CHALLENGES IN THE IMPLEMENTATION OF DIFFERENTIATED INSTRUCTION IN MATHEMATICS CLASSROOM

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Abstract:
Dealing with student heterogeneity in mathematics education has become a priority issue in education policy worldwide. In differentiated instruction, teachers use a variety of strategies to adapt to students with different abilities and interests. However, effective differentiation in mathematics instruction is challenging. This paper presents a case study examining how lower secondary mathematics teachers implement differentiation in the classroom and what influences the (non)implementation of differentiated instruction. Data were collected by recording teachers' lessons before and after the professional development and conducting interviews with them. Recording the lessons allowed us to observe the teachers and examine whether and how differentiation was implemented. In the interviews, we learned details about how and how often teachers implemented differentiation, and we gained insight into teachers' beliefs and attitudes about differentiation. The data collected through these methods allowed us to triangulate the results. The results of the study suggest that mathematics teachers encounter various barriers to differentiation and that their beliefs about instruction and classroom realities do not always align.
Keywords: differentiated instruction; classroom practice; mathematics teachers; teacher beliefs;

Introduction

Providing for the needs of every student in a classroom is a significant challenge in education. This difficulty stems from the diverse interests, learning styles, developmental levels, cultural backgrounds, language levels, and attitudes of students (Suprayogi et al., 2017). Differentiated instruction is a teaching strategy designed to overcome the aforementioned challenges. In a blended classroom with differentiated instruction, teaching and learning are tailored to students' readiness, interests, and learning profiles (e.g., Hunter et al., 2019; Tomlinson, 2016). Teachers can differentiate instruction based on a number of crucial factors that play a significant role in the teaching-learning process: content - the knowledge, understanding, and skills that students are expected to learn; process - how students understand or make sense of the content; product how students demonstrate what they know, understand, and are able to do after an extended period of learning; environment - the classroom conditions that influence how students' emotions and motivations affect their learning (Tomlinson, 2016). In addition, three general principles should guide this differentiation: a) appropriately challenging tasks (students learn best when tasks are neither too easy nor too difficult); b) flexible grouping and instructional arrangements (individual, pair, and group work allow each student to experience different roles and environments); and c) ongoing assessments and appropriate support (each student should have the opportunity to demonstrate proficiency) (Pham, 2012).

The purpose of this paper is to investigate what mathematics teachers at the lower secondary level think about differentiated instruction and its implementation in regular mathematics classrooms. This topic is particularly important because it provides valuable information for designing professional development programs for teachers that should meet teachers' needs and because ignoring student diversity in the classroom can lead to motivation loss and poor student outcomes.

Theoretical Framework

Differentiated instruction in mathematics

In mathematics classrooms, students need to be exposed to important mathematical ideas so that they can develop sound knowledge. This means that students learn mathematics better when they have to struggle and develop their own solutions than when they are exposed to prepackaged methods (Jonsson et al., 2014; Russo et al., 2020). Sullivan et al. (2015) claim that challenging tasks improve student learning because they make them try harder. A task that is cognitively challenging for one student may be routine for another (Applebaum & Leikin, 2014). One approach to meeting the needs of each student is to set tasks within each student's zone of proximal development while ensuring that every student in the class has the opportunity to contribute meaningfully to the community of learners (Small, 2017). The zone of proximal development is a term used to describe the gap between the actual level of development determined by independent problem solving and the potential level determined by problem solving under adult guidance or in collaboration with more capable peers (Vygotsky, 1978).

Developing tasks in mathematics that are appropriate and challenging for all students is not an easy task for teachers (Mellroth, 2018). To make a challenging task accessible in mixed ability classes, the teacher needs support in planning multiple levels of entry and variations of the task (Bobis et al., 2021; Sullivan et al., 2015). In other words, to meet the demands of a heterogeneous classroom, teachers need to be able to design tasks for differentiated instruction (Suprayogi et al., 2017). Such tasks include parallel tasks, open-ended questions (Small, 2017; Leuders & Prediger, 2015), or blossom tasks (germ. *Blütenaufgaben*, Bruder & Reibold, 2012). Parallel tasks are groups of tasks, usually two or three, that are designed to meet the needs of students at different developmental levels but target the same idea and are close enough in context to be discussed simultaneously (Leuders & Prediger, 2012). To create a series of parallel tasks, a teacher can select a task from a textbook and then modify it to fit a different developmental level. A question is open-ended if it is worded to allow for a variety of answers or approaches. The teacher may ask the same question to the entire class, but the question is worded in a way that allows for differentiated responses based on each student's understanding (Small, 2017). Blossom tasks consist of several subtasks of increasing difficulty on the same topic. Blossom tasks begin with a closed introductory task that is accessible to all students. This is followed by more open-ended subtasks with graded requirements. In this type of task, a single task can provide basic requirements and open up advanced requirements. The key idea is that students can make choices, i.e. not everyone has to solve all subtasks.

Bobis et al. (2021) found that three strategies for teaching mathematics with challenging tasks were particularly successful in mixed ability classes. Teachers successfully differentiated content by a) using tasks with enabling and extending prompts, b) using tasks with a low floor/high ceiling structure, and c) having students play games that naturally differentiated mathematics through choice of strategies.

Teacher perspective

Teachers' beliefs and perceptions about what it means to reach all learners are very important for effective teaching. Teachers' willingness to adapt instruction to meet students' needs is related to their ideas about responsiveness in the classroom. According to Richards and Robertson (2016), responsive teachers believe that students' ideas are the focus of instruction and that it is the teacher's job to make connections between these initial ideas and more complex thinking. Several papers have described the challenges teachers face in implementing differentiated instruction. Gaitas and Martins (2017) noted that content differentiation can be particularly difficult for teachers. In addition, research reports a lack of time and resources for teacher preparation, the need for collaboration within and across schools (Smit & Humpert, 2012), and a disconnection between teachers' understanding and implementation of

differentiated instruction (Whipple, 2012). There are mixed findings about teachers' actual use of differentiated instruction, ranging from teachers reporting that they rarely or occasionally use differentiated instruction practices in their classrooms (Pozas et al., 2020; Smit & Humpert, 2012) to using such practices daily (Prast et al., 2015; Roy et al., 2013).

Mathematics teachers appear to be aware of the need to differentiate instruction in mixed ability classes and often report having confidence in their own abilities to develop differentiated instruction (Shayshon et al., 2014). However, research shows that the idea of differentiated instruction in mathematics is a challenging and complex practice. Mathematics teachers find it difficult to differentiate between students with different abilities (Leikin & Stanger, 2011). However, in order to adapt instruction to students' ideas, teachers must not only know their students well, but also know how and when to respond appropriately. This leads us to a discussion of the project in which the current study was embedded.

Research focus

The issue of differentiation is not new, either as an idea or in the implementation itself. In mathematics education, however, differentiation itself has only recently been discussed and intensively researched. There is almost no research on differentiation in mathematics education in Croatian schools. Given the importance of this topic and the heterogeneity of classes that mathematics teachers face in Croatian schools, we decided to conduct the study with the aim of investigating differentiated instruction. Therefore, the following research question was formulated: How do secondary mathematics teachers understand the concept of differentiated instruction and how do they implement it in the classroom?

Methodology

Context of the study: Professional development on the topic of differentiated instruction

The study reported in this paper is related to the SURFPRIMA project (Teacher Professional Development Aimed at Improving Student Learning Outcomes in Biology and Mathematics) This project aims to develop professional development models for biology and mathematics teachers that can contribute to the quality of teacher education, substantial changes in teaching, and student learning outcomes. In one of the phases of the project, project members organized professional development for participating mathematics teachers, including three 6-hour in-person trainings and an online Professional Learning Community (PLC). From October to December 2021, the PLC met regularly every two weeks in 90-minute sessions. Mathematics teachers discussed topics related to effective mathematics instruction described in Jukić Matić et al. (2020). The participation of teachers was based on constructivist and situated learning theories. Therefore, teachers were expected to collaborate and design specific tasks, propose a lesson strategy, or critically reflect on the provided materials. Teachers participating in the PLC were required to design a mathematics lesson using the previously discussed elements of effective mathematics instruction. Lessons were videotaped, and selected recordings were analyzed with members of the project and other math teachers in the PLC. In the analysis, teachers played the role of critical friends, encouraging and supporting their colleagues while also providing candid, often unsettling feedback.

One of the topics discussed during the PLC meetings was differentiated mathematics instruction. Parallel tasks, open-ended questions, and blossom tasks, all of which have a high potential for differentiation, were presented to the teachers. In addition to theoretical knowledge about the tasks, examples of the tasks were provided to teachers. The teachers were then divided into groups of three and asked to design a blossom task on a particular topic. After

creating a task, they described the prerequisites for each subtask. Finally, the teachers were required to document their differentiation-related lessons.

Participants

The study presented in this paper uses a case study design. The purpose of the study is to better understand the difficulties related to differentiated instruction in secondary mathematics education in Croatian schools. Yin (2009) asserts that the case study method works when a "how" and "why" question is asked about a series of events over which the researcher has little or no control. A case study allows for exploration and understanding of dynamic, experiential, and complex issues and proves helpful when in-depth inquiry is needed (Miles et al., 2014). Stake (1995) argues that working with case studies does not change our understanding, but rather can refine it.

Two female mathematics teachers from lower secondary schools in Croatia (grades five through eight) participated in this study. For the purposes of the study, they will be referred to as Ms. M and Ms. K. We used a convenience sample (Cohen et al., 2018): of all the teachers involved in the SURFPRIMA project, Ms. M and Ms. K had the least difficulty recording lessons during the pandemic. Ms. M has more than 20 years of teaching experience, while Ms. K has 10 years. Both teachers teach in urban schools and have mixed ability classes, as is common in Croatian schools.

Data collection

Our data collection methods included recordings of participants' lessons, semi-structured interviews, and lesson plans created for the recorded lessons.

We used two recorded mathematics lessons for each teacher. One lesson was recorded at the beginning of the third phase of the project and one lesson was recorded after the PLC session on differentiation. The first recorded lesson gave us insight into the teachers' common practice, while the second lesson showed if and how professional development had affected their teaching practice, namely if and how teachers had improved their teaching in terms of differentiation in mixed ability classes. Both teachers provided the lesson plans for the recorded lessons, which gave us the opportunity to examine the prepared activities and compare the proposed plan with actual classroom implementation. Finally, both teachers participated in the semi-structured interview. The purpose of the interview was to obtain information about the teachers' attitudes and opinions about differentiation in the mathematics classroom, their views about their own classroom practices, the frequency of use of differentiation, and the difficulties in its implementation. The questions had been prepared in advance (Table 1), but the teacher was allowed to speak freely about any topic related to differentiation if she wished. If the teacher answered the prepared question earlier, we skipped the question during the interview.

Table 1. Questions for the interview

Categories	Questions
Beliefs about differentiation	What is differentiation for you? Do you think that differentiation in mathematics makes students feel successful? Do you think that differentiation in mathematics encourages students to be active and motivated? Do you think that differentiation enables more successful acquisition of new knowledge, development of logical thinking and reasoning, and encourages greater interest in mathematics?
Mathematics	Do you think that differentiation can be easily implemented in mathematics lessons? Explain.

Categories	Questions
Beliefs about differentiation	What is differentiation for you? Do you think that differentiation in mathematics makes students feel successful? Do you think that differentiation in mathematics encourages students to be active and motivated? Do you think that differentiation enables more successful acquisition of new knowledge, development of logical thinking and reasoning, and encourages greater interest in mathematics?
	Do you think that differentiation can be used with any mathematical topic?
Lesson types	How do you prepare for the lessons? Do you use differentiation in your teaching practice? How? In which parts of the lesson do you use differentiation (knowledge acquisition, practicing, reviewing for the exam)?
Resources	Do you use technology for differentiated instruction? Explain. Do you use your own materials for differentiation? Explain.

In this type of research, Goetz and LeCompte (1984) use the term 'translatability' instead of generalizability, which is a clear description of one's theoretical stance and research techniques, and the term 'comparability', which is whether the results of the study can be used as a basis for comparison. Therefore, 'thick descriptions' are essential so that others can determine whether the attributes being compared are relevant (Kvale, 1996), which is why we described the study in great detail.

Data analysis

To analyze the recorded lessons, we used OZON and COPUS observation protocols. OZON (Bezinović et al., 2012) is a classroom observation protocol used by observers as a means to describe and evaluate classroom activities. The form assesses the characteristics of the lesson, the content being taught, the expected outcomes of the lesson, and classroom behavior. COPUS (Smith et al., 2013) was developed to capture teacher- and student-directed activities in STEM classrooms. A total of 25 codes are used to characterize teacher and student behavior at 2-minute intervals. When the entries are complete, the codes are grouped into four categories for teachers (presenting, guiding, administrative activities, other teacher activities) and four categories for students (receiving, working, talking to the class, and other student activities).

We analyzed the content of the lesson plans to determine whether the activities prepared allowed for differentiation. These data were compared to data obtained through observation to get a clearer picture of whether the teacher implemented the lesson plan as intended.

The interviews were transcribed and analyzed using predetermined categories (Table 1). The data obtained were compared to the data from the observation protocols to determine the extent to which the teacher's statements were consistent with the observed instruction. The interview data is also analyzed using a constant comparative method to determine similarities and differences between cases, i.e., teachers (Harding, 2013).

The multi-method approach with classroom observation, lesson plans, and interviews allows for triangulation of data. Denzin (2015) argues that triangulation adds authenticity, trustworthiness, credibility, richness, and depth to any research.

Results

In this paper, we report on the two contrasting teachers; one who sees differentiation as the only way of working in the classroom and another who acknowledges the need for differentiated instruction but does not act upon it. Both teachers explained they see

differentiated instruction as the type of teaching adapted to the student abilities. The sections below provide details on the teachers' practice and their beliefs.

The case of Ms. M

Ms. M acknowledges the need for differentiation in her teaching practice. She explains that she has students with different abilities; some of them strive for better performance and results, but many of them fail to do so.

> They [students] always strive for better grades and try to do difficult tasks, but in the end they fall back on what is more accessible to them and what they can learn.

She uses differentiation based on content students learn; it is usually implemented in the practice phase. Ms. M claims that the most difficult part of differentiated instruction is giving students feedback on their work. However, she points out that she does not use differentiation as much as she did before the pandemic:

> Well, I have to admit that I do not use it [differentiated instruction] often, especially now at the time of the pandemic. Before, when I first started working, I used it more often. I have to honestly say that I used it more often when I first started working, but now I use it less and less.

Her statement was confirmed by recorded lessons and analyzed lesson plans. The first lesson had a knowledge acquisition phase and included different activities, but all students solved the same tasks. The second lesson, which was recorded after the PLC session, was a practice lesson in which the tasks had varying levels of difficulty, but again, all students solved the same tasks, regardless of whether the task was cognitively demanding or not. In both lessons, the teacher spent most of the time guiding the class (69% and 64% of the total time) by asking questions and occasionally giving feedback. On the other hand, in the first lesson, students spent most of their time receiving information (40% of total time), and in the second lesson, students spent most of their time talking to the class (41% of total time), i.e., listening to other students answer the teacher's questions. In both lessons, students worked individually. Some aspects related to individualization and differentiation are present but not sufficient, such as: giving some students extra instructions and explanations or extra time to work for those who needed it. The lesson plans studied did not include any statements about possible differentiation of content at the task level.

Regarding the second recorded lesson, the teacher commented that she implemented differentiation minimally and that her students could identify the level of the task set and the grade they could achieve by solving it:

> So for each teaching unit, for the test, I write down for them exactly what is for grade 5, for 4, for 3, for 2, so that it is really clear to them which task is for which grade.

Ms. M believes that she has enough knowledge to differentiate instruction, partly because of her experience and partly because of the many educations she has attended. Her professional experience also shows how she lowers the level of knowledge she requires of her students each year:

> Sometimes I take my old lesson plans, I created when I first started teaching... I look at what I required of students and compare it to what I require today... I see how much I have reduced my criteria. Kids come to school with less desire to learn than they used to.

The case of Ms. K

Ms. K sees differentiation as a necessary part of her teaching practice. She emphasizes that her students have difficulty with the math content they are learning, so she wants to adapt to the students' abilities.

> There is no point in solving an even more complex problem that only three students understand, while the others do not know where we are going or where we are now.

The teacher points out that each lesson contains differentiated instruction in some parts. She believes that her job is to make the students feel positive about mathematics. She also believes that differentiated instruction builds students' self-esteem:

> I think they feel better after a lesson like this because they learned something and accomplished something, even if it was an easier task, than if they end up with something they can not handle. Then they feel that they have worked for an hour and achieved nothing.

In contrast to Ms. M, who was more vague about the technology and its potential for differentiated instruction, Ms. K is more positive and sees the technology as a very useful tool for differentiated instruction. She uses the Teams application to assign homework, chat with her students about homework problems, and provide feedback and support. In addition, Ms. K uses various digital materials to provide additional instructions and explanations to students who need extra support.

> I often find videos on Edutorij ... I send the link to lower achievers through Teams... Most of the time when I give homework, I chat with them about teams. In the evening, they always text me.

Ms. K pointed out that lesson planning is time consuming because she tends to adapt assignments to all students and their needs. She prepares her own material using textbooks and various resources from the Internet

> I know my class. I already know what each student can solve. So I literally adapt the assignments to each student because there are four of them with high abilities and others are... well... not.

Like Ms. M, she also indicated that she differentiates the content in the practice phase. This could be seen in the recorded lessons. The first recorded lesson was about the knowledge acquisition phase. The students had organized different activities, some as group work, others as individual work. In this lesson, the teacher gave additional instructions and explanations to the students who needed help. The second lesson, which was recorded after the PLC session, was a practice lesson in which the tasks had different levels of difficulty and the students had the freedom to choose the tasks themselves. This lesson focused on the group work and included ideas from PLC, such as blossom tasks. However, the lesson was conducted as a competition between groups, so the result was not successful. The students had selected the tasks with the most points (the most difficult ones) to win but were not able to solve them. In both lessons, Ms. K spent most of the time (70% and 57% of the total time, respectively) guiding the students by asking questions, giving feedback, and answering the students' questions. In the first lesson, students received information, talked to the class, and worked in almost equal proportions (approximately 30%), while in the second lesson, they worked most of the time (50% of the total time). The lesson plan studied was consistent with the observed activities in the records.

Like Ms. M, Ms. K believes that she has enough knowledge for differentiated instruction, but believes that continuous professional development is a requirement for the teaching profession:

> I think I can do it now, but it would be better to continue my education. I think it is necessary.

Discussion and Conclusion

In this study, we examine how lower secondary mathematics teachers conceptualize and implement differentiated instruction in their classrooms. Our teachers have developed implicit theories regarding differentiated instruction. According to them, differentiated instruction is a form of instruction that is solely adapted to students' abilities, disregarding their diverse

interests and learning styles. Ms. M believes that it is sufficient to use tasks with different levels of difficulty in the classroom and that students can identify which task is appropriate for which level. Therefore, the PLC session did not affect her way of teaching as her beliefs are extremely stable. On the other hand, Ms. K differentiates instruction, focusing primarily on supporting students who are behind, and the PLC differentiation session has given her the opportunity to address other students. This demonstrates how crucial it is for teachers to comprehend what differentiated instruction entails. The significance that teachers attach to it determines whether they will implement it, retain it, abandon it after a brief trial, or persist and apply it despite numerous obstacles (Valiandes & Neophytou, 2018). Ms. M abandons differentiation, whereas Ms. K exerts greater effort.

PLC appears to be an excellent starting point for a conversation about differentiated instruction. Mellroth et al. (2021) demonstrated how teachers in a PLC increased their understanding of differentiated instruction by collaborating on tasks and resolving issues that arose. Our research demonstrates that a single professional development session on differentiated instruction is insufficient to enhance teachers' comprehension about this topic. Differentiated instruction extends beyond modifying the practice phase of a lesson or altering the classroom environment. It provides multiple avenues for acquiring content, processing ideas, and creating products so that each student can effectively acquire knowledge (Tomlinson, 2016). Consequently, differentiation can and should be reflected in various aspects of mathematics instruction in classes of varying abilities. Therefore, this complex subject must be discussed in multiple PLC meetings over time. During the PLC sessions, it is essential to explain to teachers how differentiated instruction can also be implemented during the knowledge acquisition phase, how knowledge assessment can also be differentiated, and how the needs all students must be met. Furthermore, it is essential for colleagues and experts/scholars to provide continuous feedback on teaching instruction in order to correct misconceptions about differentiated instruction and align teachers' practices with desired learning outcomes. This necessitates the incorporation of continuous observation of teaching into PLC meetings with the aim of fostering its growth. Moreover, we propose introducing the concept of differentiated instruction into all teachers' professional development trainings. Our proposal is based on the premise that the concept of differentiated instruction becomes ingrained in the teacher's practice and classroom culture because, in order to achieve fundamental changes in mathematics education, it is necessary to implement the changes consistently.

To obtain a more complete picture of differentiated instruction in mathematics in Croatia, additional qualitative and quantitative research could be conducted with a larger sample size and a greater number of participants.

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