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The Impact of the Self-Questioning Teaching Model on the Identification of Learning Objectives and Knowledge Criteria in Teaching Mathematics*

Abstract. 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 students' recognition of learning objectives and criteria for assessing tasks in mathematics lessons. 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 students' better recognition of learning objectives and assessment criteria in both phases and, for both low- and high-achievers. The results of the study show the importance and the impact of systematic teaching of elements that are important for the process of students' self-monitoring, self-control of their learning process and the formation of a realistic awareness of their knowledge.

1. Introduction

The learning objectives (or goals, intentions) specify what students are expected to learn.[1] The knowledge (or assessment, success) criteria are derived from the learning objectives (Panadero and Tapia, 2013) and are specific guidelines against which students' knowledge, expressed in different ways, is assessed. They are therefore qualitative descriptions of important aspects of the learning objectives; these aspects can be expressed as characteristics of task responses related to specific learning objectives (Sadler, 1989) and must be task specific, concrete, measurable (Butler, 2018; Hattie et al., 2017). The knowledge criteria help students to be aware of what is expected of them in the task (Santos and Pinto, 2014).

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[1]Learning objectives are also skills, attitudes etc., not just contents.

Knowledge criteria should not be confused with standards, which are not in the focus of the presented research. The standards define the level of achievement of the criteria (Sadler, 1987) or expected level of performance (Labuhn, Zimmerman and Hasselhorn, 2010). Knowledge of the standards includes information about what is considered as a well-done task and identification of the criteria to which the standards refer (Boud, Lawson, Thompson, 2013). Panadero and Tapia (2013) claim that students can obtain the criteria in three ways: through externally provided criteria (the criteria are designed by teachers and given to students), reciprocal design (teachers discuss the criteria with students), and through internal design (students design and set the criteria of knowledge based on tasks or other activities). Yan and Brown (2017) refer to the external design of the criteria by the teacher and the design of the criteria in collaboration with the teacher as formal criteria. The criteria that arise from a students' personal goals or past experiences, are subjective and are therefore defined as the students' internal criteria (Yan and Brown, 2017). These criteria are covert, implicitly given and often used as a general rule in all similar tasks. Coffey (2003) also states that in each class, the criteria for the quality of work are expressed in a particular way (implicitly or explicitly). Thus, students use different sources of information about the criteria, which affects the way the criteria are used in the self-assessment of their knowledge. Regarding the extent to which students adopt learning objectives and criteria in the process of self-assessment, Bourke (2000) found in her study that students reach different levels of self-assessment ability. At the lowest level, students only ask themselves if they know (the subject of learning). At the next level, they already ask themselves how much they know. At the third level, the learning objectives and the students' awareness of them already play an important role in the students' self-assessment. Students ask themselves what they have learned, i.e. what they know, but their answer is still based on their intuitive feeling while performing a task or activity. At the next level, students begin to use the criteria provided by the teacher in self-assessment by identifying them (e.g., when performing the task, they ask themselves what they need to know to successfully solve the task, what the task requires of them). Students reach the highest level of self-asessment ability when they set the learning objectives and criteria. In doing so, they ask themselves what they want to learn and later why the learning content is important.

The importance of knowing the learning objectives and knowledge criteria for self-assessment

Several authors (e.g., Harris and Brown, 2018; Hattie et al., 2017; Timperlay and Paar, 2009) emphasise that teachers need to ensure that learning objectives and knowledge criteria are as visible and understandable as possible to students. Hattie et al. (2017) state that teachers should communicate their learning intentions (objectives), as this has been shown by extensive research to increase students' learning and achievement, as well as their internal motivation. However, related to our research, we highlight the importance of students' knowledge of learning objectives in self-assessing their knowledge. Students should be aware of knowledge criteria that help them to self-assess (Andrade, 2019; Hattie et al., 2017; Yan et al., 2021). Boud (1986) was one of the first who define the concept of self-assessment. He says that self-assessment means that students participate in the identification of standards and/or criteria and assess the extent to which they have achieved these standards and/or criteria in a particular task. Many researches (e.g., Andrade, 2019; Black and Wiliam, 2010, Bruce, 2001; Suurtamm, Koch, & Arden, 2010) claim that students can realistically self-assess their understanding of learning content if they understand what they are learning, i.e. what they are expected to know. Mastnak, Valenčič Zuljan and Magajna (2023) confirmed this in their study. They found that students were more accurate in their self-assessment when teachers used a self-assessment model in which the learning objectives were highlighted and the assessment criteria were clear to students. León, Panadero and García-Martínez (2023) make a similar point by saying, that providing assessment criteria when asking students to self-assess is widely recommended because students' internal criteria aren't the same as the teacher's criteria. If we want to increase students' accuracy, we should make implicit criteria explicit to students. Implicit, internal process of self-assessment can become explicit if the self-assessment actions are made observable, such as through discussing assessment criteria (Yan et al., 2021). Timperlay and Paar (2009) also emphasise the importance of students' knowledge of learning objectives in the context of self-regulated learning and formative monitoring of knowledge. They say that students who do not not know what they are supposed to know cannot effectively monitor and regulate their learning process and provide relevant feedback on the achievement of learning objectives (Timperlay and Paar, 2009). Suurtamm, Koch and Arden (2010) stress the importance of knowing the learning objectives in mathematics lessons, saying that in mathematics lessons it is not only important that students know how to solve problems, but also that they understand what they are doing and that they can explain it. The teacher should therefore clearly state to the students the expectations of their knowledge. This includes clearly stating the learning objectives, criteria and standards and providing examples. Bourke (2000) and Coffey (2003) have also found in their study that an important factor in students' self-assessment is clear objectives that are communicated to the students in an explicit and understandable way. Indeed, they found that students in the classroom are often not aware of the learning objectives, criteria and standards on which they should base their self-assessment of knowledge.

Teaching and identifying learning objectives and knowledge criteria via self-assessment

Knowing learning objectives allows a better quality of self-assessment. On the other hand, as we present in this section, different methods of self-assessment may help in recognising learning objectives and knowledge criteria. In order to systematise existing models or practices of self-assessment, a number of authors have developed typologies of self-assessment that try to highlight the differences and similarities between them. To better understand our research, we will highlight the typology developed by Tapio and Panadera (2010). Their typology is based on a classification of existing models and practices of self-assessment according to the presence and design of criteria in the self-assessment process. The typology distinguishes three models of self-assessment (Tapio and Panadera, 2010):

- standard self-assessment ('*standard self-assessment*', commonly referred to as '*self-grading*');

- the use of rubrics;
- the use of scripts.

According to Panadero, Brown and Strijbos (2016), one of the strengths of this typology is that it focuses on understanding the process of self-assessment and the elements that are important in this process. From the presented typology, two main models of self-assessment could be formulated according to the explicitness of the expression of learning objectives and knowledge criteria. The first model is based on implicit elements of self-assessment ('*standard self-assessment*'). It can be implemented in two ways. Firstly, the teacher is not aware of the importance of the student's knowledge of the criteria. The student is more likely to make his self-assessment according to his internal criteria, which may not be the same as the teacher's criteria. An example of this type of self-assessment would be when, at the end of a lesson, the teacher asks students to rate how well they understood the lesson or how well they were able to solve a problem. This is done using one of several self-assessment techniques: e.g., traffic lights, thumbs up, thumbs down (Keeley and Tobey, 2011). Secondly, in the model of implicitly given criteria, the teacher can familiarise students with the criteria by integrating them into everyday activities. In this way, the criteria are still implicitly taught because the student has to understand them by talking to the teacher, explaining the learning content, observing an example, and so on. Panadero and Tapia (2013) present an example of this model where the teacher helps the student to develop self-assessment skills by giving him or her a solved example of the task. The student compares his or her solution with the example solution. Criteria are implicitly given and the student has to figure them out for himself or herself. Unfortunately, not all students are able to self-assess their work in this way. Yan and Boud (2022) also said that self-grading is a less effective self-assessment model because it may not involve eliciting and using criteria and making meaningful evaluative judgments. The second model of self-assessment is based on explicit criteria. Tapio and Panadera's (2010) tipology lists two models of explicitly given criteria: rubrics (Andrade, 2000; Egodawatte, 2010) and self-assessment scripts (Montague, 2007). Rubrics take the form of a table containing a list of criteria for assessing important learning objectives related to the task, a scale for assessing the degree to which these criteria are met, and a description of each level for assessing whether the selected criteria are met. Egodawatte (2010) says that students need to understand the criteria written in the rubric, so the rubric alone will not help students improve their learning. Rubrics also do not, by themselves, facilitate accurate self-assessment (Leon, Panadero and Garcia-Martinez, 2023), and that may also be true for other self-assessment tools. Scripts, on the other hand, consist of a specific set of questions structured according to the steps to solve the task, so that the student follows the steps just as the teacher would. They are designed to encourage students to think about the whole process of solving the task, because they are designed to get the student to analyse the process of solving the task from start to finish. Scripts can also be used to analyse the final solution of the task. The questions in the script contain key knowledge that the student has to demonstrate in the task, so that the student can determine whether he or she has understood the task (e.g., Have I read and analysed the mathematical problem task? Do I know what the task requires of me? Have I written all the symbols and variables correctly?) Tapio and Panadera's (2010) typology doesn't include models of self-assessment where teachers verbally communicate the criteria to students, but relies only on self-assessment tools or on implicitly given criteria. Coffey (2003), who introduced the practice of self-assessment in the classroom, suggested that teachers communicate the criteria in the context of a classroom discussion. Teachers in her study therefore encouraged students to talk about the quality of a product or the adequacy of the solution of a task during their daily activities, highlighting the key criteria for evaluating the product/task. McDonald (2009) also gives an example of how a teacher can establish criteria together with the students. In a mathematics lesson, the teacher can give the students a task and write three solutions on the board. Students should discuss the characteristics of a good or correct solution to the task. McDonald (2009) says that it is also important to justify why the chosen criteria are appropriate (or to explain why a particular feature of the task determines the quality of the answers). Keeley and Tobey (2011) also list some techniques that teachers can incorporate into their teaching to encourage student self-assessment. Among these techniques, Keeley and Tobey (2011) list some that focus on qualitative self-assessment of knowledge and encourage students to articulate learning objectives (e.g, '*Point of most significance*': a technique in which the learner summarises the three most important things he or she has learned at the end of the lesson; the '*3-2-1*' technique, in which the learner is given a sheet at the end of the lesson on which he or she writes down three new things he or she has learned, two things he or she is still struggling with, and one thing that will help him or her if he or she doesn't know how to do something), and others that focus on the learner's review of products and the formulation of feedback (e.g, '*Comments only marking*' technique, where the teacher reviews the learner's product/assignment and gives feedback to the learner on it, expressing the key assessment criteria of the assignment). In the existing literature and teaching practice, we can find a variety of techniques that teachers can use to help learners to identify learning objectives and criteria and to develop accurate self-assessment of their knowledge.

The need for a teaching model that integrates learning objectives and self-assessment

The existing examples of self-assessment techniques are presented as pieces that can be incorporated into the classroom, but they do not represent a holistic model of self-assessment that a teacher would incorporate into his or her teaching of self-assessment. Therefore, there is a need to develop a model that can be integrated into existing teaching methods and should not just involve adding some techniques as extra activities to be taught. It is also important that the model does not change existing teaching styles. Based on our knowledge of existing self-assessment techniques and practices, we wanted to develop a model of self-assessment that would enable the teacher to incorporate existing self-assessment techniques and practices in a thoughtful way and provide effective ways of implicitly and explicitly articulating learning objectives and knowledge criteria. In our model, we considered that the teacher needs to clearly present learning objectives during a lesson in a variety of ways and in language that students can understand (Bourke, 2000; Hattie et al., 2017; Tan, 2008). The model we have developed is designed to be applicable at all stages of the learning process. As Schramm (2018, p. 40) says, *'self-assessment is not a procedure that only takes place at the end of a learning path'*. In designing the model, we also followed some other guidelines for quality teaching of mathematics that are suggested by Hattie et al. (2017), e.g. teacher clarity, linking learning objectives to prior knowledge). Teacher clarity is a clarity of assessment that is seen by students (Hattie et al., 2017). Learning objectives and knowledge criteria contribute to teacher clarity and should be shared with students (Hattie et al., 2017). Hattie et al. (2017, p. 84) claim: '*Excellent teachers don't just set learning intentions early in tle lesson and then forgot them. They refer to this intentions throught instruction, keeping students focused on what it is they're supposed to learn*.' One of the important features of our model is that it facilitates intentional teaching and self-questioning strategies. Students benefit from self-questioning by developing metacognitive skills, especially self-monitoring. Questioning provides students with the opportunity to self-assess their learning, to monitor their understanding and to develop their own cognitive processes (Dogan and Yucel-Toy, 2021). The model that we have developed and present here is specific to the field of mathematics and we believe that it can be integrated into teachers' existing approaches to teaching. Hattie et al. (2017) suggest that the teaching of mathematics should be based on a thoughtful combination of two teaching approaches, namely direct and dialogic instruction. We have designed a model to be best used in lessons that are based on direct instruction with some elements of dialogic instruction, and that have a clear structure and pathway for achieving learning objectives. John (Hattie, 2009) defines direct instruction as an intentional, well-planned and student-centred guided approach to teaching. According to Hattie et al. (2017, p. 58), '*Direct instruction is when the teacher determines the learning intentions and success criteria, makes them transparent to the students, demonstrates them by modelling,...*' The model, with some adaptations, would also be useful for lessons where the teacher raises learners awareness of learning objectives after an activity has been carried out. This is the case for lessons that are more open-ended (inquiry-based learning) or lessons where, due to unfamiliarity with new mathematical terms, learning objectives are communicated later, after students have learned the terms (Hattie et al., 2017). In this case, teachers can withhold the learning objectives until after the exploration or explanation has taken place. Then teacher asks students to explain what they have learned and discuss and compare this with the initial learning objectives. The main innovation and strength of our model is the strategy of student self-questioning, which can be integrated into all forms of teaching and learning mathematics.

Self-questioning teaching model for identifying learning objectives and knowledge criteria

The model is based on the teaching of self-assessment, where the teacher models, by thinking aloud, the questions related to the identification of learning objectives and criteria in relation to the specific learning content, and looks for appropriate answers in conversation with the students. In this model, learning objectives are formulated both explicitly and implicitly during the lesson. The explicit formulation of learning objectives by the teacher occurs in the presentation phase of the lesson when the teacher explains what the students will learn in the lesson and makes a connection to prior knowledge (e.g., '*We learned last lesson... and today we are going to learn...* ').

In the presentation phase of the lesson, the teacher directs each activity towards achieving the learning objectives and explicitly explains the objectives to the students (the teacher says: '*The first thing we are going to learn today, and what you need to know is..., The second thing...* '). During the lesson, the teacher also implicitly communicates the learning objectives and criteria to the students through instructions for various activities, tasks and solved examples on the board. The teacher makes these implicitly expressed learning objectives and criteria explicit by modelling the students' questions in the context of identifying the learning objectives and criteria. The modelling of the questions is done in such a way that the teacher asks himself or herself questions (self-questioning) and finds appropriate answers by talking to the students. We have 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 symmetry is? How can I make sure I have understood what symmetry is? Can I illustrate/give an example...?* ');

2. Questions that emphasise the knowledge necessary for understanding concepts and solving tasks (e.g., '*What do I need to know to understand what a bisector is? What do I need to know to solve this task? What knowledge am I supposed to show in this task? What do I need to do in this task? What do I need to pay attention to when solving the task?* ');

3. Questions that encourage students to verify the correctness of their solutions of tasks (e.g., '*Is the task solved correctly? 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?* ').

In the practice phase of the lesson, the teacher uses the same questions in the process of solving the tasks as in the presentation phase. He or she refers to these questions in specific tasks during various practice activities. At the end of the lesson, the teacher summarises what the students have learned during the lesson. Occasionally, the teacher asks the students to fill in the worksheet (Figure 1). The worksheet is discussed in the next lesson.

The model described can be integrated into existing teaching methods, but in doing so, the teacher must critically consider when it is appropriate to ask the student a question. After some time, when the model has been introduced into the classroom, students should imitate the teacher and ask themselves such questions. In doing so, they should reflect on what they need to know and how they know what the key skills are to solve a task correctly.

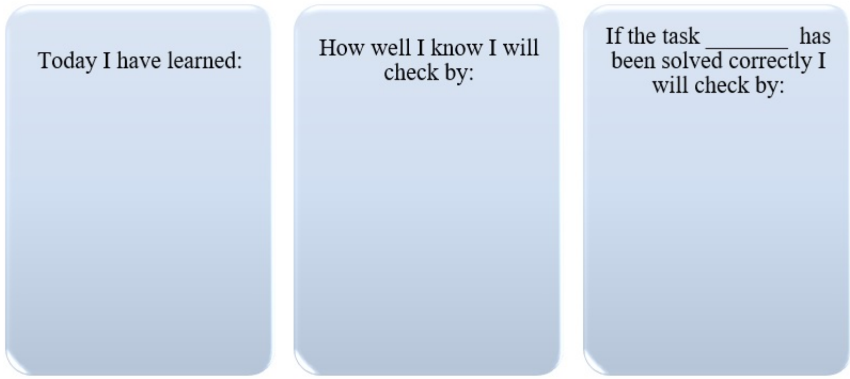

Figure 1: Knowledge self-monitoring sheet for solving tasks

2. Method

The aim of the study presented here was to investigate the impact of our model on the quality of students' identification of learning objectives and knowledge criteria in the presentation phase (which includes the introduction of the learning content and its acquiering) and the practice phase (repetition and consolidation of the content through solving tasks) of mathematics lesson.

From this point of view, the research questions are as follows:

1. What is the impact of the self-questioning teaching model on *the quality of students' identification of learning objectives* in the presentation and practice phases of mathematics lesson?

2. What is the impact of the self-questioning teaching model on *the quality of students' identification of knowledge criteria* in the presentation and practice phases of mathematics lesson?

3. How effective is the self-questioning teaching model for specific groups of students (low-achievers, high-achievers)?

The sample of the study included 164 7^{th} grade students from three schools from major Slovenian cities and their mathematics teachers. Six mathematics teachers and seven classes were involved. The students were split into two groups (low-achievers, high-achievers) based on their results in the National Knowledge Assessment Test in grade 6.

The pedagogical study used a causal, non-experimental method with a quantitative empirical approach. Basic descriptive and inferential statistics were used. Since the values of the variables were not normally distributed, appropriate non-parametric tests were used. We calculated with discrete variables (number of points for identifying the learning objectives and knowledge criteria). To better understand or feel the differences between the number of learning objectives (and the number of knowledge criteria) identified before and after the introduction of

Table 1: Structure of the sample in terms of learning 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

the self-questioning teaching model, we also calculated the mean and standard deviation. The effect size was calculated using Cohen's d and interpreted as suggested by Cohen (1988). A value of d = 0.20 indicates a small effect, d = 0.50 a medium effect and d = 0.80 a large effect (Cohen, 1988). Cohen's d can be calculated using the formula $d = z/\sqrt{N}$ (Rosenthal, 1991), where z is the standardised value obtained when determining the differences in the dependent samples (non-parametric Wilcoxon test) and N is the number of pairwise comparisons. Our study consisted of three consecutive phases (Figure 2). In the first phase, the existing situation was studied; in the second phase, the innovation was implemented (teaching according to the model); and in the third phase, the steps of the first phase of the study were repeated and the effectiveness of the innovation was determined.

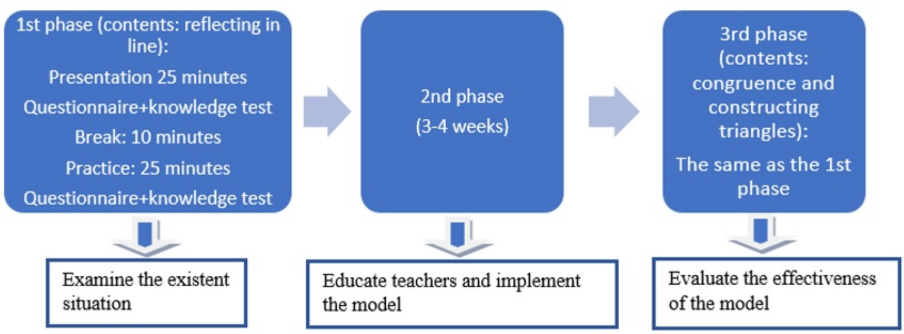

Figure 2: The course of study

Improving the quality of identifying learning objectives and knowledge criteria was investigated with regard to their perception in a 2-hour mathematics lesson in phase 1 and phase 3. For this purpose, students completed a questionnaire after the presentation phase and after the practice phase in phase 1 and phase 3 of the study. The considered content was mirroring in a line (phase 1) and simple constructions of triangles (phase 3).

In the second phase of the research, teachers were first trained to implement the self-questioning teaching model by incorporating elements of the model into their lessons with the help of the researcher who designed the model. Teachers were asked to consider where in the lesson they could incorporate the self-assessment model and how, using their lesson preparation and an example of lesson preparation that included the model. In this way they redesigned their lesson plan. Teachers were trained in the use of the model. They then taught 8 to 12 mathematics lessons using the model. For each lesson, an external observer completed a structured observation sheet to monitor the quality of the implementation of the model. The same external observer observed each teacher in all lessons. The external observers were 4th year mathematics students. They had been trained to complete the observation sheet prior to the implementation of the model. The structured observation sheet involved monitoring the incorporation of elements of the self-questioning teaching model (monitoring the way and frequency with which the teacher expressed learning objectives and knowledge criteria during the lesson). In particular, he or she monitored the way in which the learning objectives and criteria were expressed through the questions which are part of the model. Analysing the observation sheets showed that teachers were successful in using the self-questioning teaching model. Teachers expressed learning objectives on average 6 times per lesson, with a minimum of 4 and a maximum of 11. Ways of expressing learning objectives: the teacher tells the students what they are going to learn, makes a summary at the end of the lesson, explains the learning objective in a question and in a task). The knowledge criteria were emphasised by the teachers on average 6 times, minimum 1 and maximum 14 times in the lesson. Their emphasis was mostly in the questions and tasks. Teachers were interviewed after the lessons to evaluate their use of the self-assessment model. The teachers found that the easiest part of implementing the model was formulating the learning objectives. In the first few lessons, they found it most difficult to think about when it would be useful to ask students a question from the model. Teachers estimated that after about 4 hours of implementation they had internalised the questions and learned to ask them thoughtfully in class. In the interview, teachers highlighted some of the positive effects of the model and some of the barriers to its implementation. Below is an example of how two of the teachers evaluated the use of the model.

Teacher 1: *'In the first implementations of the model, lesson preparation took more time because I had to think carefully about when to announce the learning objectives, when to return to them during the lesson, when to ask which question and how to engage students and check answers. Implementing the model became easier with time. Implementing the model gave me a different perspective on how to teach mathematics. Teaching became more student-centred in the sense that students controlled what they learned and knew how to check what they had learned. Using the model I also learned more about how to check the correctness of a procedure or the understanding of a definition or a rule'.*

Teacher 2: *'When I used the model, I found it easiest to announce the learning objectives and summarise them at the end of the lesson. When it came to asking questions, I found it most difficult to think about when and how to include which questions in the lesson and what kind of answers to expect. What I have internalised most from the model and what I find most important is the articulation of learning objectives and checking the correctness of the solution of a task. In the* *first lessons, questions took a lot of time and there was less time to solve different types of tasks. But after several lessons of using the model, I became familiar with the questions and could judge when and how questions should be asked in class. The students also got used to the questions'.*

Identification of learning objectives

In the questionnaire, the students had to answer what they should know about the considered learning content. Both lessons, before and after the introduction of the model, contained 3 learning objectives. Table 3 lists the learning objectives with examples of student statements. We also wanted to know how many learning objectives students had identified, so we scored the answers about the objectives. Each student received one point for each correctly stated learning objective. If he or she only partially stated the learning objective (e.g., mirroring, mirroring a figure, mathematical notation), he or she received half a point. For a statement that does not match the learning objectives (e.g., you must know everything, you must know rules, definitions; a reference to the content of previous lessons), the student did not receive a point. The student could receive a maximum of 3 points if he or she correctly stated all learning objectives.

Table 2: Learning objectives before and after the introduction of the model, with examples of students' statements

Phase of study	Learning objectives	Example of students' statements
Before the model introduction	The student knows how to mirror a point, a line, a figure, a line in a line.	To mirror different figures in a line; describe the constructions steps to mirror in a line.
	The student knows how to simbolize mirroring in a line.	To know the notation $Z_P : A \to A'$; to write with symbols what we mirrored.
	The student knows the properties of mirroring transformation.	When mirroring figures in a line, their orientation changes; if the point is on the mirroring axis, it stays there.
After the model introduction	The student knows how to draw a triangle if all three sides are given.	To be able to draw a triangle; to draw a triangle with given length of its sides.
	The student knows the procedure for executing a geometric construction.	To know how to draw a triangle; to know how to write down data and draw a sketch.
	The student knows when two triangles are congruent.	State the criteria for congruence of triangles; distinguish between congruent and non-congruent triangles.

Identification of knowledge criteria

Both before and after the introduction of the model, the students also had to solve a task after the presentation and after the practice phase of the learning content. They were also asked to write down the most important knowledge or criteria that the teacher should pay attention to when assessing their task. Table 3 shows the criteria (given by the teachers) for assessing the task.

Table 3: Criteria for the assessment of the tasks before and after the introduction of the model

Before the model introduction *Task: mirror a triangle segment in a line*	After the model introduction *Task: draw a triangle given its three sides*
They correctly mirror geometric objects across a line (draw perpendiculars).	They write down the data given and draw a sketch.
The mirrored points are correctly connected to form a triangle/segment.	They draw the base side correctly.
They correctly label mirror images, mark intersections and right angles.	They correctly measure and draw both arcs related to the remaining sides.
They correctly write the mirroring transformation with symbols.	They connect the sides to form a triangle and mark the vertices and sides correctly.

Students' answers on the criteria for assessing the task were scored. The student received a point for each relevant content criterion he wrote down. The relevant content criterion is a criterion that is consistent with the indication of one of the teacher's criteria. A student could receive a maximum of 4 points, i.e. if he recognized all the relevant content criteria for assessing the task.

3. Results

By introducing the self-questioning teaching model, we aimed to develop part of the student's mechanisms that are very important for the assessment process, namely the identification of learning objectives and related knowledge criteria. The results of the impact of the self-questioning teaching model on the quality of the identification of learning objectives and knowledge criteria are presented below.

Changes in the quality of the identification of learning objectives after the introduction of the model

Both before and after the introduction of the model, students considered and practised three learning objectives. Before the introduction of the model, teachers generally did not explicitly emphasise the learning objectives in mathematics lessons. Students therefore tried to find out the learning objectives on their own. By introducing the self-questioning teaching model, teachers intentionally guided students to identify the learning objectives already during the lesson. The results of the students' identification of learning objectives are presented in Table 4. In Table 4, N is the number of students and M is the mean of the students' scores on the identification of learning objectives. It is worth repeating that we have used the number of points as a measure of the identification of the learning objectives. Students received 1 point for a fully identified and clearly articulated learning objective and 0.5 points for a partially identified learning objective. We found that before and after the introduction of the model, there were statistically significant differences in the set of objectives identified by the students in both the presentation phase (Z = -8.056; p = 0.000) and the practice phase (Z = -6.681; p = 0.000) (Table 4). After the introduction of the model, students improved in identifying the learning objectives in both phases of the lesson. Mean scores for identifying learning objectives improved from 0.68 to 1.47 points in the presentation phase, and from 0.57 to 1.22 points in the practice phase. We also wanted to know what proportion of students improved in identifying learning objectives after the model was introduced. After the presentation phase, 61.6 % of the students identified more learning objectives, 16.5 % fewer and 21.9 % the same number. After the practice, half of the students (53.0 %) identified more learning objectives, 16.5 % identified fewer and 30.5 % identified the same number of learning objectives.

Table 4: Identification of the learning objectives after presentation and after practice before and after the introduction of the model

Phase of math lesson	Phase of study	*N*	*M*	*SD*	Average Ranking	Wilcoxon *Z*	*p*
Presentation	Before	130	0.68	0.564	26.27	-8.056	.000
	After		1.47	0.820	58.36		
Practice	Before	121	0.57	0.543	30.75	-6.681	.000
	After		1.22	0.750	46.76		

Table 5 shows the number and the percentage of students who were able to identify or partially identify the learning objectives. After the introduction of the model in the presentation phase, more than half of the students (59.0 %) recognised and were able to state at least two learning objectives, compared to just over a tenth of the students (15.1 %) before the introduction of the model (Table 5). After the practice phase, slightly less than half of the students (39.3 %) stated at least two learning objectives after the introduction of the model, compared to only one tenth (9.8 %) of the students before the introduction of the model. The teaching model had a very large effect (d = 0.71) on better identification of learning objectives in the presentation phase and a medium effect (d = 0.59) in the practice phase of teaching.

Changes in the quality of the identification of learning objectives in relation to student performance

We were also interested in how effective the model was in identifying learning objectives for a particular group of students in terms of their learning performance.

Table 5: The number of learning objectives identified or partialy identified after presentation and after practice before and after the introduction of the model

Number of learning objectives	Presentation				Practice			
	Before		After		Before		After	
	f	f %	f	f %	f	f %	f	f %
0	37	24.3	17	12.2	48	33.6	21	15.6
1	92	60.5	40	28.8	81	56.6	61	45.2
2	21	13.8	67	48.2	13	9.1	46	34.1
3	2	1.3	15	10.8	1	0.7	7	5.2
Total	152	100.0	139	100.0	143	100.0	135	100.0

Table 6 shows that the low-achievers showed statistically significant differences in the number of learning objectives identified in the presentation phase (Z = -5.541, p = 0.000) and in the practice phase of the learning content (Z = -4.074, p = 0.000) before and after the introduction of the model. The low-achievers improved in identification of the learning objectives after the introduction of the model. Mean scores for identifying learning objectives improved from 0.58 to 1.37 points in the presentation phase, and from 0.51 to 1.06 points in the practice phase. We also wanted to know what proportion of low-achievers improved in identifying learning objectives after the model was introduced. After the presentation phase, 65.3 % of the students identified more learning objectives, 10.2 % fewer and 24.5 % the same number. After the practice, half of the students (55.1 %) identified more learning objectives, 12.2 % identified fewer and 32.7 % identified the same number of learning objectives. In the presentation phase, the effect of the model on the identification of learning objectives was very large (d = 0.70) and in the practice phase it was medium (d = 0.54).

Table 6: Identification of the learning objectives for low-achievers before and after the introduction of the model

Phase of math lesson	Phase of study	*N*	*M*	*SD*	Average Ranking	Wilcoxon *Z*	*p*
Presentation	Before	62	0.58	0.551	11.67	-5.541	.000
	After		1.37	0.816	27.39		
Practice	Before	57	0.51	0.500	14.64	-4.074	.000
	After		1.06	0.798	21.17		

We also found (Table 7) that there were statistically significant differences in the identification of learning objectives by the high-achievers in the presentation phase (Z = -5.699, p = 0.000) and in the practice phase (Z = -5.248, p = 0.000).

After the introduction of the model, the high-achievers improved in identification of the learning objectives. Mean scores for identifying learning objectives improved from 0.58 to 1.37 points in the presentation phase, and from 0.51 to 1.06 points in the practice phase. We also wanted to know what proportion of high-achievers improved in identifying learning objectives after the model was introduced. After the presentation phase, 75.9 % of the students identified more learning objectives, 9.6 % fewer and 14.5 % the same number. After the practice, more than half of the students (68.9 %) identified more learning objectives, 8.1 % identified fewer and 23.0 % identified the same number of learning objectives. The impact of the model on the identification of the learning objectives was very large in the presentation phase (d = 0.72) and in the practice phase (d = 0.68).

Table 7: Identification of the learning objectives for high-achievers before and after the introduction of the model

Phase of math lesson	Phase of study	*N*	*M*	*SD*	Average Ranking	Wilcoxon *Z*	*p*
Presentation	Before	63	0.82	0.586	14.42	-5.699	.000
	After		1.69	0.833	29.14		
Practice	Before	59	0.68	0.597	12.25	-5.248	.000
	After		1.38	0.690	23.53		

Changes in the quality of the identification of knowledge criteria after the introduction of the model

After the presentation phase and the practice phase of the learning content, the students had to solve a task both before the introduction and after the introduction of the model and write down what they had to pay attention to in the task if they wanted to get all the points. We were interested in the impact of the model on the students' identification of the relevant content criteria for assessing the task. The results of the students' identification of knowledge criteria are presented in Table 8. In Table 8, N is the number of students and M is the mean of the students' scores on the identification of knowledge criteria. It is worth repeating that we have used the number of points as a measure of the identification of the knowledge criteria. Students received 1 point for each clearly written knowledge criterion. The number of points is therefore equal to the number of knowledge criteria identified. Table 8 shows that there are statistically significant differences (Z=-3.252; p=0.001) in students' identification of knowledge criteria before and after the model was introduced. In the presentation phase, students improved in identification of the criteria for assessing the task. After the practice phase, the differences in the identification of the knowledge criteria before and after the introduction of the model were close to statistical significance (Z = -1.927, p = 0.054). Also in the practice phase the students improved in identifying the knowledge criteria. Mean scores for identifying knowledge criteria improved from 1.11 to 1.51 points in the presentation phase, and from 1.18 to 1.56 points in the practice phase. We also wanted to know what proportion of students improved in identifying knowledge criteria after the model was introduced. After the presentation phase, 37.8% of the students identified more knowledge criteria, 20.1 % fewer and 42.7 % the same number. After the practice, 42.7 % students identified more knowledge criteria, 12.2 % identified fewer and 45.1 % identified the same number of knowledge criteria.

Table 8: The identification of knowledge criteria before and after the introduction of the model

Phase of math lesson	Phase of study	*N*	*M*	*SD*	Average Ranking	Wilcoxon *Z*	*p*
Presentation	Before	81	1.11	1.037	22.64	-3.252	.001
	After		1.51	1.180	23.77		
Practice	Before	73	1.18	1.101	23.93	-1.927	.054
	After		1.56	1.262	29.02		

Table 9 shows that after the presentation phase, at least two knowledge criteria were stated by almost half of the students (47.4 %) after the introduction of the model and by about one third of the students (30.1 %) before the introduction of the model. The teaching model had a small effect (d = 0.36) on the identification of knowledge criteria in the presentation phase. After the practice phase, almost half of the students (49.1 %) stated at least two knowledge criteria after the introduction of the model and about one third of the students (31.9 %) before the introduction of the model (Table 9). The teaching model also had a small effect (d = 0.23) on better identification of criteria in the practice phase.

Table 9: The number of stated knowledge criteria before and after the introduction of the model

Number of criteria	Presentation				Practice			
	Before		After		Before		After	
	f	f %	f	f %	f	f %	f	f %
0	30	32.3	29	22.5	29	31.9	29	25.4
1	35	37.6	39	30.2	33	36.3	29	25.4
2	19	20.4	37	28.7	16	17.6	29	25.4
3	6	6.5	14	10.9	10	11.0	17	14.9
4	3	3.2	10	7.8	3	3.3	10	8.8
Total	93	100.0	129	100.0	91	100.0	114	100.0

Changes in the quality of the identification of knowledge criteria in relation to student performance

We were also interested in how effective the model was in identifying knowledge criteria for a particular group of students in terms of their learning performance.

Table 10 shows that before and after the introduction of the model there were statistically significant differences in the identification of knowledge criteria during the presentation phase for the low-achievers (Z = -3.405, p = 0.001). After the introduction of the model, the low-achievers improved in identification of the knowledge criteria, and the effect of the model was medium (d = 0.58). In the practice phase, there was no statistically significant difference (Z = -1.057, p = 0.291) in the number of identified knowledge criteria before and after the introduction of the model. Nevertheless, the results show a tendency towards improvement in the identification of criteria. Mean scores for identifying knowledge criteria improved from 0.76 to 1.51 points in the presentation phase, and from 0.88 to 1.47 points in the practice phase. We also wanted to know what proportion of low-achievers improved in identifying knowledge criteria after the model was introduced. After the presentation phase, 40.7 % of the students identified more knowledge criteria, 3.7 % fewer and 55.6 % the same number. After the practice, 44.5 % students identified more knowledge criteria, 22.2 % identified fewer and 33.3 % identified the same number of knowledge criteria.

Table 10: Knowledge criteria for assessing the task for low-achievers before and after the introduction of the model

Phase of math lesson	Phase of study	*N*	*M*	*SD*	Average Ranking	Wilcoxon *Z*	*p*
Presentation	Before	36	0.76	0.799	6.50	-3.405	.001
	After		1.51	1.113	10.41		
Practice	Before	33	0.88	1.005	12.67	-1.057	.291
	After		1.47	1.219	12.40		

Table 11 shows that there is no statistically significant difference (Z = -1.632, p = 0.103) in the identification of the knowledge criteria before and after the introduction of the model for the high-achievers in the presentation phase. In the practice phase, the difference is close to statistical significance (Z = -1.748, p = 0.081). Mean scores for identifying knowledge criteria only improved from 1.44 to 1.47 points in the presentation phase and remained the same in the practice phase. We also wanted to know what proportion of high-achievers improved in identifying knowledge criteria after the model was introduced. After the presentation phase, 42.6 % of the students identified more knowledge criteria, 18.5 % fewer and 38.9 % the same number. After the practice, 40.8 % students identified more knowledge criteria, 34.7 % identified fewer and 24.5 % identified the same number of knowledge criteria. The teaching model had a small effect (d = 0.27) on the high-achievers in the practice phase in terms of better identification of criteria after the introduction of the model.

Table 11: Knowledge criteria for assessing the task for high-achievers before and after the introduction of the model

Phase of math lesson	Phase of study	*N*	*M*	*SD*	Average Ranking	Wilcoxon *Z*	*p*
Presentation	Before	41	1.44	1.147	12.88	-1.632	.103
	After		1.47	1.219	12.40		
Practice	Before	36	1.73	1.247	13.06	-1.748	.081
	After		1.73	1.312	16.38		

4. Discussion

The study investigated whether the use of a self-questioning teaching model can improve students' ability to identify learning objectives and knowledge criteria. It also investigated the impact of the model on the different groups of students in terms of their learning performance.

In line with the first research question, we found that there were statistically significant differences in the identification of learning objectives in both phases of the lesson when teaching with the self-questioning teaching model. After the introduction of the model, more than half of the students improved in identifying the learning objectives. The use of the model had a very large effect on better identification of the learning objectives in the presentation phase and a medium effect in the practice phase of the lesson. Some other authors (e.g., Bourke, 2000; Coffey, 2003) found in their study that students could not identify the learning objectives themselves. Timperlay and Paar (2009) found in their study that students did not know the purpose of the activities during the lesson until the teachers explained them clearly. Students focused on general learning objectives, which hindered their success in achieving the learning objectives (Timperlay and Paar, 2009).

In line with the second research question, we found that there were statistically significant differences in the number of knowledge criteria identified in the presentation phase and the marginal importance of the differences in the practice phase when teaching the self-questioning teaching model. Although there was not such a large difference in the number of criteria identified before and after the introduction of the model, more than a third of the students improved in identifying knowledge criteria in the presentation phase and almost half in the practice phase. There are no studies with which to compare the results obtained. Most of the other studies examine the impact of clear presentation and identification of the learning objectives and criteria on learning performance (e.g., Hattie, 2009; Andrade, Du, & Wang, 2008), or on the accuracy of the students' self-assessment (e.g., Boud, Lawsonn and Thompson, 2013; Wong, 2016) and find it to be positive.

In line with the third research question, we found that there were statistically significant differences in the identification of learning objectives for both groups of students. After the introduction of the model, more than half of the low-achievers and more than half of the high-achievers improved in identifying the learning objectives. The effect of the model on identifying learning objectives in the presentation phase was the same for both groups of students. However, the effect was slightly larger for the high-achievers in the practice phase of the lesson. Liu (2022) found that high achievers outperformed low achievers in identifying learning objectives, but he did not analyse the progress of individual groups of students using a self-assessment model. In terms of improving the identification of the knowledge criteria, we found out that the model had a medium effect on the low-achievers in the presentation phase and a small effect on the high-achievers in the practice phase. However, it is also important to note that slightly less than half of both low-achievers and high-achievers made progress in the number of criteria identified in both phases of the lesson. Differences in the effect of the model according to students' learning abilities may be related to differences in students' mathematical knowledge and metacognitive development. Kruger and Dunning (1999) claim that low-achievers not only lack content knowledge, but also lack the metacognitive skills to recognise that they do not have this knowledge. With appropriate questions, we further encouraged the students to use metacognitive thinking. This helped the low-achievers to improve their identification of knowledge criteria in the presentation phase. We believe that the high-achievers were better than low-achievers at identifying knowledge criteria before the introduction of the model and didn't make such progress. The high-achievers improved mainly in the practice phase. The low-achievers were more concerned with solving tasks, as they had not yet mastered the procedures. It was therefore more difficult for them to think metacognitively about the knowledge criteria while solving a task. It seems that the low-achievers need more experience in using the model while solving the tasks in order to make greater progress in identifying the knowledge criteria. There are no studies with which to compare results obtained. Liu (2022) argues that high-achievers are better at identifying learning objectives and knowledge criteria than low-achievers. At the same time, Händel et al. (2020, in Liu, 2022) points out that both groups benefit from self-assessment training.

5. Conclusion

To summarise, the present study extends the existing research on some of the mechanisms of the self-assessment process and presents a model where the teacher makes the learning objectives and knowledge criteria clear to the students and directs their attention to them throughout the lesson, mainly through self-questioning strategies. The results of the study showed that the presented model could be an example of the effective implementation of a new teaching practice of self-assessement in mathematics lessons, which helps students to become aware of what they are learning in the lesson and how they can know, if they are correct in solving the tasks. The model is suitable for both low- and high-achivers. Using a model, students learn self-regulation skills, in particular self-questioning, which is directed to students awareness of learning objectives and knowledge criteria. The model also aims to the develop students' metacognitive monitoring skills, including students' self-correction skills, which can also lead to improved learning (Andrade, 2019).

We are aware of the limitations of the study. The study was designed and conducted with a small sample of students, and therefore the findings cannot be generalised to the entire student population. Therefore, the relevance of the study could be increased by involving more teachers and their students and by conducting the study over a longer period of time. This would allow teachers to introduce the model gradually, which could certainly improve the quality of implementation. In addition, we have limited the model to selected mathematical content and teaching approaches based on a direct teaching approach with elements of dialogical teaching. The presented model has been tested on a lesson structure with two clearly identified teaching phases. In this respect, our results are limited to the application of the model to similar lesson designs. We believe that the model is flexible and could be adapted to some extent (e.g. self-questioning during learning activities) to other teaching approaches (e.g. inquiry teaching), but we should reconsider its implementation in less structured lesson designs.

Further research could focus on determining the effectiveness of the model in relation to different groups of learners, divided into more groups according to learning ability (low-, medium- and hig-achievers), gender and different levels of education. It would also be useful to investigate how long it takes students to internalise the self-questioning strategy, how effective the use of the model is when applied to other mathematical content, and whether the model is transferable to other areas of education. Further research could also use a qualitative pedagogical research approach to gain a deeper insight into students' identification of learning objectives and knowledge criteria in lessons using the model. In addition, it might be worth investigating which questions students most frequently ask and how they identify learning objectives and knowledge criteria when they have been using the model for some time.

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