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Self-Assessment by Self-Questioning in the Instructional and Practical Phases of Mathematics Learning

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Annotation. In this paper, we present a study in which we developed a self-assessment model based on students' self-questioning, and investigated its impact on improving the accuracy of students' self-assessment. The impact of the model was determined on a sample of 164 Grade 7 students in the instructional and practical phases of mathematics learning. It was found that the use of the model resulted in improved accuracy in students' self-assessment in both phases and, for low- and high- achievers.

Keywords: *accuracy of self-assessment, instructional and practical phases of learning, mathematics teaching, self-assessment by self-questioning.*

Introduction

In the last two decades the concept of self-assessment, whose origins date back to the 1930s and 1940s (Brookhart, 2009), has become important as an aspect of the study of formative assessment and as one of key competencies and lifelong learning in the context of the European trends in quality education. As an element of formative assessment, self-assessment is essential for supporting and guiding students in their learning and for involving them into critical evaluation of their own work (Black & Wiliam, 1998). In her meta-analysis, Andrade (2019) found that the term self-assessment has been used to describe a variety of activities, but she pointed out that it should be formative. Self-assessment may refer to an estimate of a student's own understanding of the learning content or to his performance in an activity or task. It can be expressed quantitatively (e.g., number of tasks solved, number of points earned, or a numerical grade) or qualitatively (e.g., describing one's strengths and weaknesses). Many studies confirm the importance of self-assessment for an individual's learning progress (Karaman, 2021). For this reason, self-assessment should be seen as a learning strategy and not as a substitute for other types of assessment (Yan, 2020). Also, self-assessment is a process that supports the development of learning to learn competence and is important as one of the key competences and lifelong learning in the context of European trends in quality education (Yan, 2020).

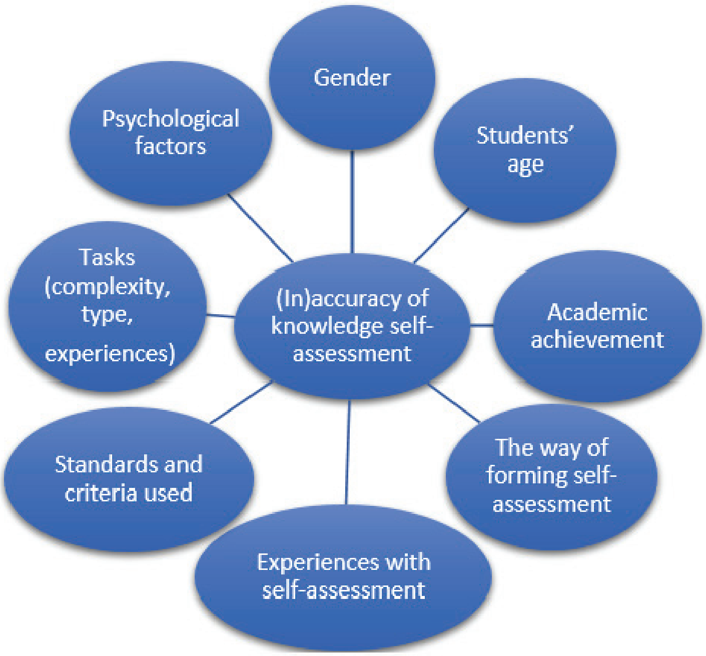
Formative assessment of teaching and learning fits well with inquiry-based learning, where the teacher's role is to facilitate learning rather than direct students along a particular path (Koksalan & Ogan-Bekiroglu, 2019). There are different levels of inquiry-based learning, from open inquiry to more closed levels of inquiry. In an open inquiry students contribute their ideas for exploring the topic by asking questions themselves (Herranen & Aksela, 2019; Harrison et al., 2018). More closed levels of inquiry are structured and guided by the teacher (Herranen & Aksela, 2019; Koksalan & Ogan-Bekiroglu, 2019). In both cases, students take an active role in the learning process and have to learn independently to some extent. For this reason, it is important to teach students self-assessment strategies that help them to identify the goals of the lesson, identify their prior knowledge, self-assess their progress in problem solving, and evaluate the quality of their work.

In this paper, we present factors that influence the accuracy of students' self-assessment, and the importance of self-assessment accuracy in the learning process. In the central part of the paper, we describe a model of self-questioning that we developed in order to improve the accuracy of students' self-assessment. We also consider the impact of the model on the accuracy of students' self-assessment in mathematics.

Factors of (in)Accuracy of Aelf-Assessment

The accuracy of self-assessment is a measure for the agreement between students' self-assessments and assessment in accordance with some absolute standards (Sadler & Good, 2006). Inaccuracy of self-assessment can be caused by various factors. Panadero et al. (2015) emphasise two of them: first, students base their self-assessment on emotions rather than their actual abilities; and second, students' form unrealistic ideas of what they have learned. In the latter case self-assessment can be incorrect because students feel that they master the learned topic or they have a prejudice that they cannot be successful. Inaccuracy of self-assessment can also be due to lack of feedback about one's performance, to neglecting relevant information in the feedback received, or to basing self-assessment on less relevant criteria (Dunning et al., 2004). Students' wrong ideas of their knowledge are due to several causes related to various factors associated to students' self-assessment. We succinctly show them in Figure 1.

Figure 1
Factors of (In)Accuracy in Self-Assessment



The relationship between various factors and the accuracy of self-assessment was widely researched in the past. Several studies (e.g., Brown & Harris, 2013) found that the accuracy of students' self-assessment improves with increasing age. The results of studies on the influence of gender on the accuracy of students' self-assessment are contradictory. O'Neill (1985) found that girls are more accurate in self-assessment, while some other authors (e.g., Boud, 1995) found the opposite. Studies that examined the relation between academic achievement and the accuracy of self-assessment (e.g., Boud, 1995; Brown & Harris, 2013; Oudman et al., 2022) found that high-achievers are more accurate in self-assessment than low-achievers. Leon et al. (2021) showed in their study that low-achievers tend to over-estimate their performance while high-achievers under-estimate their performance. The accuracy of self-assessment also depends on the way in which it was formed: self-assessment may be based on comparing one's knowledge to the knowledge of a (sub)group of schoolmates, to perceived teacher's expectations or otherwise. The most relevant is the comparison of their own self-assessment with that of the teacher (Leach, 2012). Moreover, the accuracy of self-assessment is related to the type of self-assessment we expect from students. Hattie (2013) claims that students' self-assessments of general knowledge of a topic are more accurate than those related to specific tasks. Ramdass & Zimmerman (2008) found that self-assessed performance of solved tasks is more accurate than self-assessed prediction of performance. Once a task is solved, students have a better idea about their own knowledge (Hacker et al., 2000). The accuracy of self-assessment is influenced also by previous experiences with the task. Students' self-assessment is more accurate on tasks with which they are familiar. Task difficulty affects the accuracy of self-assessment as well. Students are more likely to underestimate themselves on difficult tasks, while they overestimate themselves on easy tasks (Krüger, 1999). In addition, the accuracy of self-assessment is influenced by teaching-related factors. Panadero et al. (2015) found that students' knowledge of self-assessment criteria influences self-assessment accuracy. When assessment criteria are concrete and well specified for students, students are more likely to make accurate self-assessment (Hosein & Harle, 2018). Also, for this reason, it is important that teachers in the classroom clearly state the learning objectives, criteria, and standards (Andrade & Valtcheva, 2009). Several studies (e.g., Brown & Harris, 2013; Ramdass & Zimmerman, 2008) found that students improved the accuracy of their self-assessment if they were engaged in the process of self-assessment during instruction. In this regard, it is important for teachers to encourage students to regularly reflect on their learning and understanding. Huff and Nietfeld (2009) showed in their study that training students to self-monitor while solving tasks improved the accuracy of their self-assessed performance in solving tasks within just two weeks.

The Importance of Accuracy in Student Self-Assessment

There are two basic views on the importance of students' self-assessment accuracy in the learning process. On the one hand, there are researchers (e.g., Brown & Harris, 2013; Dunning et al., 2004) who have found out that the accuracy of students' self-assessment has a significant impact on improving students' academic achievement. To this, Brown & Harris (2014) add that accurate self-assessment enables students to adopt appropriate decisions in the learning process. Several studies (Brown & Harris, 2013) have also shown that self-assessment practice particularly improves the academic achievement of low-achievers. Leon et al. (2021) emphasise that inaccurate student self-assessment can even cause harm in classroom settings (e.g., task avoidance, not enrolling in future subjects). All these facts indicate that it is useful to support students in developing the accuracy of their self-assessment. On the other hand, other authors (e.g., Andrade, 2010) emphasise that self-assessment is an important process that mainly helps students develop an awareness of the quality of their work and criteria that can be used to evaluate it. The accuracy of self-assessment is less important here, as even accurate self-assessment can be useless if it is not based on relevant criteria that are linked to learning objectives, and thus does not help students figure out what they know and what they still need to learn. Thus, what really matters in self-assessment is not its accuracy, but the active involvement of students in the learning process, which improves their reflection and metacognitive monitoring, and leads to better learning (Yan, 2016). Accuracy in self-assessment should be viewed in this way also in inquiry-based learning approach. During an inquiry activity, students seek answers to questions raised by teachers and need feedback on their progress (Harrison et al, 2018). Students' attention is to the self-learning process and appropriate learning content (Dagys, 2017). In this way students become more independent learners and develop their self-regulation skills (Schramm, 2018).

Formulation of the Problem and the Research Questions

Since it is important to develop self-assessment skills in the learning process, several models and techniques for teaching self-assessment have been developed. Rolheiser & Ross (2001) considered the question of what types of self-assessment techniques improve students' academic achievement and the accuracy of self-assessment. They suggest that the self-assessment process should be carefully designed; it should provide students with explicit criteria at an appropriate level of generalization; involve students in self-assessment decision making; enhance student recognition of their achievement, which is based on setting learning objectives and criteria; and that it should be integrated in the teaching process.

Self-questioning is an important self-assessment strategy that should be taught to students, because it helps them self-evaluate their learning and monitor their understanding (Dogan & Yucel-Toy, 2021). Dogan & Yucel-Toy (2021) also claim that self-questioning helps students develop metacognitive skills because asking questions gives opportunities to students for self-evaluating their learning, monitoring their understanding, and developing their own cognitive process. Self-questioning (e.g., "What do I know about this topic?") also supports students' knowledge construction (Chin & Chia, 2004). Correia and Harrison (2019, p. 28) have suggested some questions (e.g., *"Can I explain my idea clearly to another person? Does this idea make a sense to me? How does fit into what I already know?"*) that allow students to reflect on their learning during inquiry-based activities. Therefore, one of the self-assessment strategies for students could be to ask themselves appropriate questions that enable them to self-assess and self-regulate the learning process during different learning activities. Since it is not easy for students to formulate questions, it is important to teach them how to use the strategy of self-questioning. The teacher should first demonstrate the process of self-questioning to the students. Then students need to practise the strategy to make their self-assessment more accurate (Schramm, 2018).

To find out how accurate is self-assessment by self-questioning, we devised a model for self-assessment of mathematical knowledge. The model is based on a specific type of questions which the teacher utters aloud during the presentation of the learning material as well as during the practice phase of the learning process, so that the students have the opportunity to appropriate the described teacher's way of self-questioning.

We classified the used types of questions into three categories:

1. Questions that stimulate students to verify their understanding (e.g., Did I understand well what congruence is? How can I make sure I understand what congruence is? Can I illustrate/give an example...?);
2. Questions that emphasise the necessary knowledge for understanding concepts and solving tasks (What do I have to know to understand what a bisector is? What do I have to know to solve the task? What knowledge am I supposed to show at this task? What does the task require me to do? What do I have to pay attention to when solving the task?);
3. Questions that encourage students to verify the correctness of their solutions of tasks (Is the task correctly solved? How can I verify whether the solution is correct? How can I verify if the procedure is correct? How can I verify whether I correctly reflected a line segment in a line?).

Students can ask themselves how well they understand the lesson content and thus give a general self-assessment of their understanding. Since mathematics is mainly learned by solving tasks, students can also give a self-assessed prediction on their performance in task solving beforehand, or they assess their performance of the tasks they have already solved. In our study, we consider the accuracy of three types of self-assessment: self-assessment of understanding of the mathematics content presented, self-assessed prediction of performance in task solving and self-assessed performance in task solving after its completion.

The aim of the study presented here was to investigate the effects of our model of self-assessment on the accuracy of students' self-assessment of mathematics knowledge in the presentation phase (which includes the introduction to the learning content and its explanation) and the practice phase (repetition and consolidation of the content through solving tasks).

In this perspective, we considered the following research questions:

1. Do students improve the accuracy of self-assessment of mathematics knowledge when the self-assessment model is used during the presentation of the learning content?
2. Do students improve the accuracy of self-assessment of mathematics knowledge when the self-assessment model is used while practicing learning content?
3. How effective is the self-assessment model for certain groups of students (low-achievers, high-achievers)?

Method

The participants in our study were 164 seventh graders from seven classes in three schools in major Slovenian cities and six mathematics teachers. Based on their performance on the national mathematics exams in 6th grade, students were classified into two groups: low-achievers and high-achievers. The structure of the sample can be seen in Table 1.

Table 1
Sample Structure by Performance

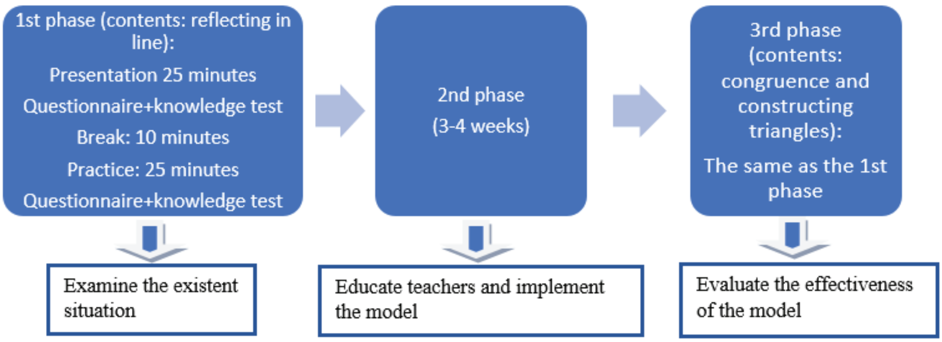
Students' performance in reference to the national examinations	N	%
Low-achievers	83	50.6
High-achievers	74	45.1
Missing	7	4.3
Total	164	100

Our study was based on a quantitative approach, using the causal-non-experimental method of educational research. Basic statistical calculations of descriptive and inferential statistics were performed. Since the values of the variables were not normally distributed, we used appropriate nonparametric tests. Effect size was expressed using Cohen's d, using the formula $d = Z/\sqrt{N}$ (Rosenthal, 1991), where Z is the standardized value obtained when determining differences for dependent samples (Wilcoxon test) and N is the number of pairwise comparisons. The effect sizes of Cohen's d were interpreted as follows: the value which varies around $d = 0.20$ represents a small effect, $d = 0.50$ represents a medium effect, and $d = 0.80$ represents a large effect (Cohen, 1988).

Our study consisted of three consecutive phases (Figure 2). In the first phase the accuracy of students' self-assessment was examined. In the second phase the innovation (teaching in accordance with the model of self-assessment by self-questioning) was implemented. Finally, in the third phase, the accuracy of students' self-assessment was re-examined and the effectiveness of the innovation was established. The accuracy of self-assessment of mathematics knowledge was determined by means of a questionnaire and a knowledge test used after the presentation and after the practice. In all phases geometry contents were considered. Comparison of the assessment accuracy determined in the first and third phases of the study provided information on how effective our model of self-assessment by self-questioning is in this regard.

Figure 2

The Course of Study



Calculating the Accuracy of Student's Self-Assessment

By the accuracy of student's self-assessment, we mean the level of its agreement with the teacher's assessment. In our study all teacher's assessments and all students' self-assessments were based on a 4-point scale (1-very poor, 2-poor, 3-good, 4-excellent). The accuracy of the self-assessment was expressed with a KMA coefficient calculated according to a formula developed by Gama (2004) and converted from a 3-point to a 4-point scale. The value of the calculated KMA coefficient ranges from -1 to 1.

An example of the calculation of the KMA value for a student's self-assessed performance in solving tasks used in our 4-point scale can be found in Table 2. For other types of self-assessment (predicted performance in solving tasks, self-assessment of understanding of the covered content) the criteria were adapted accordingly.

Table 2

KMA Values on a 4-Point Scale for Self-Assessed Performance in Task Solving

Actual performance in task solving		A student's self-assessed performance in task solving			
		I could not solve the task	I could only solve a small part of the task correctly	I could correctly solve most of the task	I could solve the task correctly
		1	2	3	4
Completely wrong task solution.	1	1	$-\frac{1}{3}$	$-\frac{2}{3}$	-1
Only a small part of the task is correctly solved.	2	$-\frac{1}{3}$	1	$-\frac{1}{3}$	$-\frac{2}{3}$
Mostly correctly solved task.	3	$-\frac{2}{3}$	$-\frac{1}{3}$	1	$-\frac{1}{3}$
Completely correct task solution.	4	-1	$-\frac{2}{3}$	$-\frac{1}{3}$	1

Data were collected with a questionnaire and a test on the learning content. In the questionnaire, which was completed after the presentation and after practice, students were asked to self-assess their overall understanding of the learned content, and to predict their performance on four tasks that they subsequently solved. After each solved task, they provided a self-assessment of their performance in solving the tasks. In the study, we considered the accuracy of three students' self-assessments:

1. Self-assessed general understanding.

After each phase of the learning process (presentation, practice), students self-assessed their general understanding of the topic learned on a scale of 1 to 4, where 1 means that the student understands very little and 4 means that the student understands everything. A rounded average of teacher's scores on the 4-point scale of the four-task test was used as the reference score. This was the basis for obtaining the KMA for self-assessment of general understanding. Students were classified into one of the groups according to their KMA value (Table 3).

Table 3
Classifying Students in Groups According to KMA Value of Self-Assessed General Understanding

KMA value	Group	Interpretation
(−1, −0.67]	Low KMA	Student's self-assessment is very or completely wrong.
(−0.67, 0.67)	Average KMA	Student's self-assessment contains a small error.
[0.67, 1]	High KMA	Student's self-assessment is accurate.

2. Prediction of task-solving performance.

For each of the four test tasks, the student predicted their own task-solving performance on a scale of 1 to 4, where 1 meant an expectation of a completely wrong solution to the task, and 4 an expectation of a completely correct solution. A student's prediction was compared to the teacher's assessment of the solved task on the 4-point scale, and the KMA was determined. The average KMA for 4 tasks was considered as the accuracy of the student's prediction. To interpret the student's average KMA, we used the same categories as Gama (2004). Accordingly, the students were classified into 3 groups (Table 4).

Table 4
Criteria for Average KMA Value for Self-Assessed (Predicted) Solution of Tasks

Average KMA value	Group	Interpretation
(−1, −0.25]	Low KMA	Student's self-assessment is incorrect in most cases.
(−0.25, 0.5)	Average KMA	Student's self-assessment is sometimes correct, but often partly or completely incorrect.
[0.5, 1]	High KMA	Student's self-assessment is correct in most cases.

3. Self-assessed performance in task-solving.

For each test task, students assessed their own performance in solving the task on the scale of 1 to 4, where 1 meant that nothing was solved correctly and 4 that everything was solved correctly. This value was compared to the teacher's assessment of the solved task on the 4-point scale, and the KMA was determined. The student's accuracy or self-assessed performance in solving was considered as the average KMA for 4 tasks. We used the same criteria for interpreting the average KMA values as for self-assessed predictions of task solving performance (Table 4). Tasks for which students did not self-assess (predict) their task solving performance were excluded from the calculations. Cases where students left a task unsolved and self-assessed it as incorrectly solved were considered as completely incorrect solutions to the task.

Results

Our model of self-assessment by self-questioning was introduced with the aim of improving the accuracy of students' self-assessment of mathematics knowledge. Considering that self-assessment is an ongoing process that occurs during presentation as well as before, during, and after solving tasks, we were interested in the accuracy of different types of self-assessments: self-assessed general understanding (**SA general**), prediction of task-solving performance (**SA ante**), and self-assessed performance in task-solving (**SA post**). In this section, we first present the results of different types of self-assessment before the implementation of the model (**Before**) and after its implementation (**After**) for the instructional phases of presentation and practice (Table 5).

Table 5

Overview of Self-Assessed and Teacher's Scores Before and After the Implementation of the Model of Self-Assessment by Self-Questioning

Type of self-assessment	**Presentation**				**Practice**			
	Before		**After**		**Before**		**After**	
	M	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
SA general	3.38	0.73	3.28	0.73	3.17	0.84	3.43	0.69
SA ante	2.87	0.70	3.26	0.68	3.13	0.73	3.32	0.69
SA post	2.64	0.88	3.22	0.57	3.12	0.82	3.26	0.66
Teacher's scores	2.16	0.78	2.90	0.63	2.44	0.70	2.80	0.55

In all cases (before and after the implementation of the model and after both phases of the learning process) students, on average, estimated that they mostly understood the subject matter. They also predicted that they mostly knew how to solve the tasks, and after solving that they were mostly successful (Table 5).

In the rest of the section, we consider the accuracy of self-assessment. More precisely, we present the effect of the implemented model on the accuracy of self-assessment after presentation and after practice, as well as for the groups of low- and high-achievers.

Changes in the Accuracy of Self-Assessment After the Presentation Phase

Table 6 shows the accuracy of all three types of self-assessments after the presentation phase, before and after the implementation of the model.

Table 6

The Accuracy of Self-Assessment After the Presentation of the Learning Content Before and After the Implementation of the Model

Type of self-assessment	Phase	KMA			Average Ranking	Wilcoxon *Z*	*p*	Cohen's *d*
		N	*M*	*SD*				
SA general	Before	132	-0.15	0.67	41.90	-5.511	.000	0.48
	After		0.33	0.69	44.44			
SA ante	Before	164	-0.14	0.67	55.39	-4.245	.000	0.33
	After		0.31	0.69	74.96			
SA post	Before	128	0.14	0.45	52.28	-3.813	.000	0.34
	After		0.35	0.40	63.21			

Students' assessments after the presentation phase of the learning content were more accurate after the introduction of the model than before its implementation, as is evident from the average KMA values. There are statistically significant differences in the accuracy of all three types of self-assessment before and after the implementation of the model (Table 6). Cohen's effect size shows that the model had the greatest impact on the accuracy of self-assessed general understanding (d = 0.48). The model had less influence on self-assessed prediction of task solving performance (d = 0.33) and self-assessed task solving performance (d = 0.34).

A good indicator of the changes in accuracy is the proportion of students that self-assess correctly (high KMA group) or incorrectly (low KMA group). The shifts of proportion of students that accurately self-assessed after the presentation phase (high KMA) are as follows: for general understanding from 24.0% before to 50.7% after the implementation of the model, for predicted performance from 3.7% to 18.4%, and for task solution from 21.3% to 42.9 %. On the other hand, there was a decrease of proportion of students in low KMA group after the implementation of the model. The shifts were: for general understanding from 37.3% to 6.3%, for predicted performance from 33.5% to 20.9%, and after solving tasks from 19.5% to 7.9%.

Changes in the Accuracy of Self-Assessment After the Practice Phase

Table 7 shows calculations of the accuracy of all three types of self-assessments after the practice phase before and after the implementation of the model of self-assessment by self-questioning.

Table 7
The Accuracy of Self-Assessment After the Practice of Learning Contents Before and After the Implementation of the Model

Type of self-assessment	Phase	KMA			Average Ranking	Wilcoxon *Z*	*p*	Cohen's *d*
		N	*M*	*SD*				
SA general	Before	117	0.12	0.68	31.50	-0.252	.801	-
	After		0.09	0.68	29.63			
SA ante	Before	164	0.13	0.69	78.97	-0.368	.713	-
	After		0.09	0.68	65.71			
SA post	Before	117	0.15	0.47	55.12	-2.337	.019	0.22
	After		0.23	0.41	52.60			

In Table 7, it can be seen that during the practice phase the use of our model of self-assessment improved only the accuracy of self-assessed performance in solving tasks. Here, the effect of the model was small (d = 0.22). It should be noted that the proportion of students that self-assess inaccurately (low KMA group) decreased from 25.7% before implementation to 12.8% after the implementation, while the proportion of students in the high KMA group remained about the same (27.9% before implementation, 28.6% after implementation).

The accuracy of students' self-assessment of their general understanding after practice showed no statistically significant differences before and after the implementation of the model. About the same proportion of students gave an accurate self-assessment of their general knowledge (35.1% before, 36.9% after the implementation).

There were also no statistically significant differences in the accuracy of self-assessed predictions of task-solving performance after the practice phase. Only slightly more than one-tenth of students accurately predicted their task-solving performance (12.2% before, 11.6% after implementation).

Changes in the Accuracy of Self-Assessment Within the Groups of High- and Low-Achievers

We also considered how our model of self-assessment affects the accuracy of self-assessment in the groups of low- and high-achievers.

Low-achievers

Tables 8 and 9 show the changes in the accuracy of self-assessment for low-achievers.

Table 8
Changes in the Accuracy of Self-Assessment of Low-Achievers in the Presentation Phase After the Implementation of the Model

Type of self-assessment	Phase	KMA			Average Ranking	Wilcoxon *Z*	*p*	Cohen's *d*
		N	*M*	*SD*				
SA general	Before	64	-0.20	0.65	22.64	-3.557	.000	0.44
	After		0.21	0.69	20.66			
SA ante	Before	83	-0.64	0.31	28.96	-1.975	.048	0.22
	After		0.02	0.34	33.11			
SA post	Before	62	0.13	0.51	29.46	-1.314	.189	-
	After		0.24	0.40	31.24			

It can be seen from Table 8 that within the group of low-achievers the implementation of our model in the presentation phase resulted in improved accuracy of self-assessed general understanding and self-assessed predictions of performance in task solving. The effect on accuracy of self-assessed general understanding was medium (d = 0.44) in the presentation phase. After implementation of the model, a high KMA was found for nearly half of the low-achievers (42.3%), whereas this was the case for less than one-fifth (18.1%) before implementation. A slightly smaller effect (d = 0.22) was found for the accuracy of self-assessed prediction of task solving performance. The proportion of low-achievers with a high KMA in self-assessed prediction was 8.4% after implementation of the model and 1.2% before implementation. Self-assessed performance in task solving before and after implementation of the model showed no statistically significant differences.

Table 9

Changes in the Accuracy of Self-Assessment of Low-Achievers in the Practice Phase After the Implementation of the Model

Type of self-assessment	Phase	KMA			Average Ranking	Wilcoxon *Z*	*p*	Cohen's *d*
		N	*M*	*SD*				
SA general	Before	56	0.10	0.69	12.50	-0.016	.988	-
	After		0.08	0.69	11.54			
SA ante	Before	83	-0.04	0.34	38.45	-0.715	.475	-
	After		-0.02	0.32	34.21			
SA post	Before	55	0.09	0.53	24.61	-2.829	.005	0.33
	After		0.23	0.41	25.85			

For low-achievers, applying our model in the practice phase caused an improvement of the accuracy only of self-assessed performance in task solving, with an effect d = 0.33. Thus, after the implementation of the model, the percentage of students with low KMA decreased significantly (36.2% before implementation, 11.1% after implementation). For the other two types of self-assessment, we found no statistically significant differences in the accuracy of self-assessment before and after the implementation of the model (Table 9).

High-achievers

Tables 10 and 11 show the changes in the accuracy of self-assessment of high-achievers after the presentation and practice phases.

Table 10

Changes in the Accuracy of Self-Assessment of High-Achievers in the Presentation Phase After the Implementation of the Model

Type of self-assessment	Phase	KMA			Average Ranking	Wilcoxon *Z*	*p*	Cohen's *d*
		N	*M*	*SD*				
SA general	Before	63	-0.69	0.71	18.63	-3.712	.000	0.47
	After		0.41	0.69	21.58			
SA ante	Before	73	-0.10	0.39	24.81	-3.736	.000	0.44
	After		0.18	0.45	37.56			
SA post	Before	61	0.17	0.38	21.87	-3.706	.000	0.47
	After		0.46	0.37	30.30			

Table 11
Changes in the Accuracy of Self-Assessment of High-Achievers in the Practice Phase After the Implementation of the Model

Type of self-assessment	Phase	KMA			Average Ranking	Wilcoxon *Z*	*p*	Cohen's *d*
		N	*M*	*SD*				
SA general	Before	56	0.14	0.69	19.03	-0.156	.876	-
	After		0.07	0.67	18.03			
SA ante	Before	74	0.07	0.40	38.45	-0.307	.759	-
	After		0.04	0.35	29.38			
SA post	Before	57	0.23	0.40	29.23	-0.419	.675	-
	After		0.23	0.42	24.50			

Table 10 shows that for high-achievers the implementation of the model in the presentation phase resulted in an improved accuracy of all three types of self-assessments. The effect was of medium size. After implementation of the model, more than half of the high-achievers (56.9%) provided accurate self-assessments of general understanding, compared with only about one-third of the students (29.2%) before the implementation. The proportion of students who accurately predicted their performance on solving tasks also increased significantly (6.8% before implementation, 31.5% after implementation), as did accurate self-assessed performance on solving tasks (21.1% before implementation, 53.1% after implementation). However, the implementation of the model did not result in statistically significant improvements in the accuracy of the high-achievers' self-assessment in the practice phase (Table 11).

Discussions and Conclusions

The purpose of the study was to determine the impact of our model of self-assessment by self-questioning on the accuracy of a student's self-assessment of mathematics knowledge. Indeed, accuracy of self-assessment of mathematics knowledge is one of the important skills that students acquire through experience (Brown & Harris, 2013; Ramdass & Zimmerman, 2008), and it also helps them in academic achievement (Brown & Harris, 2014; Yan, 2020). In designing the type of questions used in the model, we followed the guidelines of modern teaching and considered some factors that significantly affect the accuracy of self-assessment. McDonald (2010) asserts that questions posed by the teacher in class can serve as prototype for questions that students ask themselves during self-assessment. Students are thus encouraged to reflect on their own learning and understanding of the subject matter, leading to improved accuracy of self-assessment

(Panadero et al., 2014). In designing the types of questions in our model, we considered which questions in the mathematics classroom would encourage students to self-monitor and self-verify their mathematics knowledge and which opportunities students could use to self-verify their mathematics knowledge. Such self-verification in solving tasks is one of the most important factors in improving the accuracy of self-assessment, as it has already been established by Okita (2014) and Ramdass & Zimmerman (2008) and also confirmed by the results of our study. Namely, we found that the use of designed types of questions in the presentation phase resulted in improved accuracy of all three types of self-assessment. Our model had the largest effect on improved accuracy of self-assessment of understanding the learning content, as half of the students provided an accurate assessment after using the proposed types of questions, compared to only a quarter before using the questions. For self-assessment of general understanding, the percentage of students who gave an incorrect self-assessment decreased (they had a low KMA). The use of proposed questions in the presentation phase increased the percentage of students who accurately predicted their performance on the task (high KMA group). Before the implementation of the model, the percentage of these students was insignificant; while after the implementation, an accurate prediction was given by nearly one-fifth of all students. The accuracy of self-assessed performance in solving tasks also improved after the implementation of the model. The proportion of students who accurately self-assessed their solutions to mathematical tasks shifted from about one fifth before the implementation to one half after the implementation of the model. Self-assessment of performance in solving the tasks also decreased the percentage of students that self-assessed inaccurately (low KMA group). The results obtained confirm the findings of some other studies (Brookhart et al., 2004; Oudman et al., 2022; Ramdass & Zimmerman, 2008), namely that with appropriate training and practice of self-assessment, students improve the accuracy of self-assessment.

The effect of our model was slightly smaller in the practice phase than in the presentation phase. There was a statistically significant improvement only in the accuracy of self-assessed performance in solving tasks. The effect on accuracy of self-assessed performance in solving tasks was small. Our model also did not affect the students' accuracy of self-assessment of general understanding after the practicing phase. There were also no statistically significant differences in the accuracy of self-assessed predictions of task-solving performance after the practice phase. Only slightly more than one-tenth of the students accurately predicted task-solving performance both before and after the implementation of the model. The results obtained in our study on the effects of our model on the practice phase are related to several factors. The practice phase during instruction focused on solving tasks that allowed students to assess how well they understood the content. Most of the time, students solved the tasks with the help of the teacher, so it is possible that their impression of understanding the content derived from their feeling of being able to follow the teacher assisted solving of the tasks. Such connection was also discussed by Bastick (1993). A hard to achieve aim is also to improve the accuracy of self-assessed prediction of task solving performance as is emphasised by Ramdass and Zimmerman (2008). They claim that from a psychological perspective, self-assessed prediction of task solving performance is closely related to students' mathematical self-efficacy. In our opinion, the accuracy of self-assessment could be improved by giving students only tasks that they have already solved in class, since they have already developed self-monitoring mechanisms for these tasks. In fact, experience with a task is one of the important factors that increase the accuracy of self-assessment (Hacker et al., 2000). The type of knowledge assessed in a task also influences the accuracy of self-assessment (McDonald & Boud, 2003). Also in our test, some tasks assessed conceptual knowledge, and when students found an appropriate rationale for a task solution, they rated the task as correctly solved. It was in such cases that inaccurate self-assessments of task-solving performance occurred most frequently. In our opinion, asking appropriate types of questions is a good way of teaching students to self-monitor and self-check the solution of routine procedural tasks where the steps of their solution and the method of checking their correctness are well established.

When introducing the model of self-assessment by self-questioning in the classroom, it is important to examine how it affects different groups of students. Researches (e.g., Oudman et al., 2022; Tobias & Everson, 1996) found that high-achievers give more accurate self-assessments of their mathematical knowledge compared to low-achievers because their metacognitive skills are better developed. Therefore, our goal was to improve the accuracy of self-assessment, especially for low-achievers. In this regard, Brown & Harris (2013) mention that several studies indicate that academic performance, especially of low-achievers, improves with the use of self-assessments in the classroom. Through the use of our model in the classroom, we have found that teacher's questions have a different effect on certain groups of students depending on the stage of the learning process and also the type of self-assessment. In the phase of presentation of the learning content, both low- and high-achievers more accurately self-assessed their understanding after the implementation of the model and also more accurately predicted their performance in solving tasks than prior to the implementation of the model. The model had a slightly greater effect on high-achievers, especially in the phase of the presentation of the learning content. In our opinion, low-achievers need more experience with tasks, repeated emphasis on critical skills for tasks, so that their accuracy of self-assessed performance in solving tasks improves. In fact, low-achievers improved the accuracy of self-assessed task solving performance in the practice phase. The model helped the high-achievers especially in the presentation phase, while for the practice phase we assume that their acquired knowledge was sufficient to adequately understand the task requirements and no improvement occurred in the accuracy of self-assessed performance. And we can confirm Okita's (2014) findings that for both groups of students, the accuracy of self-assessment can improve with self-assessment training that focuses on reviewing and eliminating students' errors in the tasks. In our opinion, students could have improved the accuracy of self-assessment even more if our model had been applied over a longer period of time and perhaps incrementally.

Thus, the results of our study open up new questions and dilemmas about improving the accuracy of students' self-assessment. At the same time, they suggest that teachers who use a variety of instructional approaches and methods in their mathematics classes can integrate into their lessons questions that encourage students to reflect on their own knowledge and provide them with tangible methods for self-monitoring and self-checking the correctness of the solution to a task. This can be achieved without significant changes in the way of teaching. Students' ability to accurately assess their knowledge can enable them to self-regulate their learning through metacognitive monitoring (Hosein & Harle, 2018). For a deep understanding of how students form an assessment of their own knowledge, it is important to look at self-assessment not only from a didactic perspective, but also from a psychological perspective. Namely, the process of self-assessment is closely connected with students' metacognitive and self-regulatory processes and takes place under the influence of various factors.

The question of extension validity of the study results is open to some degree, both in terms of students' age and learning content. It would still be useful to introduce the model to different age groups of students and assess at what age the model becomes efficient. Since we believe that questioning in this context is transferable to other mathematical content (other than geometry), it would be necessary to think about specific types of questions to be used in the model of self-assessment by self-questioning. The efficacy of our model could also be tested in other cultural contexts and by teachers, using other teaching approaches (e.g., inquiry-based learning).

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Įsivertinimas taikant savęs klausinėjimą matematikos mokomosios medžiagos pristatymo ir praktinio mokymosi etape

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Santrauka

Viena iš svarbiausių efektyviai besimokančių mokinių savybių yra ta, kad jie realiai suvokia savo žinias, kurias gali panaudoti tolesniam mokymuisi. Mokinių įsivertinimo įgūdžiams ugdyti mokytojai naudoja įvairius metodus, kurių dauguma taikomi pamokose kaip papildoma veikla.

Šiame straipsnyje pristatomas tyrimas, kurio metu sukurtas įsivertinimo modelis, pagrįstas mokinių savęs klausinėjimu, ir ištirtas jo poveikis mokinių įsivertinimo tikslumui didinti. Tyrime dalyvavo 164 septintų klasių mokiniai iš trijų didžiųjų Slovėnijos miestų ir 6 matematikos mokytojai. Remiantis 6 klasės nacionalinių matematikos egzaminų rezultatais, mokiniai buvo suskirstyti į dvi grupes: žemų pasiekimų mokiniai ir aukštų pasiekimų mokiniai.

Šis modelis grindžiamas specifinio tipo klausimais, kuriuos mokytojai garsiai užduoda pristatydami mokomąją medžiagą, taip pat praktinio mokymosi proceso etapo metu, kad mokiniai turėtų galimybę save klausinėti. Nustatyta, kad modelio naudojimas abiejuose etapuose pagerino savarankiškos veiklos rezultatų prognozavimo tikslumą sprendžiant užduotis, o įsivertinimo tikslumas pagerėjo tik pristatymo etape. Be to, taikant šį modelį pagerėjo tiek žemų, tiek aukštų pasiekimų mokinių įsivertinimo tikslumas.

Esminiai žodžiai: *įsivertinimo tikslumas, pristatymo ir praktinio mokymosi etapai, matematikos mokymas, įsivertinimas taikant savęs klausinėjimą.*

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