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Biology teaching that develops the metacognitive aspect of learning: How to learn competence

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Abstract

Higher-order thinking and metacognition are closely related and are part of learning to develop competence. The goal of this research was to determine the practice of teaching biology that develops metacognition and evaluate whether teachers require specific professional training for this purpose or if broader cognitive-focused training can also enhance metacognitive development in students. The original Teaching Observation Form (TOF) has been adapted for research objectives. A survey was designed to capture the subjective perspectives of 292 students and their teachers regarding metacognition development. Additionally, the research involved six biology teachers who were professionally trained in a program focused on higher-order thinking. The survey results indicate a self-assessed good teaching practice for the development of metacognition. However, analysis of the first lesson's video recordings showed that some components had been eliminated from biology classes which hindered students' ability to develop metacognition. Although higher-order thinking and metacognition are interconnected phenomena, professional development training focuses solely on higher-order thinking whose impact we established through analysis of other lessons does not induce the necessary positive changes for the comprehensive development of metacognition in students. In a nutshell, explicit professional development programs aimed at fostering metacognitive awareness among teachers need to be designed. These programs should instruct teachers on how to model the development of metacognition in students through their teaching.

Keywords: Biology instructions, Higher-order thinking, Metacognition, Professional development, Reflection, Self-regulated learning.

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Contents

Contribution of this paper to the literature
This research highlights how the teaching of biology contributes to metacognitive growth and assesses whether teachers need specialized professional training for this objective. Additionally, the study explored the possibility of broader cognitive-focused training as an alternative approach to fostering metacognitive development in students.

1. Introduction

The competence of *learning how to learn* represents the process and outcome of education (Marušić, 2019) and enables an individual to learn in depth, be effective, adaptable and self-organize the learning process (Drăghicescu, Cristea, Petrescu, Gorghiu, & Gorghiu, 2015). It encompasses the knowledge of human cognition and critical awareness of thoughts, feelings and behaviors during learning (Smith, 1999). It is a metacompetence that supports the memory, strengthening and application of other competencies (Harvest, 2020). *Learning* competence comprises cognitive, affective and metacognitive dimensions.

Metacognition in a broader sense refers to reflection or awareness of one's own thinking (Flavell, 1979) while in a narrow sense it includes cognitive processes and awareness of their unfolding when planning, monitoring and evaluating a task or learning process (Ristić Dedić, 2019). Metacognitive knowledge, experiences and skills are the three components of metacognition which is a crucial component of self-regulated learning and the basis for learning how to learn. Although metacognitive knowledge and experiences are part of the monitoring function, they also have a significant impact on cognitive processes. On the other hand, metacognitive skills are a tool for managing and regulating cognitive activities indicating that they ensure the successful implementation of the intended activity (Efklides, 2006). Metacognitive knowledge represents explicit or implicit ideas or beliefs about oneself and others as cognitive beings about task requirements, the environment and strategies that are available and necessary to solve a task or learn (Ristić Dedić, 2019). It is a prerequisite for metacognitive thinking because it represents a constantly expanding valuable collection of experiences, knowledge, ideas, theories and facts that enable more effective and successful learning or problem solving (Pintrich, 2002). Understanding a method that was previously used to complete a task and realising that the same strategy can be used for the current challenge are two specific examples of metacognitive knowledge. A metacognitive experience is an affective and subjective experience that accompanies almost every cognitive activity (Efklides, 2001). It assists in the self-regulation of learning because it enables students to make modifications based on their own assessment of how successful the learning process or task-solving have been so far. Metacognitive skills are a set of abilities that the student possesses that enable the actual regulation of cognitive processes. These skills enable individuals to monitor, control and regulate their thinking, learning and problem-solving activities and to become more strategically oriented and effective in learning or problem-solving (Veenman, Prins, & Elshout, 2002; Veenman, Wilhelm, & Beishuizen, 2004). They represent procedural knowledge that enables the implementation of activities and the achievement of a goal according to the guidelines of metacognitive knowledge and experiences as well as a tool for achieving the goal.

Metacognition is considered by some authors to be the strongest predictor of learning success in various areas regardless of age (Veenman, Van Hout-Wolters, & Afflerbach, 2006). Its importance is manifested in mastering complex or non-routine tasks whereby students rely on metacognitive skills (van der Stel & Veenman, 2010; Veenman et al., 2002; Veenman & Spaans, 2005) because the development of general metacognitive skills early in life increases students' repertoire in later educational years (Veenman & Spaans, 2005). Although metacognition in children can develop spontaneously without external incentives (Kuhn, 1999), many students have difficulty using metacognitive knowledge during education. They need external support and incentives to develop their metacognitive abilities and incorporate them into their way of thinking (Kuhn, 2000). Metacognitive knowledge should be invoked frequently to make it more accessible and useful (Kesselman & Kuhn, 2002; Zohar & David, 2008) and although there is a natural inclination of the human brain to reflect on its own cognition, external support for learning and the development of metacognition should begin in the early stages of learning.

One of the most important challenges in education is to support students in the development of the competence of *learning how to learn* (Baas, Castelijns, Vermeulen, Martens, & Segers, 2015) and in its development along with cognitive, motivational and emotional processes. Metacognitive processes are considered a key factor (Ristić Dedić, 2019). In the early stages of learning, teachers must provide structured support when students lack the metacognitive knowledge and skills necessary to independently structure their learning process. As students advance through the learning process and obtain experience, their knowledge and skills will also gradually change and the support must adjust to these new circumstances (Ristić Dedić, 2019). According to research by Pintrich, Wolters, and Baxter (2000), Ben-David and Orion (2012) and Zohar and Barzilai (2015), teachers need training in this field which points to the exceptional importance of consistent teacher training on metacognition and how teaching the subject matter prescribed by the outcomes of the subject curricula also develops metacognition in students and is used in mastering the subject matter.

The development of teachers' metacognitive awareness has been the main focus of numerous professional development programmes since it is believed that teachers who lack established metacognitive awareness cannot encourage the same in their students (Prytula, 2012). Hughes (2017) investigated teachers' metacognitive awareness and the need for professional development and found that teachers have a moderate to low level of metacognitive knowledge which is linked to their learning ability, pedagogical knowledge and adaptability to the complex educational environment (Lin, Schwartz, & Hatano, 2005; Wilson & Bai, 2010). This suggests that professional development must take place with metacognition and for the development of metacognition.

The introduction of the curriculum in Croatia is indicative of efforts to guide education towards the development of metacognition or overall learning competence. This curriculum with its expectations within a specific educational cycle equips students for metacognitive processes and as a result helps to achieve all of the biology curricula's objectives (and other subject curricula). The outcomes of the biology curricula are focused on the development of higher-order thinking involving cognitive activities such as analysis, evaluation and creation achieved through constructive and reasoned discussions, the formulation of research questions and establishing cause-and-effect relationships (Zohar, 2004). In practice, these cognitive activities are carried out through an inquiry-based approach that entails questioning, problem definition, planning, modeling, analysis, interpretation and evaluation (Osborne, 2014). These components also correspond to metacognitive knowledge and skills (Zohar & Barzilai, 2015).

In this paper, we addressed two questions. First, what is the practice of teaching biology that develops the metacognitive dimension of competence in learning how to learn? Second, whether the teaching skills for the development of student metacognition are improved by professional training focused on the development of teaching that cognitively actively involves the student in the teaching process and thus enables the acquisition of knowledge at higher cognitive levels which implicitly includes metacognition or whether it is necessary to plan professional training that explicitly improves teaching skills for the development of student metacognition?

Theoretical progress in the conceptualization of *learning-how-to-learn* competence and metacognition is generally apparent but according to Marušić (2019), it is not accompanied by increased representation in class. Although this curriculum was introduced in Croatian education in 2019, there is a potential dissonance between the theoretical and curriculum provisions of teaching for the development of the metacognitive dimension of *learning-how-to-learn* competence and the actual state of the teaching process of biology in class which points to the need for professional training of teachers in this aspect. It's not easy for teachers to embrace research-based ideas about metacognition and translate them into practical classroom recommendations (Leat & Lin, 2003). After considering everything mentioned above, the hypothesis for the first question is that there are variations between the objective assessments of biology teaching practices that foster the metacognitive dimension of learning how to learn competence and the subjective assessments of biology teaching practices that are based on survey data. The objective assessments are made by assessors through the analysis of lesson videos. The video recordings used were captured during a project where teachers underwent professional development aimed at stimulating higher-order thinking (further details are given in the materials and methods section). While the inquiry-based approach is effective for cultivating metacognition in students, it has potential limitations. According to Ristić Dedić (2019), not all cognitive activities are consistently guided by metacognitive processes even though every metacognitive activity involves cognitive processes White and Frederiksen (1998, 2000). Teachers must have an in-depth awareness of the components of metacognition to use it successfully in their instruction to help students develop higher-order thinking. This means that they must possess the necessary metacognitive knowledge and abilities (Seraphin, Philippoff, Kaupp, & Vallin, 2012). Zohar and Barzilai (2015) highlight the relationship between higher-order thinking and metacognition suggesting that teachers' knowledge in this context can be considered through the dimension of understanding the elements of higher-order thinking or metacognition as well as through the dimension of pedagogical knowledge in the context of teaching higher-order thinking or metacognition. Therefore, the hypothesis for the second question is that explicit professional development focused on specific content and examples on how to simultaneously develop higher-order thinking and metacognition through teaching to enhance teaching skills aimed at fostering metacognition in students.

2. Materials and Methods

2.1. Participants

In the survey conducted in the school year 2022 -2023, 292 students participated of which 147 were primary school students and 145 were secondary school students. In primary school, the distribution of students by sex is approximately equal to 71 male students and 76 female students while in secondary school, the survey included 38 male students and 107 female students. The distribution of primary school students according to final grades in biology is secondary school students. Most students had a 'very good' final grade at the time of the survey. In primary school, the percentage of students with a very good grade in biology is 47% and in secondary school it is 71%. The next largest share of students in primary school has a 'good' final grade (46%) while 39% of the surveyed primary school students have an 'excellent' grade. Only 2% of students had an 'insufficient' grade. There are no students with a final insufficient grade in high school and the percentage of students with a 'sufficient' final grade in primary school (11%) is about 13%. In high school, students with good and excellent final grades are similarly distributed, so 33% of students have a good grade in biology while 30% have an excellent grade. In addition to the students, their primary teachers (14 biology teachers) and secondary teachers (3 biology teachers) also participated in the research. Most primary and secondary teachers have between 9 and 13 years of service (35%) and between 14 and 18 years of service (29%). Only one teacher has less than 3 years of service and for more than 18 years, biology has been taught by two teachers. Among the primary school teachers, six teachers who teach biology in the eighth grade participated by analyzing videos of their teaching in class. The videos were recorded during the implementation of the project "Professional development of teachers with the purpose of improving the learning results of primary school students in the natural science and mathematics field" funded by the Croatian Science Foundation (IP-2018-01-8363). Teachers were assigned initials to preserve their anonymity.

2.2. Design

1. Development of a modified teaching observation form based on the original teaching observation form(TOF) Bezinović, Marušić, and Ristić Dedić (2012) with the addition of features that enable the analysis of teaching biology that develops metacognition.
2. Constructing a survey for teachers of biology to determine self-assessed teaching practices for the development of metacognition and constructing a survey for students. The surveys were conducted online and were completely anonymous. The survey was only completed by students whose parents gave their approval to participate.
3. Video analysis of lessons taught by six primary teachers of biology according to the modified teaching observation form.

1. Modification of the original TOF form was based on the analysis of the curriculum of the cross-curricular topic *learning* how *to learn* for primary and secondary schools and relevant sources. This established the

expectations of each educational cycle and the recommendations and guidelines for achieving competence in learning how to learn. A form for monitoring metacognitive teaching was developed by adding new features to the ones that already existed.

2. Two closed surveys were created for the study's objectives: one was intended especially for teachers and the other for students. They were constructed based on the features of the modified TOF form. Both surveys had the same structure in the sense that they contained initial questions in the first part and statements in the second part. The first group of questions for teachers identified the general characteristics of respondents such as gender, workplace, years of service and initial education. Students' grade, gender, grade point average and final biology grade were all determined by the first set of questions in the survey. The second part of the teacher survey included statements in which the teachers self-assessed their own practice of metacognitive teaching with a Likert-type scale from 1 to 3 where 1=*Never*, 2=*Sometimes* and 3=*Always.* The second part of the student survey included 37 statements about the assessment of the prevalence of metacognitive teaching in biology classes. The students also answered by using the same scale with the same meanings as the teachers.

3. The teachers whose videos of their lessons were analyzed for the purposes of this paper were included in professional development training during the summer semester of the school year 2021-2022 (from February to the end of May) during the aforementioned project. The professional development training took place by exchanging the recordings and analyzing the videos of lessons and in learning communities where lectures and discussions on the analyzed lessons were held. At the beginning of their professional development training, their initial lesson teaching was recorded and analyzed in the learning communities using the original TOF form. The subjects covered in the remaining professional training sessions in learning communities were determined by analyzing the video recordings of the first class which revealed areas for each teacher's development. Thus, two topics were present: research-based learning in the teaching of biology and the flipped classroom and problem-solving in the teaching of biology throughout the professional development training. Research-based learning is a method that takes steps identical to the scientific methodology, so students learn how to set and test a hypothesis, how to draw conclusions based on the results and how to present the results of their research (Pedaste et al., 2015). In this way, students master natural science literacy by learning the contents of the biology subject that are provided by the curriculum. The method also assumes the use of self-assessment skills. The flipped classroom is a convenient approach to learning because it implies collaborative problem-solving in the classroom that students approach already prepared in the sense that they have studied all the necessary information needed to solve the problem at home. It also implies self-assessment (Ozdamli & Asiksoy, 2016).

The ultimate objective of professional development training was to raise students' cognitive active involvement in the teaching process so they could acquire knowledge at higher cognitive levels. Video analysis was carried out using the original TOF form in which certain categories were chosen, i.e., characteristics necessary for students' active involvement in the teaching process that support students' higher-level cognitive engagement (a description of all the features of the original TOF form is given in the results). At the beginning of professional training, teachers implemented what they learned in their lessons in such a way that they independently designed a lesson plan at the level of a class period (first support) and later they received ready-made lesson plans made by experts and taught their lessons according to them (second support). In this research, the same recordings were used to analyse the videos according to the modified TOF form.

A specified method and learning strategy were used to measure the students' cognitive engagement for the research's aims in order to ensure that the students were engaged cognitively. We evaluated the lessons delivered using the modified TOF form for the purposes of this paper in order to determine how much professional development centered on students' cognitive activation implicitly improves teaching abilities that also develop the use of metacognitive activities.

2.3. Instruments and Data Analysis

The reliability of the survey questionnaire was assessed by calculating the Cronbach alpha coefficient. Coefficients of values were used to assess the reliability of the survey according to Bukvić (1988). According to the same source, a coefficient of 0 is considered unacceptable while a coefficient of 0.9 or more is considered excellent.

The results of the survey were analysed using descriptive statistics. The Pearson chi-square test was carried out with a Yates correction to determine the correlation between certain characteristics of the respondents and the response to an individual statement. For teachers, an analysis of the correlation of individual statements with the workplace (primary or secondary school) and years of service was carried out while for students, the correlation of individual statements with their final grade in biology and regarding whether they attend primary or secondary school was determined. Statistics package Statistica 12 (Quest Software Inc., Aliso Viejo, CA, USA) was used for all analyses.

The data obtained by analyzing the videos of the lessons taught by six biology teachers is presented in a table. The represented feature in each group is marked with a plus sign (+), the insufficient representation of the feature with a plus and minus sign (+/-), and the absence of the feature with a minus sign (-). The lessons were analyzed independently by two raters and inter-rater reliability was determined using Cohen's kappa coefficient, whose values can range from 0 (no agreement between raters) to 1 (excellent agreement between raters), with values below 0.20 indicating poor agreement, from 0.21 to 0.40 fair, from 0.41 to 0.60 moderate, from 0.61 to 0.80 good and from 0.81 to 1.00 very good agreement (Landis & Koch, 1977).

Table 1. Distribution of responses of primary and secondary school students and their teachers to a particular statement of the survey assessing the implementation of metacognitive teaching in biology class where 1 means never, 2 sometimes and 3 always.

Statements	Teachers					High school students					Primary school students				
	N	Min.	Max.	Mean	Std. dev.	N	Min.	Max.	Mean	Std. dev.	N	Min.	Max.	Mean	Std. dev.
1. I emphasize confidence in the abilities and success of students.	17	2	3	2.9	0.4	145	1	3	2.7	0.5	147	1	3	2.6[a]	0.6
2. At the beginning of the lesson, I clearly state the topic of the lesson.	17	2	3	2.8	0.4	145	2	3	2.9	0.4	147	1	3	2.7[a]	0.5
3. At the beginning of the lesson, I encourage the evocation of prior knowledge relevant to the topic of the lesson.	17	2	3	2.6	0.5	145	2	3	2.8*	0.4	147	1	3	2.7*	0.5
4. At the end of the lesson, I encourage students to notice changes in knowledge compared to the beginning of the lesson.	17	2	3	2.3	0.5	145	1	3	2.4	0.6	147	1	3	2.3	0.7
5. I clearly state the goals of the lesson.	17	2	3	2.4	0.5	145	1	3	2.6	0.6	147	1	3	2.6	0.6
6. I encourage students to assess the effectiveness of the chosen learning method applied in the class to achieve the goal.	17	1	3	2.2	0.5	145	1	3	2.5	0.6	147	1	3	2.5	0.6
7. I present the lesson plan to students (I describe how they will learn, i.e. achieve their goal).	17	2	3	2.3	0.5	145	1	3	2.6	0.6	147	1	3	2.4	0.7
8. I encourage students to set their own goals for the lesson.	17	1	3	1.5	0.6	145	1	3	2.4	07	147	1	3	2.5	0.7
9. I encourage collaborative learning.	17	2	3	2.2	0.4	145	1	3	2.5	0.6	147	1	3	2.6	0.6
10. I provide students of different abilities or interests with tasks of different difficulty.	17	2	3	2.3	0.5	145	1	3	2*	0.9	147	1	3	2.2*	0.8
11. I provide the option of choosing the activity and manner of working.	17	1	3	1.8	0.5	145	1	3	2.1	0.8	147	1	3	2.2	0.7
12. I place emphasis on comprehension not just memorizing concepts.	17	2	3	2.9	0.3	145	1	3	2.8*	0.4	147	1	3	2.6*[a]	0.6
13. I directly teach students how to approach learning, solving certain tasks or practicing by telling them which strategy is most effective and why it is most effective.	17	2	3	2.3	0.5	145	1	3	2.5	0.6	147	1	3	2.5	0.7
13.a). The teacher demonstrates how to approach learning particular course subjects or completing specific tasks by using their personal example.						145	1	3	2.5	0.6	147	1	3	2.6	0.6
13.b) The teacher demonstrates effective planning and organisation of learning or problem-solving activities by providing an example.						145	1	3	2.3	0.7	147	1	3	2.5	0.6
13.c) The teacher demonstrates for students how to evaluate and improve their own work.						145	1	3	2.5	0.7	147	1	3	2.5	0.6
14. I demonstrate how to apply various metacognitive abilities in the classroom by discussing how to establish learning objectives, make plans for reaching them, keep track of progress and evaluate goals.	17	1	3	2.1	0.4										
15. I encourage students to explain why a particular approach was chosen when solving a task.	17	1	3	2.1	0.5	145	1	3	2.6	0.6	147	1	3	2.6*	0.6
16. I give the opportunity to independently practice metacognitive skills while working on various tasks (assessing the complexity of tasks, experiences of solving similar tasks, evocation of prior knowledge and planning the steps of solving the task).	17	2	3	2.2	0.4										
17. I encourage students to monitor and check their work (e.g. to spot and correct errors and check the solution they have come up with).	17	2	3	2.6	0.5	145	1	3	2.7	0.5	147	1	3	2.6	0.5

Statements	Teachers					High school students					Primary school students				
	N	Min.	Max.	Mean	Std. dev.	N	Min.	Max.	Mean	Std. dev.	N	Min.	Max.	Mean	Std. dev.
18. I encourage students to independently take notes and organize the content being learned (e.g. by extracting main ideas and concepts or making simple illustrations).	17	2	3	2.4	0.5	145	1	3	2.7	0.5	147	1	3	2.6	0.6
19. I talk to students about how they perceive working on some tasks or activities (e.g. whether working on a task contributes to a sense of self-confidence, how motivated they are by such work, whether they feel prepared or not, and why).	17	1	3	2.1	0.5	145	1	3	2.2	0.8	147	1	3	2.2	0.8
20. I demonstrate methods and ways of thinking that support a constructive and positive attitude towards a task or lesson by using my own experience.	17	2	3	2.5	0.5	145	1	3	2.6	0.6	147	1	3	2.6[a]	0.6
20.a) The teacher exemplifies ways of thinking and approaches that contribute to reducing stress or a negative attitude towards the lesson topic or learning.						145	1	3	2.4	0.7	147	1	3	2.4	0.6
21. I ask questions to check the students' comprehension.	17	2	3	2.9	0.3	145	1	3	2.8	0.4	147	1	3	2.7	0.5
22. I encourage students to monitor their comprehension during the lesson and react as needed.	17	2	3	2.8	0.4	145	1	3	2.7	0.5	147	1	3	2.7	0.5
23. I provide specific feedback to students about their work.	17	2	3	2.8	0.4	145	1	3	2.7	0.5	147	1	3	2.6[a]	0.6
24. I entice and encourage students to create internal feedback.	17	2	3	2.4	0.5	145	1	3	2.5	0.6	147	1	3	2.6	0.6
25. Using specific examples, I explain my criteria for evaluating the work and achievements of students.	17	2	3	2.5	0.5	145	1	3	2.7	0.5	147	1	3	2.7	0.4

Note: * statistically significant correlation between the response to the statement and the school that students attend (primary or secondary); [a] statistically significant correlation between the response to the statement and the final grade in Biology

3. Results

Primary school students generally estimate on average that their teachers always implement features important for teaching that encourage metacognition (see Table 1). Their responses to sentences with never are mostly absent but it is clear that at least one student evaluated every statement with never. High school students as well as primary school students generally estimate on average that most of the statements are always implemented in biology classes. Teachers respond to 15 statements that they sometimes implement in their teaching and to ten statements that they always implement. They do not respond to any statement that it was never implemented. Out of a total of 24 statements that are common to students and teachers, the average response of students and teachers differs in a total of seven statements. For example, students perceive that their teachers consistently promote collaborative learning and set lesson goals. Teachers generally think that they rarely do it in the classroom (see Table 1). The reliability of the survey conducted with primary and secondary school students is excellent (Cronbach's alpha coefficient is 0.94) while the reliability of the survey conducted with teachers of biology is good (Cronbach's alpha coefficient is 0.86).

At the beginning of the lesson, the teacher always encourages the evocation of prior knowledge relevant to the teaching topic as stated by 100 primary school students and 118 secondary school students. Only two primary school students state that the teacher never does this while there are no such students among high school students. Teachers as well as primary and secondary school students on average estimate that sometimes students of different abilities or interests are provided tasks of different difficulty (see Table 1). Analyzing the answer distribution in Table 2 reveals a notable trend. The majority of primary and secondary school students believe their teachers consistently engage in this behavior. 98 primary school students and 118 high school students always put emphasis on comprehension. Only six primary school students think that a teacher never does this while only one high school student thinks the same. The statement "*I encourage students to explain why a certain approach was chosen when solving a task"* is assessed differently by students and teachers on average. The teachers state on average that they sometimes do this while primary and high school students estimate on average that their teachers always do it (see Table 1). By examining the distribution of answers shown in Table 2, primary school students and high school students estimate that the teacher always does this. 21 high school students and nine primary school students believe that the teacher never does that.

Table 2. Distribution of student responses to a particular statement of the survey assessing the implementation of metacognitive teaching in biology classes according to the school they attend.

Survey statements	Students	Replies			Total	Value of χ2 test
		Never	Sometimes	Always		
At the beginning of the class, the teacher encourages the evocation of prior knowledge relevant to the lesson topic.	Primary school	2	45	100	147	$\chi^2_{(2)}=7.973$; p=0.019
	High school	0	27	118	145	
Students of different abilities or interests are provided with tasks of different difficulty by the teacher.	Primary school	31	52	64	147	$\chi^2_{(2)}=9.309$; p=0.010
	High school	54	39	52	145	
The teacher puts emphasis on comprehension not just memorizing concepts.	Primary school	6	43	98	147	$\chi^2_{(2)}=9.598$; p=0.008
	High school	1	26	118	145	
The teacher encourages students to explain why a certain approach was chosen when solving a task.	Primary school	9	52	86	147	$\chi^2_{(2)}=7.039$; p=0.030
	High school	21	56	68	145	

Table 3 shows that 103 students evaluated the teacher's emphasis on trust in students' skills and achievement, 38 students said the teacher does this occasionally and just 6 students said the teacher never does this. Among the students with excellent, very good, good and sufficient final grades in biology, most students respond to this statement always compared to those who respond to it. Only one student with an insufficient final grade, four students with a good final grade and one student with a very good final grade state that the teacher never expresses confidence in the abilities and success of the students. For the statement "*At the beginning of the lesson, the teacher clearly states the topic of the lesson*" 39 students with a grade of very good (4) which is the highest within this group believe that the teacher always clearly states the topic of the lesson at the beginning of the class. The teacher's practices are assessed by an equal number of students with excellent and very good final grades. Students with insufficient final grades evaluate the implementation of this statement equally. One student states that the teacher never clearly states the topic of the lesson at the beginning of the class while another student with the same final grade states that the teacher always does this. Six students assessed that the teacher puts emphasis only on memorizing concepts and most of them have a good final grade (3). Many students assessed that the teacher sometimes (43) or always (98) focuses on comprehension rather than memorizing concepts. In both groups, there are more students with a very good final grade (4) than students with an excellent final grade (5) while students with a sufficient final grade (2) are equally distributed in these groups. Of the 2 students who have insufficient final grades in biology, one believes that the teacher never puts emphasis on comprehension and one believes that they only do it sometimes. For the statement "*The teacher exemplifies ways of thinking and approaches that contribute to a positive attitude towards the lesson topic and learning*", 93 students agreed that the teacher always implements this in class, 47 students stated that he or she only does it sometimes as before and only seven of them assessed that the teacher never implements such modelling. Students with excellent, very good, good and sufficient final grades estimate to a greater extent that the teacher always exemplifies ways of thinking and approaches that contribute to a positive attitude towards the lesson topic and learning compared to those who believe that they do so sometimes. There are no students with excellent final grades who believe that the teacher never does this while one student with an insufficient final grade, four of them with good final grades and two with very good final grades do believe so. The largest number of students with all final grades except grade insufficient (1) believes that the teacher always provides specific information about their work and students with excellent and very good final grades stand out the most. In the groups that assess this statement with "sometimes" and "never", there are most students with good final grades; however, a noticeable number of students with very good final grades also assess this with "sometimes" while in the group that assesses this with "never" there is the same number of students with sufficient final grades as those with good final grades.

Table 3. Distribution of responses of primary school students to a particular statement of the survey assessing the implementation of metacognitive teaching in biology classes with regard to the final grade in biology.

Statements	Final grade in biology	Never	Sometimes	Always	Total	Value of χ2 test
The teacher emphasizes confidence in the abilities and success of the students.	1	1	1	0	2	$X^2_{(8)} = 18.66$; p=0.017
	2	0	4	9	13	
	3	4	13	29	46	
	4	1	12	34	47	
	5	0	8	31	39	
	Total	6	38	103	147	
At the beginning of class, the teacher clearly states the topic of the lesson.	1	1	0	1	2	$X^2_{(8)} =23.04$; p=0.003
	2	0	5	8	13	
	3	2	11	33	46	
	4	1	7	39	47	
	5	0	7	32	39	
	Total	4	30	113	147	
The teacher puts emphasis on comprehension not just memorizing concepts.	1	1	1	0	2	$X^2_{(8)} = 18.19$; p=0.02
	2	0	6	7	13	
	3	3	15	28	46	
	4	2	12	33	47	
	5	0	9	30	39	
	Total	6	43	98	147	
The teacher leads by example on approaches and ways of thinking that contribute to a positive and productive attitude towards the lesson topic or assignment.	1	1	1	0	2	$X^2_{(8)} = 18.85$; p=0.016
	2	0	4	9	13	
	3	4	13	29	46	
	4	2	20	25	47	
	5	0	9	30	39	
	Total	7	47	93	147	
The teacher provides specific feedback to students about their work.	1	1	1	0	2	X^2 (8) =21.41; p=0.006
	2	2	4	7	13	
	3	2	18	26	46	
	4	1	17	29	47	
	5	0	9	30	39	
	Total	6	49	92	147	

Video analysis was performed according to the modified TOF form. The original form consists of teaching characteristics divided into six categories: classroom atmosphere, lesson structuring (lesson organization and teaching structure), student involvement and motivation (student involvement in the teaching process and their active participation), individualization/differentiation (adaptation of teaching to individual differences in abilities, prior knowledge and interests of students), teaching metacognitive skills and learning strategies (development of higher (meta) cognitive processes, critical thinking and understanding and improving one's own learning) and feedback and formative assessment (checking what has been learned and providing feedback that facilitates comprehension and acquisition of learning content). New features specific to the development of metacognition have been added to the existing features (shown in Table 4 shaded and in italics) to allow in addition to the existing ones, the assessment of teaching practice for the development of metacognition in students.

The analysis of the initial recordings of the lessons (see Table 4) indicates that none of the teachers emphasizes confidence in the abilities and success of students in any of their lessons. This feature of teaching has not improved even during the professional training of the teachers. For the same feature, the teachers on average declare in the survey that it is always present in their lessons (see Table 1). Features that were also not present in any of the teachers in the initial lessons and which were not improved in any of them during the professional development of the features are those related to the encouragement of students to independently set their own goals for the lesson, those that relate to the fact that students of different abilities or interests are given tasks of different difficulty and features related to the possibility of providing choices of various activities and methods of work. The features related to asking questions and having enticing conversations about the metacognitive experience of the teaching topic or task as well as the features related to modelling the way of thinking and approaches that contribute to positive academic emotions and metacognitive experience do not appear in any of the teachers at any of their lessons during the initial lessons and they do not even appear during professional training in any of them. In the self-assessment of the presence of these features, none of these features were assessed as one that were never implemented in the lesson (see Table 1).

Table 4. Teaching features in the analysis of the initial, second and third recorded lessons during professional development and the progress made regarding a particular feature.

Features of metacognitive teaching (All features begin with the teacher)	Teacher						Teacher						Teacher					
	1st (initial) lesson						2nd lesson: 1st line of support						3rd lesson: 2nd line of support					
	KČ	DM	MĐ	MŠ	KR	MS	KČ	DM	MĐ	MŠ	KR	MS	KČ	DM	MĐ	MŠ	KR	MS
1. Emphasizes confidence in the abilities and success of students.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2. Clearly state the topic of the lesson at the beginning of the lesson.	+	-	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+
3. At the beginning of the lesson encourage the evocation of relevant prior knowledge for the lesson.	+	+	-	-	-	+	+	+	-	+	-	+	+	+	+	+	+	+
4. At the end of the lesson encourage the perception of changes in knowledge in relation to the beginning of the lesson.	-	+	-	-	-	-	+	+	+	+	-	-	+	+	+	+	+	+
5. Clearly states the goals of the lesson (Learning outcomes).	-	-	-	-	-	-	-	+	+	-	-	-	-	+	+	+	-	+
6. Encourages the assessment of the effectiveness of learning methods to achieve the goal.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
7. Presents the lesson plan (Describe how they will learn or achieve the goal of the lesson).	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-
8. Encourages students to set their own goals for the lesson.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9. Encourages collaborative learning.	-	+/-	-	-	-	-	+	+/-	+	+/-	+/-	-	+	+	+	+	+	+/-
10. Gives students of different abilities or interests tasks of different difficulty.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11. Provides the option of choosing activities and manner of working.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12. Places emphasis on comprehension not just memorizing concepts.	+	+/-	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+
13. Directly teaches students how to approach learning, solving certain tasks or practicing.	-	+/-	+	-	-	-	+	+	+	+	-	-	+	+	+	+	+	+
14. The use of different metacognitive strategies and activities in specific contexts.	-	-	+	+	-	-	-	+/-	+	+/-	+/-	-	+	+	+	+/-	+	+/-
15. Encourages students to explain why a certain approach was chosen when solving a task.	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+
16. Gives the opportunity to independently practice the use of metacognitive strategies on various tasks.	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+/-	+	+/-
17. Encourages students to monitor and check their work.	-	+/-	-	+	-	+/-	+	+/-	-	+	+/-	+	+	+	-	+	+	+
18. Encourages students to independently take notes and organize the content being learned.	-	-	+	-	+	-	-	-	+	+/-	-	+	+	+	+	+	+	+
19. Asks questions and encourages conversation about the metacognitive experience of a teaching topic or assignment (e.g. whether they feel confident, unprepared, afraid, and calm).	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
20. Ways of thinking and approaches that contribute to positive academic emotions and metacognitive experience.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
21. Asks questions to check students' comprehension.	+	+	+	+	+/-	+	+	+	+	+	+	+	+	+	+	+	+	+

Features of metacognitive teaching (All features begin with the teacher)	Teacher						Teacher						Teacher					
	1st (initial) lesson						2nd lesson: 1st line of support						3rd lesson: 2nd line of support					
	KČ	DM	MĐ	MŠ	KR	MS	KČ	DM	MĐ	MŠ	KR	MS	KČ	DM	MĐ	MŠ	KR	MS
22. Encourages students to monitor their comprehension during the lesson and react as needed.	-	-	+	+	-	-	-	-	+	+	-	-	-	-	+	+	+	-
23. Provides specific feedback to students about their work.	-	-	-	+/-	-	-	-	-	-	-	-	-	-	+/-	+	+	-	+
24. Entices and encourages students to create internal feedback.	-	-	-	-	-	-	-	+	-	-	-	-	-	+	-	-	-	-
25. Uses specific examples to explain the criteria for evaluating the work and achievements of students.	-	-	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-	-

Note: For teacher KČ, Fleiss' kappa showed that there was good agreement between the raters (κ=.744 (95% CI, .738 to 0.750), p < .0005); For teacher DM Fleiss' kappa showed that there was very good agreement between the raters (κ=.810 (95% CI, 0.804 to .815), p < 0.0005); for teacher MĐ Fleiss' kappa showed that there was very good agreement between the raters (κ=0.850 (95% CI, 0.843 to 0.856), p < 0.0005); For teacher MŠ Fleiss' kappa showed that there was very good agreement between the raters (κ=0.883 (95% CI, 0.877 to .889), p < 0.0005); For teacher KR Fleiss' kappa showed that there was very good agreement between the raters (κ=0.827 (95% CI, 0.821 to 0.832), p < 0.0005); For teacher MS Fleiss' kappa showed that there was very good agreement between the raters (κ=0.842 (95% CI, 0.836 to 0.847), p < 0.0005).

The feature related to the incentive for students to assess the effectiveness of learning methods for achieving the goal was improved only by one teacher and only at the end of professional development training when another method of support was implemented. A similar case is evident regarding the features related to stating the lesson plan and the feature related to explaining the criteria for assessing the work and achievements of students. It was only after implementing the second support in the third lesson that these features were present in two of the six teachers. Other teaching features related to the practice of teaching to strengthen metacognition in students have improved. For example, a feature related to giving incentives to students to notice a change in knowledge at the end of the lesson compared to the beginning of the lesson during the initial lesson was present only in one teacher after the second form of support was implemented; it was present in four teachers after the third form of support occurred in all the teachers. The same is true for encouraging students to engage in collaborative learning and for encouraging students to independently keep notes and organize the content being learned. Features that were mostly well represented in the initial lesson (present in five or all teachers) are those related to placing emphasis on comprehension not just memorizing concepts and those related to asking questions that check the comprehension of students. The same features remained throughout professional development (see Table 4).

4. Discussion

The research established the practice of teaching biology which also develops metacognition in students by analyzing a survey conducted among teachers and students (subjective assessment) and analyzing videos of biology classes (objective assessment). Differences in teaching practice were established which confirmed the first hypothesis by comparing the subjective and objective assessments. Subjective assessment indicates good teaching practice for the development of metacognition while objective assessment identifies aspects that need to be improved during professional development.

The feature "*Teacher emphasizes confidence in the abilities and success of students*" in the survey was assessed by teachers and primary and high school students as a feature that is always present in class (see Table 1) while the objective assessment did not record it in any of the classes taught by any of the six teachers (see Table 4). Students with varying final grades largely state that this feature is always present in class (see Table 3). This feature was added to the original TOF form and is related to the domain of metacognitive experience and enables the assessment of the presence of teaching features that contribute to the management of emotions and motivation. The difference in assessments can be attributed to the fact that primary and high school teachers truly often and spontaneously praise students' efforts from their perspective. However, in an objective assessment, this feature was assessed in the context of modelling self-regulated learning. If there were no features present in a lesson related to setting the goal of the lesson (5th and 8th features) (see Table 4), planning the achievement of the goal (7th, 10th, 11th, 13th and 14th features) (see Table 4) and to reviewing the achievement of the goal (4th, 6th, 15th, 18th, 23rd, 24th and 25th features) (see Table 4) which is especially evident in the analysis of the initial lesson (see Table 4), then there was also a lack of confidence in the students' ability for self-regulated learning and belief that such learning can lead them to success. The features related to the teacher's goal setting (5th feature) are important for the metacognitive dimension in teaching students self-regulated learning as an example of a lesson structure. In addition, it is important to provide them with the opportunity to practice such learning on their own, encouraging students to set their own goals for the lesson (8th feature) (see Table 4). This feature is important for the development of metacognitive skills such as goal setting and organizing learning. Dignath and Büttner (2008) clearly conclude in their research that metacognition in teaching can only develop successfully when it is systematically and explicitly named as the goal of the lesson and if teachers prioritize metacognitive activities and incentives that affect the processes of planning, monitoring and regulating learning. Therefore, it can be concluded that frequently encouraging students to supervise their comprehension or to check their work or solutions will have a greater effect on their metacognitive development than clearly stating the topic of the lesson. It is important to emphasize that clearly stating the topic of the lesson is not less important as a feature but it has a lesser impact on the explicit metacognitive development of students who are not skilled in metacognitive thinking. However, those students who already have certain metacognitive knowledge and skills will greatly benefit from the presentation of the teaching topic or the evocation of relevant knowledge for their activation and orientation in class. A more detailed analysis of the study reveals that the fifth aspect is considered by teachers as a phenomenon that occurs occasionally when teaching whereas it is evaluated as something that occurs every time in biology lessons by primary and high school students (see Table 1). This feature was recorded only after the second support as being present in four teachers (see Table 4). On the other hand, the 8th feature was not present in any of the teachers in any of the analyzed lessons (see Table 4) while the teachers on average estimate that it is sometimes present in class (see Table 1).

The feature *"The teacher encourages students to explain why a certain approach was chosen when solving a task"* (15th feature) (see Table 4) was added to the original TOF form to encourage students to argue the reasons for choosing a certain approach that leads to an understanding of strategies so that the knowledge of strategies would not remain only at the level of declarative knowledge. It is important for students to develop knowledge and skills that are general and that can be applied to different situations and types of tasks not just specific knowledge and skills for solving certain types of tasks (Jackson, Fleming, & Rowe, 2019). Accordingly, a feature was added: "*The teacher gives the opportunity to independently practice the use of metacognitive strategies on various tasks*" which is related to the training and consolidation of metacognitive knowledge related to learning and task solving strategies which research cites as a key factor for the successful transfer of metacognitive abilities (Kesselman, 2003; Kesselman & Kuhn, 2002). Research shows that certain metacognitive knowledge and skills appear at different ages, for example, the explicit ability to evaluate learning or work appears steadily only around the age of fourteen while the ability to reflect on one's own learning or oneself as a cognitive being appears only in later adolescence which is why it makes no sense to require or practice knowledge or skills that students are not yet able to perform (Veenman, 2015). Nevertheless, it is useful to model the use of different strategies or metacognitive activities even if students cannot yet be expected to carry out these metacognitive activities independently as modelling has proven to be a very effective way of learning the metacognitive way of thinking (Veenman, 2012). For this reason, the feature "*The* *teacher models the use of different metacognitive strategies and activities in certain contexts* (14th feature) was added. This feature was improved after the third support when teachers implemented the lesson with a flipped classroom learning approach that includes problem solving in class so teachers first modelled the problem-solving process on an example and then gave students the opportunity to practice independently (see Table 4) (16th feature). However, the described flipped classroom did not improve an important aspect of metacognition, namely the incentive for students to verbalize the reasons for which a certain approach was chosen in solving the problem (feature 15) (see Table 4).

Since self-assessment is an important way to learn and develop metacognition and self-regulated learning (McMillan & Hearn, 2008), a feature was added to the original TOF form: "*The teacher entices and encourages students to create internal feedback.*" (24th feature) (see Table 4). In this feature, a difference was observed between subjective (see Table 1) and objective assessment (see Table 4). The feature did not improve even after the third support. Here, as with the 15th feature, there was no opportunity for students to verbalize and thus become better aware of the entire learning process. Research shows that self-assessment is an important aspect of learning because it affects the construction of knowledge, evaluation, linking existing knowledge and the organization of learning (Shepard, 2001). However, it is important that the student plays a major role in this process, that they independently practice self-assessment as a metacognitive skill and that they notice progress in learning based on their own feedback which strengthens their self-confidence, understanding of the lesson content and intrinsic motivation to learn in order to realize the benefits of self-evaluation (McMillan & Hearn, 2008).

The features "*The teacher asks questions and encourages conversation about the metacognitive experience of the teaching topic or task (e.g., whether they feel confident, unprepared, afraid or calm)* and "*The teacher models ways of thinking and approaches that contribute to positive academic emotions and metacognitive experience*" were also added to the original TOF form. According to Efklides (2006), these are features related to metacognitive experience and emotions that greatly influence decision-making about starting or finishing learning or working on a task about changing activities or modelling one's own beliefs about success. Therefore, talking about academic emotion or metacognitive experience itself can prove extremely useful in fostering self-regulated learning. It is important to note that the highlighted statements do not serve to activate a pleasant metacognitive experience in students but rather teach students how to recognize, define and influence their own metacognitive experience which is cited as one of the important components for using metacognitive experiences in learning (Efklides & Volet, 2005). These two characteristics were not recorded by objective assessment in either teacher during the initial lesson and did not appear after the first and second support provided during their professional training which is in agreement with some authors who point out that it is necessary to pay much more attention in class to this part of metacognition (Dignath & Büttner, 2008; Efklides & Volet, 2005; Tornare, Czajkowski, & Pons, 2015).

The video analyses showed that the features related to the metacognitive experience were not improved (1st, 19th and 20th features) and neither were the important ones for the planning of learning during class for its monitoring and or reflection. The individualization of teaching which is necessary in teaching for the development of metacognition (10th and 11th features) was also not improved. The independent implementation of inquiry-based research learning that the teachers used during the first line of support and the use of ready-made lesson plans that included a flipped classroom with problem-solving during the third line of support led to the improvement of only some features which confirms our second hypothesis. Teachers' lessons we analyzed for the purposes of this research continuously self-reflected on their learning during their professional development training (by analyzing video recordings of teaching lessons and reviewing and discussing them during learning communities). The changes in their knowledge and teaching skills were thus self-assessed which in turn reflected changes in teaching and ultimately affected students' more successful learning. Teachers whose courses we studied got continuous feedback and support from project colleagues and experts in addition to reflections and video analysis. Hughes (2015) identifies these elements as effective professional development. According to Mirosavljevic and Bognar (2019), they also used a variety of educational material and lesson plans which are also features of professional development. Therefore, although teachers were subjected to effective professional development training, they did not experience complete positive changes in their knowledge and teaching skills to strengthen metacognition in students because the general goal and topics of their professional development were not explicitly focused on this but only on how to teach for higher-order thinking. Explicit professional training is required for the development of metacognitive teaching in order to generate substantial changes in teachers and their teaching in which the practice of modelling all processes characteristic of metacognition is prevalent. A teacher who teaches with metacognition understands the importance of metacognition, possesses awareness of their own and students' metacognitive processes, uses techniques to develop metacognitive knowledge and is capable of creating an environment that fosters metacognition (Hartman, 2001). According to Gourgey (1998), Duke and David Pearson (2002), Veenman et al. (2006) and Dignath and Büttner (2008), the implementation of continuous and long-term activities that promote metacognition is crucial for the acquisition of metacognitive knowledge and skills. This facilitates the transfer of knowledge and skills and allows the process to become automatic. Representing a metacognition-relevant element carelessly or unintentionally will prevent the required modelling from occurring and prevent taught students from applying their metacognition. The distinction between objective and subjective assessment further emphasises the necessity of professional growth with a specific focus on enhancing metacognitive teaching. According to Halamish (2018) and Ozturk (2017), teachers lack knowledge about metacognition and its implementation in teaching. To achieve competence in *learning how to learn* in primary and high schools, one of the most important prerequisites is having teachers who are well educated on this subject. Teachers must first demonstrate a high level of declarative and practical knowledge of metacognition and excellence in metacognitive and cognitive thinking systems to achieve this goal (Zohar & Schwartzer, 2005). Numerous studies have shown that foreign teachers do not have enough knowledge about metacognition to successfully teach it in class (Ben-David & Orion, 2012; Ozturk, 2018; Zohar, 2006; Zohar & Schwartzer, 2005). The main problem is the lack of theoretical and practical knowledge about metacognition as a way of thinking and about the way of teaching metacognition and teaching that includes metacognition (Ozturk, 2018). Research suggests that teachers would benefit from professional development training on the importance of including students in the learning process. More attention should also be focused on educating teachers on how and when to effectively implement teaching metacognition or metacognitive activity in class (Wilson & Bai, 2010). According to Zohar and Schwartzer (2005), there is also a clear need to change the role that teachers play in the educational process. The current, somewhat outdated role of the teacher as a source of knowledge that is transferred in the direction of the teacher-student simply cannot support new teaching requirements or new educational expectations. Teachers must take on a new role in education that embodies the person who encourages, guides and steers students in their education. Such a change would potentially meet the need for greater involvement and activation of students in the teaching process. Changing the role of the teacher from the person who is the source of education to the person who assists in the education process allows for a change in the dynamics in the teacher-student relationship. Such a new dynamic would affect students' independence and competence in learning because it would put them in a position where they themselves are responsible for their own education and actively participate in it. Teaching teachers how to include students in activities, methods of thinking and the learning process itself is essential for helping students develop metacognition. This will help them accomplish this goal more successfully (Zohar & Schwartzer, 2005).

The teachers must possess both metacognitive knowledge and skills to effectively impart the principles of metacognition. They need to guide students in using these metacognitive tools and employ them in the management of their professional development (Labak, 2022). Recognizing areas for improvement is crucial for teachers and this can be achieved through objective assessments of students during formative and summative evaluations. Moreover, self-reflection techniques such as analyzing video recordings of lessons or engaging in collegial observation enable teachers to evaluate their own instructional methods. This self-regulation process allows teachers to align their professional growth with the needs of students, the educational environment and society. The disadvantages of the paper are the small number of teachers and the focus being only on teaching biology. Hughes and Partida (2020) demonstrated positive outcomes in developing metacognitive awareness among STEM teachers through specialized professional development programs tailored explicitly for this purpose. Our study focused on changes in teaching techniques rather than monitoring shifts in teacher knowledge or awareness that differ from their method (Hughes & Partida, 2020). Desimone, Porter, Garet, Yoon, and Birman (2002) have found a relationship between changes in teaching practice and changes in teachers' knowledge and awareness. As the teachers we observed used teaching methods and approaches (such as inquiry-based learning and flipped classroom) that inherently involve some metacognitive activities like student self-assessment based on the results of our research claims about changes in teachers' metacognitive awareness cannot be drawn. It is possible that the observed feature of teaching appeared due to the applied methods rather than changes in teachers' metacognitive awareness. However, the research can contribute to the discussion on effective professional development for biology teaching that develops the metacognitive dimension of the competence to learn how to learn. Future research will focus on designing explicit professional development programs for the development of metacognitive awareness among both teachers and students comparing teaching practice before and after professional development and determining changes in students' learning outcomes caused by changes in teachers' knowledge and awareness.

5. Conclusion

The results of the analysis of the initial lesson video recordings, reflective of typical teaching practices indicate that during the teaching of biology, features of teaching conducive to the development of students' metacognition are lacking. The same features of teaching were self-assessed in a survey as occasionally or always occurring. Positive changes in teaching strategies were noted with the occurrence of more than half of all observed characteristics after teachers' application of strategies and tactics they had learned during professional development to promote higher-order thinking and as a result, metacognitive development was examined in other lessons. These are inherent characteristics of the methods and teaching approaches used and it's possible that they would have been absent if different methods or approaches not involving activities conducive to metacognition had been used. What did not advance through their professional development were the specific features of teaching crucial for metacognitive modeling which were not part of the applied teaching methods and approaches or were not defined by the objectives and plans of the conducted professional development. Therefore, the conducted research concludes that to determine changes in teaching practice for the development of metacognition, it is necessary to establish changes in teachers' metacognitive awareness and metacognitive teaching, professional development solely focused on higher-order thinking is not sufficient. Instead, there is a need to design explicit professional development programs where teachers can develop their metacognitive awareness and learn how to model the development of metacognition in students through their teaching.

References

Baas, D., Castelijns, J., Vermeulen, M., Martens, R., & Segers, M. (2015). The relationship between assessment for learning and elementary students' cognitive and metacognitive strategy use. *British Journal of Educational Psychology, 85*(1), 33–46. https://doi.org/10.1111/bjep.12058

Ben-David, A., & Orion, N. (2012). Teachers' voices on integrating metacognition into science education. *International Journal of Science Education, 35*(18), 3161–3193. https://doi.org/10.1080/09500693.2012.697208

Bezinović, P., Marušić, I., & Ristić Dedić, Z. (2012). *Observation and improvement of school teaching*. Zagreb: Education and Teacher Training Agency.

Bukvić, A. (1988). *Principles of psychological testing*. Belgrade, Serbia: Institute for Textbooks and Teaching Aids.

Desimone, L. M., Porter, A. C., Garet, M. S., Yoon, K. S., & Birman, B. F. (2002). Effects of professional development on teachers' instruction: Results from a three-year longitudinal study. *Educational Evaluation and Policy Analysis, 24*(2), 81–112.

Dignath, C., & Büttner, G. (2008). Components of fostering self-regulated learning among students a meta-analysis on intervention studies at primary and secondary school level. *Metacognition and Learning, 3*(3), 231–264. https://doi.org/10.1007/s11409-008-9029-x

Drăghicescu, L., Cristea, S., Petrescu, A. M., Gorghiu, G., & Gorghiu, L. (2015). The learning to learn competence—guarantor of personal development. *Procedia - Social and Behavioral Science, 191*, 2487-2493. https://doi.org/10.1016/j.sbspro.2015.04.571

Duke, N. K., & David Pearson, P. (2002). Effective practices for developing reading comprehension in: Farstrup, A. E., Samuels, S.J. (Eds.) What research has to say about reading instructions. In (pp. 205–242). Newark: International Reading Association.

Efklides, A. (2001). Metacognitive experiences in problem solving in: Efklides, A., Kuhl, J., Sorrentino, R.M. (Eds.) Trends and prospects in motivation research. In (pp. 297-323). Dordrecht: Springer.

Efklides, A. (2006). Metacognition and impact: What can metacognitive experiences tell us about the learning process? *Educational Research Review, 1*(1), 3–14. https://doi.org/10.1016/j.edurev.2005.11.001

Efklides, A., & Volet, S. (2005). Emotional experiences during learning: Multiple, located and dynamic. *Learning and Instruction, 15*(5), 377–380. https://doi.org/10.1016/j.learninstruc.2005.07.006

Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive–developmental inquiry. *American Psychologist, 34*(10), 906–911. https://doi.org/10.1037/0003-066X.34.10.906

Gourgey, A. F. (1998). Metacognition in basic skills instruction. *Instructional Science, 26*(1), 81–96. https://doi.org/10.1023/A:1003092414893

Halamish, V. (2018). Pre-service and in-service teachers' metacognitive knowledge of learning strategies. *Frontiers in Psychology, 9*, 2152. https://doi.org/10.3389/fpsyg.2018.02152

Hartman, H. J. (2001). *Metacognition in learning and instruction: Theory, research and practice*. Dordrecht, the Netherlands: Springer.

Harvest, A. (2020). Development of students' learning to learn competence in primary science. *Education Sciences, 10*(11), 11. https://doi.org/10.3390/educsci10110325

Hughes, A. J. (2015). *Impact of online self-regulated professional development on technology and engineering educators metacognitive awareness*. (UMI Number: 3710627) Doctoral Dissertation , North Carolina State University.

Hughes, A. J. (2017). Educational complexity and professional development: Teachers' need for metacognitive awareness. *Journal of Technology Education, 29*(1), 25–44. http://doi.org/10.21061/jte.v29i1.a.2

Hughes, A. J., & Partida, E. (2020). Promoting preservice stem education teachers' metacognitive awareness: Professional development designed to improve teacher metacognitive awareness. *Journal of Technology Education, 32*(1), 5-20. http://doi.org/10.21061/jte.v32i1.a.1

Jackson, D., Fleming, J., & Rowe, A. (2019). Enabling the transfer of skills and knowledge across classroom and work contexts. *Vocations and Learning, 12*(3), 459–478. https://doi.org/10.1007/s12186-019-09224-1

Kesselman, A. (2003). Supporting inquiry learning by promoting normative understanding of multivariable causality. *Journal of Research in Science Teaching, 40*(9), 898–921. https://doi.org/10.1002/tea.10115

Kesselman, A., & Kuhn, D. (2002). *Facilitating self-directed experimentation in the computer environment*. Retrieved from https://www.researchgate.net/publication/2496407_Facilitating_Self-Directed_Experimentation_in_the_Computer_Environment#fullTextFileContent

Kuhn, D. (1999). A developmental model of critical thinking. *Educational Researcher, 28*(2), 16–46. https://doi.org/10.3102/0013189X028002016

Kuhn, D. (2000). Metacognitive development. *Current Directions in Psychological Science, 9*(5), 178–181.

Labak, I. (2022). Improving the metacognitive dimension of competence to learn how to learn from teachers. *Napredak: Journal of Interdisciplinary Research in Education, 163*(1-2), 181–199.

Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics, 33*(1), 159–174. https://doi.org/10.2307/2529310

Leat, D., & Lin, M. E. I. (2003). Developing a pedagogy of metacognition and transfer: Some signposts for the generation and use of knowledge and the creation of research partnerships. *British Educational Research Journal, 29*(3), 383-414.

Lin, X., Schwartz, D. L., & Hatano, G. (2005). Toward teachers' adaptive metacognition. *Educational Psychologist, 40*(4), 245–255. https://doi.org/10.1207/s15326985ep4004_6

Marušić, I. (2019). Competence to learn how to learn in an international environment in: Vizek Vidović, V., Marušić, I. (Eds) competence to learn how to learn theoretical foundations and research in the croatian context. In (pp. 11 -28). Zagreb: Institute for Social Research in Zagreb.

McMillan, J. H., & Hearn, J. (2008). Student self-assessment: The key to stronger student motivation and higher achievement. *Educational Horizons, 87*(1), 40–49.

Mirosavljevic, A., & Bognar, B. (2019). Features of effective professional development of teachers of the natural science group of subjects: Systematic literature review. *Methodical Reviews: Journal of the Philosophy of Education, 26*(2), 147–177. https://doi.org/10.21464/mo.26.2.10

Osborne, J. (2014). Teaching scientific practices: Meeting the challenge of change. *Journal of Science Teacher Education, 25*(2), 177-196. https://doi.org/10.1007/s10972-014-9384-1

Ozdamli, F., & Asiksoy, G. (2016). Flipped classroom approach. *World Journal on Educational Technology: Current Issues, 8*(2), 98–105.

Ozturk, N. (2017). Assessing metacognition: Theory and practices. *International Journal of Assessment Tools in Education, 4*, 134–134. https://doi.org/10.21449/ijate.298299

Ozturk, N. (2018). The relation between teachers` self-reported metacognitive awareness and teaching with metacognition. *International Journal of Research in Teacher Education, 9*(2), 26–35.

Pedaste, M., Mäeots, M., Siiman, L. A., de Jong, T., van Riesen, S. A. N., Kamp, E. T., . . . Tsourlidaki, E. (2015). Phases of inquiry-based learning: Definitions and the inquiry cycle. *Educational Research Review, 14*, 47–61. https://doi.org/10.1016/j.edurev.2015.02.003

Pintrich, P. R. (2002). The role of metacognitive knowledge in learning, teaching, and assessing. *Theory into Practice, 41*(4), 219–225. https://doi.org/10.1207/s15430421tip4104_3

Pintrich, P. R., Wolters, C., & Baxter, G. P. (2000). Assessing metacognition and self-regulated learning, in: S. Gregory & Impara James C. (Eds.), Issues in the measurement of metacognition. In (pp. 43-97). Lincoln, NE: Buros Institute of Mental Measurements.

Prytula, M. P. (2012). Teacher metacognition within the professional learning community. *International Education Studies, 5*(4), 112–121.

Ristić Dedić, Z. (2019). Metacognitive aspects of self-regulation of learning in V. Vizek Vidović & I. Marušić (Eds.), competence to learn how to learn theoretical foundations and research in the croatian context. In (pp. 89–110). Zagreb: Institute for Social Research in Zagreb.

Seraphin, K. D., Philippoff, J., Kaupp, L., & Vallin, L. M. (2012). Metacognition as means to increase the effectiveness of inquiry-based science education. *Science Education International, 23*(4), 366-382.

Shepard, L. A. (2001). *The role of classroom assessment in teaching and learning*. Boulder: Technical Report Crest/University of Colorado.

Smith, D. C. (1999). Changing our teaching: The role of pedagogical content knowledge in elementary science. and J. Gess-newsome & N. G. Lederman (eds.), examining pedagogical content knowledge: The construct and its implications for science education. In (pp. 163–197): Springer Netherlands. https://doi.org/10.1007/0-306-47217-1_7.

Tornare, E., Czajkowski, N. O., & Pons, F. (2015). Children's emotions in math problem solving situations: Contributions of self-concept, metacognitive experiences, and performance. *Learning and Instruction, 39*, 88–96. https://doi.org/10.1016/j.learninstruc.2015.05.011

van der Stel, M., & Veenman, M. V. J. (2010). Development of metacognitive skillfulness: A longitudinal study. *Learning and Individual Differences, 20*(3), 220–224. https://doi.org/10.1016/j.lindif.2009.11.005

Veenman, M. V. J. (2012). Metacognition in science education: Definitions, constituents, and their intricate relationship with cognition in: Zohar, A., Dori, Y. (Eds.) Metacognition in science education contemporary trends and issues in science education. In (pp. 21-36). Dordrecht: Springer.

Veenman, M. V. J. (2015). *Teaching for metacognition*. Retrieved from https://www.researchgate.net/publication/304194077_Teaching_for_Metacognition

Veenman, M. V. J., Prins, F. J., & Elshout, J. J. (2002). Initial inductive learning in a complex computer simulated environment: The role of metacognitive skills and intellectual ability. *Computers in Human Behavior, 18*(3), 327–341. https://doi.org/10.1016/S0747-5632(01)00038-3

Veenman, M. V. J., & Spaans, M. A. (2005). Relation between intellectual and metacognitive skills: Age and task differences. *Learning and Individual Differences, 15*(2), 159–176. https://doi.org/10.1016/j.lindif.2004.12.001

Veenman, M. V. J., Van Hout-Wolters, B. H. A. M., & Afflerbach, P. (2006). Metacognition and learning: Conceptual and methodological considerations. *Metacognition and Learning, 1*(1), 3–14. https://doi.org/10.1007/s11409-006-6893-0

Veenman, M. V. J., Wilhelm, P., & Beishuizen, J. J. (2004). The relationship between intellectual and metacognitive skills from a developmental perspective. *Learning and Instruction*, *14*(1), 89–109. https://doi.org/10.1016/j.learninstruc.2003.10.004

White, B. Y., & Frederiksen, J. R. (1998). Inquiry, modeling, and metacognition: Making science accessible to all students. *Cognition and Instruction*, *16*(1), 3–118.

White, B. Y., & Frederiksen, J. R. (2000). Metacognitive facilitation: An approach to making scientific inquiry accessible to all in J. L. Minstrell & E. H. Van-Zee (Eds.), Nquiry into inquiry learning and teaching in science. In (pp. 331-370). Washington D.C: American Association for the Advancement of Science.

Wilson, N. S., & Bai, H. (2010). The relationships and impact of teachers' metacognitive knowledge and pedagogical understandings of metacognition. *Metacognition and Learning*, *5*(3), 269–288. https://doi.org/10.1007/s11409-010-9062-4

Zohar, A. (2004). *Higher-order thinking in science classrooms: Students' learning and teacher' professional development*. Dordrecht, the Netherlands: Kluwer Academic Press.

Zohar, A. (2006). The nature and development of teachers' metastrategic knowledge in the context of teaching higher order thinking. *Journal of the Learning Sciences*, *15*(3), 331–377. https://doi.org/10.1207/s15327809jls1503_2

Zohar, A., & Barzilai, S. (2015). Metacognition and teaching higher order thinking (HOT) in science education: Students' thinking, teachers' knowledge, and instructional practices in R. Wegerif, L. Li & J. Kaufman (Eds.), Routledge international handbook of research on teaching thinking. In (pp. 229-242). Oxon, UK: Routledge.

Zohar, A., & David, A. B. (2008). Explicit teaching of meta-strategic knowledge in authentic classroom situations. *Metacognition and Learning*, *3*(1), 59–82. https://doi.org/10.1007/s11409-007-9019-4

Zohar, A., & Schwartzer, N. (2005). Assessing teachers' pedagogical knowledge in the context of teaching higher-order thinking. *International Journal of Science Education*, *27*(13), 1595–1620. https://doi.org/10.1080/09500690500186592