitoring learning processes as well as evaluating their goals and results (Sjuts, 2016, p. 217). Problem solving involves two subprocesses: problem representation and the actual solving process. During the problem-solving process, students continuously use activities related to self-regulation, such as metacognitive, motivational or cognitive strategies, according to Herold-Blasius (2021, p. 115). Using specific heuristic strategies as well as being aware of various methods can help to reduce deficits (Gürtler et al., 2002, pp. 225 et seq.).

Modelling tasks focus on an authentic, real-life situation. Firstly, the task must be structured and analysed. Then the learner needs to find out how mathematics can help to describe and ideally solve the problem presented. These kinds of tasks are usually not exercises on a specific area, as they usually cover several mathematical sub-areas (Humenberger, 2017, pp. 109 et seq.). Solving a modelling task can be described with the modelling cycle according to Blum and Leiß (2005): The starting point of the modelling process is a situation from the rest of the world that contains an authentic problem that is to be solved using mathematical tools. Depending on knowledge, goals and interests, this situation is first abstracted into a model. Tasks to be solved by modelling include optimization processes or technical problems. If necessary, real data must be collected in order to get a solution. Through a so-called mathematization process, all relevant information from the rest of the world is translated into mathematics, resulting in a mathematical model. Subsequently, mathematical methods are applied to answer the questions that arose during the translation of the real problem. In the next step, the previous process is validated. This involves checking whether the developed model and the interpreted mathematical results appear plausible about the original problem. If this is not the case, individual steps or the entire process must be repeated using a modified or even a completely new model. Finally, the solution to the original real-world problem is presented (Wess, 2020, pp. 12 et seq.).

Blum et al. (2007) refer to the skills involved in the solution process described in the modelling cycle as so-called modelling competences. These include the following sub-skills: Understanding, simplifying, mathematizing, mathematical work, interpreting, validating and communicating. At this point, we will focus on the two skills of mathematizing and working mathematically. On the one hand, mathematizing means transferring relevant information into a mathematical model and selecting a suitable mathematical form of representation. Mathematical work, on the other hand, involves applying suitable heuristic strategies and mathematical knowledge to solve the problem. It should be noted that the focus of the sub-competencies can be different for other cycle models, but mathematical work is usually not considered as it is not specific to the modelling process (Hankeln & Greefrath, 2021, p. 370).

An example for a modelling task is the so-called "fuel-problem" (as in Blum et al., 2010, p. 42): In this task, students are asked to calculate whether it is worth travelling further for a cheaper fuel price filling up or nearby at a higher price. The first step is to determine how "it is worth" is interpreted. If it is understood as cost savings, this results in an approach that requires the definition of parameters for tank volume, petrol consumption and the distance to the petrol stations. The total cost can be calculated by adding the cost of the petrol filled plus the cost of the petrol which is needed to drive to the petrol station. Furthermore, students have to make assumptions about those parameters that are not given in the task. There are different solution approaches, but they all require a translation of a real-life situation into the world of math. Then the learner goes through the steps of the modelling cycle to get to a result.

Even though the usage of strategies is important in all areas of mathematics, the strategic repertoire plays a special role in solving modelling tasks. In most cases, a variety of activities are needed which requires learners to use different strategies. These are the cognitive strategies already mentioned (repetition techniques, elaboration and organizational strategies) on the one hand, and metacognitive strategies on the other (Schukajlow & Leiss, 2011, pp. 56 et seq.). Krüger (2021, pp. 51 et seqq.) defines metacognitive strategies in connection with modelling tasks as the targeted use of cognitive strategies from the areas of planning and organization, monitoring and regulation as well as evaluation. Studies have shown that the use of metacognitive strategies simplifies work on application tasks, can be helpful in overcoming obstacles and increases commitment and attention during task processing. Although metacognitive skills do not yet guarantee optimal learning behaviour on the part of learners, they do provide the foundation for the use of suitable learning strategies. Particularly in mathematical modelling, metacognitive strategies have been shown to have a positive effect on the learning process, see, for example, Schneider & Artelt (2010).

Methods and sample

To gather information on mathematics teachers' integration of self-regulating learning in their teaching, an online survey which asked about different aspects of self-regulated learning was conducted. Based on former studies, such as Baumert et al. (2019), Rakoczy et al. (2005), Maag-Merki et al. (2015) and Diel (2011), 31 questions were developed. 16 of these questions were closed-ended, using a 5-point Likert scale (including "no answer"), while nine were open-ended. Six items are dedicated to personal attributes (age, gender, teaching experience, for example). Thus, this survey makes use of the so-called embedded (or nested) design, following the mixed-methods-approach according to Kuckartz (2014).

The open questions in the questionnaire were analysed using the content-structuring qualitative content analysis according to Kuckartz and Rädiker (2022). Based on the research question "How do teachers at secondary schools asses the possibilities and limitations of self-regulated learning in mathematics lessons?", subcategories were developed inductively for each question after reviewing and summarizing the material; the main categories could already be deduced from the questions posed (e.g., difficulties in carrying out self-regulated learning processes, prerequisites for self-regulated learning processes). According to Kuckartz and Rädiker (2022), one text passage can be assigned to more than one category.

In the next step, the initially formulated categories were differentiated and subcategories matching the main categories were formed. This involved going again through the text passages already coded with the main categories and creating new subcategories on a case-by-case basis. Finally, the results of the coding processes were analysed, whereby, on the one hand, a category-based analysis along the main categories (guided by the questions "What is said about this topic?" and "What is not or only marginally mentioned?") is carried out and, on the other hand, the connections between subcategories and the related main category are analysed.

To be able to analyse certain aspects that were addressed in the questionnaire in more detail, selected variables were combined to form a key figure (index). According to Latcheva and Davidov (2019, pp. 893 et seqq.), the term index refers to the combination of several individual indicators into a new variable. This is an evaluation procedure that results in a reduction of data.

After an initial review of the responses, the two indexes "Use of self-regulated learning processes" and "Use of problem-solving and modelling tasks" were created using SPSS. For the evaluation of the indexes, values between 1 and 4 were assigned to the response options "strongly disagree" (= 1), "somewhat disagree" (= 2), "somewhat agree" (= 3), and "strongly agree" (= 4). An average value (arithmetic mean) for each participant was then calculated from a person's answers to the questions of the respective index. In this context, the data is considered to be quasi-metrically scaled (Völkl & Korb, 2018, p. 20). The selected indexes are analysed with regard to statistical characteristics on the one hand, and the connection between the groups of people surveyed and their answers is presented on the other.

The survey was conducted from May 2023 until July 2023. 52 teachers from secondary schools of different types (middle school, gymnasium, vocational college) spread over entire Austria took part. 75% were female, the age ranges from 24 to 60, whilst the average age is 37 years. Although the sample size is rather small, this study allows to give insights into tendencies among the group surveyed. Moreover, the results provide interesting approaches for further research.

The results presented in this article are in line with other studies on the same subject. As an example, Vandevelde et al. (2012, pp. 1566 et seqq.) conducted a study involving 162 teachers from Flemish elementary schools, investigating the challenges associated with implementing self-regulated learning processes. The findings were consistent with those observed in the present study.

Results

Evaluation of the open questions

In the following, the detected subcategories are presented, sorted by the related main categories.

In Table 1, the subcategories of the main category "Difficulties in the implementation of self-regulated learning" which were identified through the participants' answers are listed and explained.

Most interviewees identified learners as an obstacle to the implementation of self-regulated learning processes. This subcategory could be assigned to 41 text passages, which equals 59% of all passages in this category. In detail, it was mentioned most frequently by all teachers, regardless of their years of service (furthermore, for teachers with 11 to 20 years of service, it was mentioned just as often as the subcategory time).

Moreover, it should be noted that only two participants mentioned the role of the teacher in this context. A lack of knowledge about the use of methods for self-regulated learning was also not mentioned at all, although 43 of the 52 participants stated that they had not been confronted with this topic during their training. However, some of the interviewees do consider the teacher's knowledge regarding self-regulated learning processes to be a prerequisite. Problems with heterogeneous classes are also repeatedly mentioned.

Subcategory	Distinction of the respective subcategories	Example
Time	Includes mentions of the lack of time in lessons (more lessons per week, need of more double lessons, too little time due to set exams) or preparation time	"[…] it takes a lot of time in the classroom and in preparation […]" (P31, item 1)
Learners	Includes mentions of learner skills, learner attitudes or class dynamics	"impatient [students] who also don't want to make an effort and simply demand 'recipes', many have little interest in math [...]" (P33, item 1)
Framework conditions	Includes mentioned systematic framework conditions (class size, team teaching, curriculum, testing, frequent teacher changes, ...)	"Curriculum, centralized [testing] [...]" (P24, item 1), "Lack of team teaching in large classes." (P2, item 1)

Table 1. Subcategories difficulties in the implementation of self-regulated learning

If one takes into account the responses in relation to years of service, it becomes clear that it was primarily respondents who have worked as a teacher for ten years or less who identified framework conditions as a difficulty. Only a fraction of teachers with more than ten years of experience sees the framework conditions as a problem, too, when it comes to the implementation of self-regulated learning processes.

As already mentioned, Vandevelde et al. (2012, pp. 1566 et seqq.) came to comparable results. In an open question about "hampering factors of SRL practices" (SRL – self-regulated learning), around 40% (27% in the presented study) of the participants stated "Lack of time and work pressure" (i.e.: Lack of time to realize SRL practice due to an overloaded curriculum, too many side and after-school activities. SRL practices are time consuming and demand a lot of teachers, while they are already over-tasked.) as a difficulty. Vandevelde et al. (2012, p. 1567) identified the category "Diversity" (i.e.: Diversity between pupils regarding intelligence, prior knowledge, social background, home situation, self-confidence, and self-regulatory skills.) as the second most common difficulty (for just under a third of respondents).

Although the answers in that study were divided into more differentiated categories than those in Table 1, there are obvious parallels in terms of the results. In both surveys, teachers primarily mentioned aspects relating to learners, the general conditions and a lack of time in the school day. However, in the study by Vandevelde et al. (2012), the lack of familiarity was also identified as a category for at least 11% of respondents.

Concerning the main category "Prerequisites for the success of self-regulated learning processes", the interviewees stated a variety of prerequisites for successful self-regulated learning in mathematics lessons. These include small class sizes, appropriate class dynamics and a pleasant learning environment. Teachers should start from the first grade and gradually introduce pupils to self-regulated learning processes. Consolidation of basic skills as well as motivation and self-initiative on behalf of learners are also significant. Another aspect that is mentioned by many participants is the time factor (see Table 2).

Subcategory	**Distinction of the respective subcategories**	**Example**
Framework conditions	Includes named systematic framework conditions (class size, team teaching, curriculum, testing, frequent teacher changes, ...)	"Fewer children in a class, more staff, less material in the [curriculum]" (P16, item 2)
Learners	Includes comments concerning learners (motivation, interest, skills, working atmosphere, ...)	"[...] quiet working environment, motivation" (P51, item 2)
Time	Includes mentions of time (more time, double lessons, more math lessons, ...)	"More math lessons = time, difficult to do with [two] weekly lessons in the long term" (P49, item 2)
Teachers	Includes mentions of teacher skills or actions (preparation, knowledge of self-regulated learning, ...)	"Structure in lessons, self-regulated learning must be [introduced] slowly" (P12, item 2)

Table 2. Subcategories prerequisites for the success of self-regulated learning processes

It is noteworthy that the subcategories framework conditions, learners and time were identified once again. The subcategory "Framework conditions" was mentioned most frequently by the respondents (32% of all coded text passages), followed closely by the subcategory "Time" (30% of all coded text passages). The subcategory "Learners" could be identified 16 times (21% of all coded text passages), and "Teachers" 13 times (17% of all coded text passages).

Evaluation of the closed-ended questions

In the second and third sections of the questionnaire, the participants were asked about the specific use of self-regulatory processes in their lessons. Questions 7 to 14 were aimed at general self-regulatory processes, and Questions 15 to 21 at the use of problem-solving and modelling tasks.

In general, it can be stated that almost all the participating teachers are quite open to self-regulated learning. The answers to items 7 "I discuss with my students how they can best learn independently" and 8 "If yes, in what form does this take place? (selectively, continuously, are special materials used?)" are presented. As shown in Table 3, most of the respondents answered this question positively. Although the conducted t-test resulted in a p-value of 0.185, there could still be a difference in the use of self-regulated learning between genders: women tended to respond more positively to the question Q7 (Table 3) compared to men. The lack of a statistically significant difference might, however, be due to the small sample size. Further research with a larger sample would be necessary to determine whether a significant gender difference exists in this context.

Q7 I discuss with my students how they can learn independently.

		Frequencies	Percentage	Valid Percentage	Cumulated Percentage
Valid	1 Do not agree at all	1	1,9	1,9	1,9
	2 Tend to disagree	5	9,6	9,6	11,5
	3 Tend to agree	33	63,5	63,5	75,0
	4 Strongly agree	13	25,0	25,0	100,0
	Total	52	100,0	100,0	

Table 3. Evaluation of the answers to Question 7

In response to the related open question, 17 of the 52 respondents stated that they only occasionally discuss with their pupils how they can best learn independently. Most of them mentioned talking about this before assignments. Twelve teachers, on the other hand, do this on an ongoing basis, for example, through regular feedback discussions with learners. It is interesting to note that all male respondents who answered this question stated that they only occasionally talked to their students about independent learning. For the female respondents, on the contrary, the number of answer categories was balanced.

Analysis of items 15 to 21 revealed that almost all the surveyed teachers work with problem-solving and modelling tasks at least occasionally. The items 15 (Table 4) and 19 (Table 5) were specifically aimed at the use of these tasks. It is noticeable that the answers to item Q19 were mostly positive, as seen in Table 5. A chi-square test of homogeneity reveals highly significant differences of the distributions shown in Table 4 and Table 5.

Twelve respondents answered the related open question on how often problem-solving tasks are used with "(rather) rarely". Ten of the survey participants use problem-solving tasks frequently – at least once per subject, weekly or even almost every lesson. Most of the respondents use problem-solving tasks during practice phases. Other areas of use mentioned include open work phases, "project lessons", introductions or as a "bonus task for faster students at the end of a subject area". Interestingly, regardless of the type of school, respondents state that they rarely use problem-solving tasks due to the performance level of their pupils. Furthermore, as seen in Table 5, almost all participants think it is important that their students can convert everyday situations into mathematical models.

Q15 In math lessons, I work with tasks in which my students must solve problems.

		Frequencies	Percentage	Valid Percentage	Cumulated Percentage
Valid	1 Do not agree at all	1	1,9	2,0	2,0
	2 Tend to disagree	12	23,1	24,5	26,5
	3 Tend to agree	26	50,0	53,1	79,6
	4 Strongly agree	10	19,2	20,4	100,0
	Sum	49	94,2	100,0	
Missing	-9	3	5,8		
Total		52	100,0		

Table 4. Evaluation of the answers to Question 15

Q19 It is important to me that my students can translate everyday situations into mathematical models.

		Frequencies	Percentage	Valid Percentage	Cumulated Percentage
Valid	1 Do not agree at all	1	1,9	1,9	1,9
	2 Tend to disagree	2	3,8	3,8	5,8
	3 Tend to agree	20	38,5	38,5	44,2
	4 Strongly agree	29	55,8	55,8	100,0
	Total	52	100,0	100,0	

Table 5. Evaluation of the answers to Question 19

Analysis of the index values

For the index "Implementation of self-regulated learning processes", the following items were selected from the section "Use of self-regulatory processes in the classroom" of the questionnaire, with the response scale for Question 11 being reversed:

(Q7) I discuss with my students how they can best learn independently.

(Q9) I try to teach my students different strategies to solve problems.

(Q10) I let my students explain their thought processes and solutions in detail.

(Q11) I prefer to give my students a standardized solution path. (Reversed answer scale!)

(Q12) I allow my students to find their own solutions when working on a task.

(Q14) It is important to me that the students check whether they are on the right track when working on an assignment.

An average value (arithmetic mean) can be calculated from a person's answers to the questions in the respective index. In this context, the data is viewed as quasi-metrically scaled (Völkl & Korb, 2018, p. 20).

Figure 1 shows the distribution of the determined index values. A mean of 3.24 indicates a high index level, as also illustrated in the corresponding diagram. The low standard deviation (0.354) suggests a narrow distribution of values around the mean. It can be concluded from these key figures that most participants attempt to integrate self-regulated learning processes into their lessons. The study by Dignath-van Ewijk and van der Werf (2012, p. 7) produced a similar

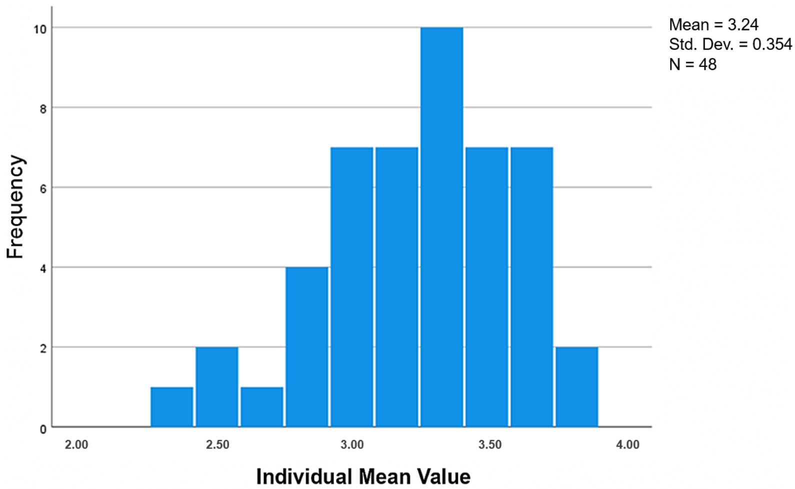

Figure 1. Distribution index implementation of self-regulated learning processes

result, with only seven of the 45 primary school teachers surveyed stating that they did not integrate any aspects of self-regulated learning into their lessons.

However, the associated Cronbach's alpha value of 0.548 indicates a low internal consistency of the index. This could be since the teachers surveyed do not use all aspects of self-regulated learning in their lessons, but only selected ones. It can also be seen that the mean value of the indices of the female participants (3.28) is (not significantly) higher than the mean value of the male participants (3.13). If we look at the indices regarding the type of school at which the respondents teach, the indices of teachers at vocational secondary schools (3.39) and grammar schools (3.36) are higher than those of teachers at secondary schools (3.15). An ANOVA test was used to check the significance of the differences in the responses according to the three school types. The calculated p-value of 0.121 is above the usual significance level of 0.05, which is why the differences cannot be regarded as statistically significant in this case. However, due to the small sample size, this value could nevertheless indicate that there are differences between the school types that would possibly be more clearly visible with a larger sample.

The following items were selected for creating of the index "Implementation of problem-solving and modelling tasks":

(Q15) I work with tasks in mathematics lessons that require my students to solve problems.

(Q18) It is important to me that my students can argue mathematically.

(Q19) It is important to me that my students can translate everyday situations into mathematical models.

(Q20) For me, teaching mathematics means, among other things, getting students to think about mathematical relations.

Figure 2 shows the distribution of the index values. The mean value at 3.39 is similar to the previous one, but this index has a higher standard deviation (0.44) as in Figure 1. The calculated Cronbach's alpha value of 0.667 indicates an acceptable consistency of the index. It can be assumed from the values obtained that most respondents use problem-solving and modelling tasks (which are closely associated with self-regulated learning processes) in their lessons (Tables 4 and 5). The comparison between male (3.46) and female (3.36) teachers demonstrates a negligible difference in mean values. The analysis of the index values by type of school is like the 'use of self-regulated learning processes' index. Teachers at vocational secondary schools (index value 3.50) and grammar schools (index value 3.47) gave more positive responses than those who teach at secondary schools (index value 3.31). The differences are not significant.

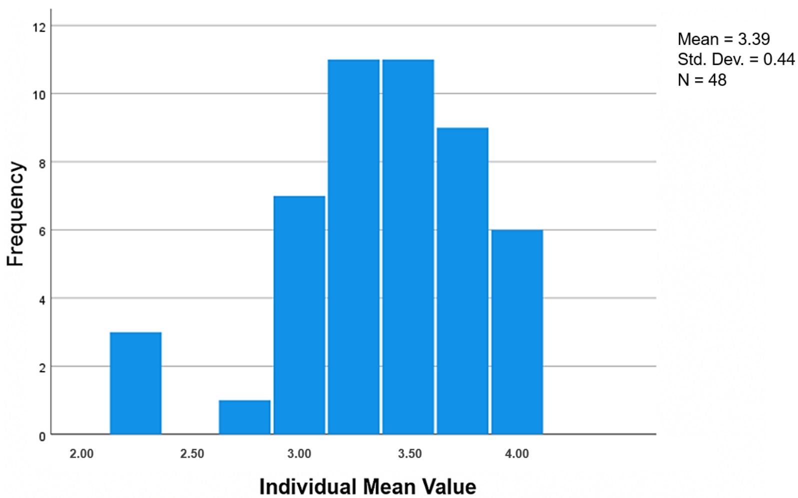

Figure 2. Distribution index implementation of problem-solving and modelling tasks

Conclusion

The question regarding the assessment of the possibilities and limitations of self-regulated learning in mathematics lessons by secondary school teachers is answered in a revealing way by the results of the questionnaire. From the responses of the 52 teachers, as shown in Table 1, a lack of time, learners' attitude and mathematical skills as well as difficult framework conditions were identified as the most important obstacles to the implementation of self-regulated learning processes. The subcategories time, learners and framework conditions were identified from the responses of the teachers surveyed. The analysis by seniority also shows that the teachers surveyed with ten or fewer years of service primarily see the prevailing framework conditions as a challenge to self-regulated learning. In contrast, only a small proportion of teachers with more than ten years of service consider these conditions to be problematic for the successful implementation of self-regulated learning processes. It can also be seen that similar studies (for example, Vandevelde et al., 2012) come to comparable conclusions. However, a significant difference to the study by Vandevelde et al. (2012) is that the competence of the teacher was virtually unmentioned as a difficulty by the respondents in this study.

In general, a predominantly positive attitude towards the use of self-regulatory learning processes was found among the mathematics teachers surveyed. Most respondents stated that strategies for independent learning are discussed and that problem-solving and modelling tasks are used in class, as can be seen in Table 3, Table 4 and Table 5. In this context, two index values were created that summarise the answers to selected questions (Figure 1 and Figure 2). This procedure revealed that most respondents try to integrate self-regulated learning processes in lessons, which is also compatible with the results of similar studies (e.g., Dignath-van Ewijk & van der Werf, 2012).

These insights open up interesting perspectives for future research in self-regulated learning in math lessons. For example, further research could focus on finding out which of these identified success factors (Table 2) are effective, and to what extent they have a positive effect on the promotion of self-regulatory learning processes among learners.

In conclusion, however, it must be emphasized once again that the significance of the results presented is limited due to the number of participants ($n = 52$), which must be considered when generalizing and transferring the results to all teachers. Another limitation is that the probands provided self-reports. This can lead to subjective distortions. However, it was found that other studies in which teachers were asked about self-regulated learning came to similar conclusions.

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SOPHIE RUSZNAK
UNIVERSITY OF VIENNA, AUSTRIA

E-mail: sophie.rusznak@univie.ac.at

STEFAN GÖTZ
UNIVERSITY OF VIENNA, FACULTY OF MATHEMATICS, AUSTRIA

E-mail: stefan.goetz@univie.ac.at

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