

Miroslava Brožová

Personalisation in Montessori environments during mathematics lessons *

Abstract. This study examines personalization from a personal autonomy, responsibility, and flexibility point of view. It is determined that personalization is one of the approaches which is utilized in a Montessori program, its principles, teachers' beliefs, and practices in the teaching of mathematics at a selected elementary school in the Czech Republic. The work explores if and how teachers implement personalization principles and strategies in the Montessori approach. Why some principles of personalized learning are not well incorporated in the Montessori approach is also noted. The research findings show that the kinds of activities of teachers using the Montessori approach are in accordance with personalization.

1. Introduction

The diversity of children and the best ways of learning mathematics have been investigated in countless studies for decades (among them Adler, 1972; Wood et al., 1991; McKinsey and Company, 2010). There are less motivated children who are not able to work independently, as well as learners with inner motivation and skills well beyond their current grade. Once students have emerging or well-developed individual interests, and such topics are connected to academic content topics in school, for which they may have a lower level of interest, the connection between these two areas might support them in developing situational interest based on their enjoyment, ultimately leading to the development of an individual interest in a topic at school. As an example, Bernacky and Walkington (2014) consider a learner who has a well-developed individual interest in music but is not interested in algebra. Nonetheless, in an algebra class, learners may engage with a variety of problems and projects that explore the mathematics behind musical pieces. The

*2010 Mathematics Subject Classification: 97D40

Keywords and phrases: *personalization, approach to teaching mathematics, independent learning, Montessori approach, elementary level*

authors concluded that “personalization can impact the development of learners’ interest in their math course, the domain of mathematics, and ultimately their long-term learning” (p. 7).

The twenty-first century calls for modern principles such as establishing mathematics goals to focus learning, increase student confidence, implementing tasks that promote reasoning and problem solving, using, and connecting mathematical age appropriate representations, facilitating meaningful mathematical discussions, and building procedural fluency from conceptual understanding to deepen learning and reduce mathematical anxiety (NCTM, 2014). Personalisation is considered in many studies (for example Grant and Basye, 2014; Bray and McClaskey, 2013; Keefe and Jenkins, 2002) as one of the effective strategies in education. It remains to be seen whether personalisation is included in Montessori mathematics teaching, and thus whether the Montessori method meets the demands of today’s modern age.

2. Personalized learning

One of the first attempts to implement personalization in a time-based and standardized system was Keller’s interpretation of personalization. He outlined the five key features of personalized learning: “self-pacing, mastery of material before proceeding to the next material, use of lectures for motivational purposes, importance of the written word, and use of peer mentors” (Keller, 1968, p. 83). Some researchers, for example The Office of Educational Technology (2010) and Keefe and Jenkins (2002) define personalization as instruction that considers individual student characteristics and is paced to learning needs. Keefe (2007) wrote three key elements for personalized learning: an actively involved learner, the teacher as a learning facilitator, and a success-oriented students’ program.

Christou, C. et al. (2023) emphasized that beside academic improvement, educators need to consider humanizing and social aspects of mathematics teaching and learning. For example, they focus on tailoring mathematics tasks and problems to learners. Students concentrate on finding solutions based on their own mathematical understanding and have voice to their own ways of mathematical thinking.

Students develop creative and critical thinking abilities and apply them to the expansion of their knowledge and skills. The intellectual satisfaction that one gets when discovering concepts and procedures as well as the generalizations of rules in different contexts are the major components of personalized mathematics (Christou et al., 2023, p. 85).

Learners’ search for understanding motivates them to learn with efficiency. Intrinsically motivated people engage in activities that interest them, and they do so freely, with a full sense of volition and without the necessity of material rewards or constraints (Deci and Ryan, 1985). When learners want to know more about an idea, a topic, or an entire discipline, they put more cognitive energy into their investigation and discussion and study more on their own (Brooks and Brooks, 1999, cited in Bautista, 2012). Järvelä (2006) points out that “care must be taken

to remain realistic in terms of the individual's ability to be a competent, adaptive, active, goal-oriented, and motivated learner" (p. 32).

Miller and Kulhavy (1991) as cited in (López and Sullivan, 1992), hypothesize that personalization improves memory by increasing the associative strength of the personalized material and closely related content. They found out that incorporating personalized representations during encoding led to significantly greater recall of related information. The meaningfulness of the problem context may increase when its context is personalized; thereby enabling learners to place themselves mentally more readily in the problem situation. Personalization may not only build stronger associations related to the task, but in doing so it may ease the cognitive demands imposed by the problem-solving process.

Strong et al. (2004) determined the principles to which we should make a commitment as mathematics teachers thoughtfully preparing our classes:

include all four dimensions of mathematical learning – computation, explanation, application, and problem solving – in every unit we teach, help students to recognize their own mathematical learning styles, use a variety of teaching strategies to explore mathematical topics, and create or revise our assessments to reflect all four dimensions of mathematical learning and all four learning styles (p. 78).

The following main tenets characterize how I see and understand personalization. First, learners have a choice in terms of what, how, where and when they should learn; second, work-based and skills-focused learning is supported as a more authentic form of education; and third, personal autonomy, responsibility and flexibility are paramount (Meighan and Toogood, 1992).

Common challenges with the use of personalization

To implement personalization, there are several significant challenges that must be addressed. Researchers (Bentley and Miller, 2006, Hanover Research, 2014) identified the following major obstacles.

The biggest challenge is the change in teachers' beliefs. Teachers are responsible for delivering the curriculum, so if they are unsure or not convinced of the potential benefits of personalisation, this approach is not an option. When personalized learning isn't consistent or comprehensive, it can be frustrating for educators and learners. To maintain a consistency, teachers should be encouraged to proactively use personalized learning terminology and appropriate techniques on a regular basis in their classrooms. A selected teaching approach and its theory has an enormous relevance to the context of personalized learning.

Extra time investment is required to address curriculum, content delivery and assessment needs to ensure regulatory compliance. Given the nature of personalization, where the learner's needs are determined by the learner, the challenge for institutions is to make sure that what the student learns meets the curriculum and competencies as articulated in the academic program (Jeřábek and Tupý, 2007). This can be achieved through effective feedback on learning outcomes and monitoring of student's progress (Attwell, 2006) but requires additional effort from teachers and administrators.

One of the significant factors in determining successful implementation is also the space in a classroom. Personalized instruction focuses on group learning and finding physical classroom space for small groups to gather and interact can be challenging. Sometimes personalized learning involves heavy utilization of technology which means for example small school activity spaces. One of the challenges of personalized learning can be described as insufficient tooling. While the right tools help educators set up personalized learning experiences, the wrong ones can get in the way or prevent teachers from creating them altogether.

The Montessori approach

As part of the mathematics curriculum revision, the European Commission emphasized the importance of the methods being used. They stated that:

appropriate teaching methods can improve students' level of understanding and help them master mathematical rules and procedures. The methods used also influence how students engage with and enjoy their learning, which, in turn, also impacts indirectly on how much and how well they learn (Parveva et al. 2011, p. 51).

The Montessori approach is one of the child-centred methods and it is often described as a holistic approach to learning with the ambition to educate the learner as a whole, including physical, spiritual, social, mental and emotional education. This means that one might find a Montessori child meditating or doing yoga while another is practicing subtraction nearby. Each of these components are considered equally important.

The Montessori approach is not entirely original. The one-hundred year-old method is in effect the history of the work of Pereira, Itard and Seguin (Fynne, 1924). Initially, Montessori shared the principle of individuality with Locke and Rousseau (Wasson and Boyles, 1998).

Montessori education is characterized by multi-age classrooms, a special set of educational materials, student-chosen work in long time blocks, collaboration, absence of grades and tests, and individual and small group instruction in both academic and social skills (Lillard and Else-Quest, 2006). "In summary there are two aspects of Montessori classrooms that are very different to conventional classrooms: the learning materials themselves, and the individual self-directed nature of the learning under the teacher's expert guidance" (Marshall, 2017, p. 3).

In this approach, children learn at their own pace through manipulation of objects. As such, personal independence, self-discipline, and initiative are essential for learning and motivation, with motivation purportedly fostered through interactions with the environment (Kendall, 1992, cited by Lopata, Wallace, and Finn, 2005). Individualized pacing and instruction are the features which pronouncedly characterize Montessori programs (Diamond and Lee, 2011).

Hiles (2018) in his meta-analysis listed Montessori principles. 1. Respect for the child where learners should be supported in doing and learning things for themselves without unnecessary help or interruption, choosing their own pace. 2. Support for self-education which means avoiding external rewards or punishment. 3. Protection of the child's spirit to learn. McFarland (2013) described the following principles: 4. Support for an inquiring mind when learners can reason as

well as to consciously select and remember what they are learning. 5. Allowance of sensitive periods when learner's attention is intently focused on self-mastery, sometimes to the exclusion of other things.

All authentic Montessori schools have long, uninterrupted work periods (generally 2–3 hours depending on age). This long time period allows children to engage with the materials deeply and reach intense concentration. In addition to maths, language, and science, Montessori schools include two other academic areas: practical life and sensorial. Practical life consists of exercises to help children learn skills used in everyday life. For older children, this includes things like budgeting and starting a small business. Montessori teachers are sometimes referred to as guides. The teacher's job is to observe the children and introduce them to the academic materials at just the right time.

Definitions and characteristics of personalization have various interpretations. This investigation found that, for the most part personalisation is not well explained (various definitions exist), nor is it commonly used at schools in the Czech Republic. One of the goals in the investigation, was to look at different aspects of the Montessori teaching approach in particular and study its principles paying special attention to aspects of a personalized approach in the Montessori ways of learning.

In my research I focused on the questions:

1. What characteristics of personalization are not included or are least included in the principles, beliefs and practices of the teachers using a Montessori approach?
2. How do teachers in Montessori elementary classrooms overcome obstacles involved with the implementation of a personalized approach to learning during mathematics lessons?

3. Methodology

3.1. Methods of research

The method to analyse the data both within each situation and across situations (Yin, 2003) is a directed qualitative content analysis (Mayring, 2000). Data material is formed by written narratives, where the chosen analytical procedures and coding are in an inductive-deductive way. The lessons were videorecorded during the spring of 2019 in a public school with the agreement of head of school and all participants (teachers, learners, and their parents).

3.2. Data collection

For initial data collection in the spring of 2017, I used a semistructured interview (Fylan, 2005) with a paper-based interview guide. The guide included a list of open-ended and closed-ended questions and topics that needed to be covered during the conversation, in a particular order. Two pilot interviews with other elementary teachers were carried out in the first phase. The interviewer followed

the guide but needed to be able to follow topical trajectories in the conversation and therefore questions vary for each of the respondents. Questions were focused on teachers' beliefs and practices in the approach which they use, for example: *what is specific for mathematics lessons in their classes, how they plan and prepare their lessons, how they use textbooks, if and how they assign homework, etc.* The interviews were recorded with the approval of the teachers on a voice recorder. Transcribed audio recordings of the interviews were then analyzed.

The videorecording of each set of each teacher's three lessons followed in the spring of 2019. Both teachers Maria and Michelle teach in elementary classrooms (children age 6–12) at a public Montessori school in Prague, Czech Republic. They had 6 and 10 years of experience at the time and taught in 1–3 grades (25 pupils) and 4–6 grades (27 pupils) in their classes. Both of them graduated as teachers at elementary school and further dedicated themselves to Montessori pedagogy in accredited courses of Montessori pedagogy in the Czech Republic. They were interviewed (5–15 minutes) a priori on the topic which they were going to teach and the methods they were going to use and a posteriori after each videorecorded lesson. The questions such as: *what and how they planned the lesson, what activity they are going to do, if and how they are going to evaluate, etc.* were complementary to the analysed videorecordings. The interviews and recordings were transcribed and formed by written descriptive narratives.

3.3. Data analysis

Interviews and videorecordings were transcribed verbatim and translated by the author of this work. All the descriptive narratives were used as a source for analysis.

In the first phase of analysis, the attention was focused primarily on statements related to the teachers' beliefs and teaching style and the other comments obtained from the initial interviews. I identified statements which I considered as connected with personalization and my research questions and formed them in analytical units.

In the second phase I analyzed situations from each videorecording and I identified situations according to the characteristics of personalisation. Using axial coding I gathered related concepts in meaningful units and specified 5 codes "Planning and determination of learner's needs, objectives of learners, participation of a learner, selection of technology and resources as a support to the learning, assessment as learning" (adopted from Bray and McClaskey, 2015). To answer the research question of which characteristics of personalisation are missing (or are least included) in the teaching practice of the teachers, I analysed situations for each category.

4. Results

Firstly, I determined if any and how many principles of the approach did not correspond to the characteristics of personalization. I explored and conceptualized teachers' beliefs and the collected data. I described which characteristics of personalization were missing in teachers' practices. In the paragraphs below, I endeavour to describe how teachers overcame obstacles of personalized learning.

4.1. Characteristics of personalization missing in the approach principles (by the author or in literature)

To answer the first of my research questions, which principles of the Montessori approach did not correspond with personalization, I was looking at the principles which are presented by authors of the method or by literature. Although I tried to list the principles objectively, the principles vary in literature. Therefore, I selected the principles which were stated repeatedly by more authors (for example respect for the child, role of the teacher as a guide, and educating the whole child) or seemed the most relevant according to my experience.

The only one principle of the Montessori method from Hiles (2018) and (McFarland and McFarland, 2013) that did not evince characteristics of personalization was mixed-age classrooms. This characteristic is more related to class management and does not lead directly to personalization.

On the contrary, this very principle could be presented as a tool for personalization, because it allows the teacher to let learners work on lessons according to their real abilities and skills and not according to the grade.

Whether all teachers in Montessori schools have a consistent understanding of all principles and strictly adhere to these principles, would be a matter of further investigation.

4.2. Characteristics of personalization which were not found in teachers' beliefs

The source of data is the statements of a relatively small sample of people. Therefore, in these paragraphs I focus on the analysis of information obtained from individual respondents rather than on the generalization of data in relation to the educational program and its methods.

All characteristics of personalization were found in the beliefs of both teachers. Michelle considered the prepared environment as important, where we can find a manipulative material that is very specific and ready for learners according to their needs. She described what she considers as the most important and why she uses Montessori method.

Michelle 7: I like working with a three grade heterogeneous class. The children are not at the same level, they choose themselves what they want to do at their age. Therefore, I love first graders working on what the third graders usually do and at the same time the other third graders can do what the first graders usually do.

She complements her words with the example from the current class. She has a first grader who can multiply multi-digit numbers and work on long division material, and it is evident that he understands and knows what he is doing. It is enough to quickly introduce a material and he understands and transfers it in abstract thinking and written form. He likes problems for the development of logical thinking, he likes challenges and thinking. He was not motivated by problems intended for first grade children and he developed problems for himself. On the other hand, she has children with mental disabilities. One of them is the age of a fourth grader and is much taller than the other children. The girl usually

works with first graders, and thanks to materials, she develops her mathematical thinking. She is independent and can say what she wants to work on. The other children accept her differences.

Michelle 14: I also like when children love mathematics because it is concrete and they go through the problems and we can see what M. Montessori said, that the hand is an instrument of the mind. We can refer to the manipulation with materials and the concrete act.

Maria is convinced that, work can be interesting and beautiful when you use something different than a textbook or workbook, and paper and a pencil. Montessori is, according to her, concrete and visual. The child is able to see how it works for instance in geometric problems. The child can become a number, he/she can use the objects around him/her, and he/she can work with the real environment. The task for a teacher is to prepare such standardized problems and tasks to let him/her choose what his/her heart beats for. The freedom of choice is not limitless but structured in choices which the teacher offers. At the same time, she teaches children to be able to choose and decide. She said that learners were at different levels, and they had variable abilities to reach an “aha moment,” which the material offers.

Maria, as a teacher, follows the course of the presentation and the work with material. At the same time, she needs to observe how far the children understand the process. For example, an algorithm is a sequence of the steps, and each child can take a step back during the long presentation in a different place and stop understanding at different moments. The role of the teacher is to communicate with each child continuously during the presentation. The teacher individualizes the instruction during the process in the bases, and the children are basically divided into two groups. After the first presentation, there are children who are enthusiastic, they understand it and can start to practice the topic immediately and get better at it. They play with the material and through repetition of the work they deepen their knowledge. Then there are children who determine that they do not really understand, and the teacher presents additionally for one or two pupils at a time where they repeat the process and the teacher watches for which moment they stop understanding and identifies the biggest problem - if it is some mathematical step or operation which proceeded. It means if he/she can do it or it is too complicated, they need to go back and practice the previous topic. When the teacher can see the child struggling and starting to be fearful, then his/her role is, and that is how Maria perceives it, to eliminate or reduce. We can offer him/her something different, safely at a lower level to calm him/her down. The calm child who can say to himself/herself that he/she can make it, is able to raise the level of difficulty of schoolwork again. Maria talks about the flexibility of a teacher.

Maria 20: All children daily attend at least two presentations. Every day we also have one activity together, usually it is a creative work. In mathematics the presentations are often more individual and ten to twelve children from the same grade can be separated according to the pace of presentation they need.

In the interviews, both teachers talked about the aids they chose for the group presentations. The students' own selection which is a characteristic of personalization might come from the approach itself and therefore it was not emphasized in the interview.

Finding all characteristics of personalization in both teachers' beliefs means that Montessori teachers overcome the biggest obstacle of personalized learning by changing their beliefs, and by choosing a teaching environment that follows the principles of Montessori's pedagogy.

4.3. Characteristics of personalization not identified in teachers' practices in classrooms (including interviews a priori and a posteriori)

In the interviews a priori, lessons and the interviews a posteriori of both teachers using the Montessori method, 32 situations with characteristics of personalization were found. As we can see from table 1, the least represented characteristics of personalization in Michelle's lessons were the selection of technology and resources as a support to the learning and assessment as learning. Objectives of learners and selection of technology and resources as a support to the learning were characteristics represented least in Maria's lessons.

Table 1: Number of characteristics in teacher's practices

	Maria	Michelle
Planning and determination of learners's needs	4	4
Objectives of learners	1	5
Participation of a learner	5	6
Selection of technology and resources as a support to the learning	1	2
Assessment AS learning	3	1
Total	14	18

Analysis of Maria's lessons

The lack of active participation in setting up objectives for learners, which is one of characteristics of personalization, was identified in Maria's lesson. For the lesson, the teacher proactively planned the procedure for what a group of learners needed to learn, how they would learn it, and/or how they would show what they had learned. The teacher designed the instruction based on the learning needs of the group.

She presented a new topic and then oversaw the whole class but ultimately learners decided what they worked on, and almost all worked on distinct activities independently or with an assistant teacher. During the lessons, learners had choices to interact with the content, discuss what they watched, ask questions, or offer answers. Although students were actively participating as learners, the teacher chose the topic and controlled how learners demonstrated understanding. The teacher selected technology and resources for demonstration. After the presentation, learners could make up and solve other problems using more manipu-

latives of the same kind if they wanted to. The teacher commented on the needs for revision and made sure the students had the knowledge required for further work. When the group was finished with the work, and if they encountered any difficulties with the task, they asked the teacher to explain further.

Learners share how they would like to acquire information, express what they know, and what ways they like to engage with the content as it was identified in Maria's lesson (L1). She finds out that learners discovered something they have not talked about at school yet. She suggests that she would prepare the following presentation to introduce the topic. She identified and wanted to follow the learners' needs.

Maria L1 73: Boys, how about you, any conflict? Anything was wrong?

Learner L1 54: Something was not correct because we came across exchanging.

Maria L1 74: Exchanging... It happened, show me, and try it.

Maria L1 75: It happened... you dropped the zero here (shows out of squares). Imagine what you actually did? You have got to the area... you will have it next year. You got into a topic called a decimal number, because ... and I do not really know if you know it completely, maybe you have seen it with older learners. So far, we have counted integers and started with units ... even mathematicians have figured out that they can divide that unit, right? They can also divide it into smaller pieces. Here behind that unit (points to the green square) is such a line. It is hidden there, now it cannot be seen. The numbers behind it are getting smaller and smaller. That means smaller and smaller place values. Therefore, by inventing it, you discovered another type of problem, a task that can also be counted. Would any of you be interested in what is behind this? (The whole group raises their hands)

Maria L1 76: Hm, well. I will now tell you what the task will be, and I will prepare this presentation for you... .

Maria L1 77: ... next week, I'll take note of it, and next week I will show you what a decimal number is.

Analysis of Michelle's lessons

There were also situations which evinced a lack of characteristics of personalization in Michelle's lessons. She prepared lessons for individuals and repetitively delivered instructions to individual learners based on their needs. She evaluated verbally, and then in written form, she individually described on the report what she had observed in the class.

The teacher worked with a small group of learners in each of the videorecorded lessons. They used manipulatives. The teacher designed the instruction based on the learning needs of the group. The other learners in the class worked independently or with an assistant teacher.

The characteristic of personalization which was lacking the most was the practice of selecting resources for demonstration of the specific lesson. The teacher set

up an activity for a small group of learners who just participated in the presentation. The teacher, as in other Montessori classes, could offer participation or non-participation in the lesson. In the introductory lesson, however, it was not possible to let the students choose tools, because the teacher actually introduced how to work with the tool. However, this obstacle was overcome during practice. Any summative assessments based on student mastery were missing.

To personalize learning, Michelle and her learners co-design objectives based on each learner's learning goals. There are different objectives for each learner. Characteristics of personalized objectives described in the following paragraphs were identified in Michelle's first interview a priori and lesson.

Before the work, Michelle is empathetic and thinks of other work students might have. Considering their needs and interest, she also thinks that some of them might be busy therefore they are not interested in a lesson.

Michelle L1A 5: Others have independent work. Firstly, they have a deadline for a project which we have been doing until tomorrow, so I think they will be dedicated to it. And then they have the sentence of the week, problems of the week plus what they have such a long-term job that they know about.

For her lesson, Michelle then invites all learners who want to have a lesson on multiples. She said that some of the learners have seen this work, and some have not. The work was set as learners should use colour coded squares to indicate multiples of numbers one to nine. They notice different things and the teacher asks some of the initial questions and lets the learners express their thoughts without final comments. They notice that some numbers finish with the same numerals, and they use colour-coding to indicate it in the fleece material. They count the number of coloured squares. There are just a few of one, three, seven, and nine squares which are odd numbers. The two, four, five, six, and eight are even numbers which they count as many of them. The objectives for each learner varied according to their skills.

For lesson (L1) Michelle invites a group of learners to join her in the aside around the little rug. The other learners come because they want to see the presentation again. The participation is voluntary and discussed.

Michelle comments on the participation later during the interview a posteriori (L1P). It is explained that some of the learners come into the lesson even when they have not been ready. During L1 a boy who has already been there, signed up. He wanted to go for it, he went again, and Michelle had to restrain him. According to her he tended to reveal it to those children, or he wanted to do it quickly for those who had never been there before, so she had to restrain him a bit. Therefore, it happened there. In fact, no one stayed after the presentation to continue working with manipulatives. She thinks that they enjoyed it. The boy who had already been at the presentation left right after it was explained and did not continue working. Michelle considered that as interesting, that this boy does not really like working with aids, and when he gets to one, he goes to it repeatedly, but he does not go to them voluntarily. No one stayed with the activity in any way. Michelle comments on the specific children's participation.

Michelle L1P 2: ... In fact, at the very beginning two children appeared there, who multiplied... or more precisely: One girl is not so far away that she could handle a multiplication table, and then a boy appeared there, who knows the principle of multiplication and is very happy at all presentations and he absorbs. This is a first grader and he actually appeared there too.

During interview a posteriori (L1P 4) Michelle specifies that she planned the lesson for someone who was not there. It is an offer that she repeats from time to time during the school year, but it is not mandatory. Someone will figure it out without working with it. Michelle is convinced that not everyone enjoys this discovery, and this is more about discovery. She adds that there is always something that she says that they should learn from such an exercise. That the multiplier of two always ends in even numbers, and it keeps repeating itself, so it is just some consciousness. The children often take the paper and go draw it in the table, but this time they are so busy with another work, none of them continue.

Michelle, during the second videorecorded lesson (L2), offers a lesson on long division with manipulatives. She asks specific participants but allows them to decide if they take a lesson or not. Anybody from the whole class can participate. In the beginning of the lesson, she says that learners need to split up and exchange their roles in counting, writing notes, and observing. They can decide their order.

Michelle L2 38: And think about which of you will count now and who will write.

Learner L2 20: Jane.

Learner L2 21: I am not going to take notes...

Learner L2 22 Good Suzy will take notes.

Michelle L2 39: ... because you will watch.

Learner L2 23: Suzy writes and then I will write and then Lily will write, and Suzy will count and then I will write, and Suzy will count.

Michelle L2 40: You all should count, write, and watch.

Learner L2 24: Well, yes.

Michelle sets up the task with recommendations for a small group of learners who just participated in the presentation during the lesson (L2). Learners have a voice on when they do it. They are allowed to cooperate but can also do it individually.

Michelle L2 95: ... I recommend you do the three problems as soon as possible while you have it in your head and repeat it, because if there is something new like this, it will quickly blow away from your head again. So, as it went now, and it went really well, so count one for sure today, next one tomorrow and another one the day after tomorrow.

Learner L2 117: Or all of them today.

Michelle L2 U96: Or all of them today. I recommend doing them when you have independent work today. Take it and do another one.

Learner L2 118: And by when do we have to do it?

Learner L2 119: The first one.

Learner L2 120: No, not that.

Michelle L2 97: Three problems by the end of this week. Ok, by the end of this week.

The teacher also comments (L2P 8) on what the other learners did during her presentation and how the work is set up for each week. They have deadlines for another work. There is one assigned work for each week. They meet on Monday, and it is up to them when they do it, but it must be sometime during the week. She reminds them in the morning to have a worksheet ready. Every week they have a sentence and problems for the week. She usually has something that she wants most children to do during the school year. Therefore, in fact, in those problems of the week, she includes what she knows, that the children have already gone through, that everyone can do. For instance, second graders have already gone through written addition, and they can also do it at a level that includes writing it down. That everyone or almost all passed. On the other hand, one little girl does not even do the written addition, or any subtraction. They went through written subtraction, so Michelle actually puts it there on an ongoing basis to practise it or to automate it. A lot of children have a feeling for some reason that when they are at the presentation, they already know how to do it and do not tend to practice it again.

In personalization, learners need to monitor their progress toward them using clear criteria of good practice. Learners are guided to provide descriptive feedback and record revisions in their own words and become confident in all aspects of the process of evaluation. Such characteristics were identified during Michelle's lessons.

During the division lesson with manipulatives (L2), Michelle is observing the whole process and assigning the task for the following days. Learners work together to compare outcomes to task demands. They check their work using an answer key, calculator, or computer.

Michelle L2 93: What is next? You will each solve three problems, but I will probably write them to you separately, because it occurs to me that there are not so many of them here. So, I will write three problems for each of you. Can I. . .

Learner L2 116: We will count it.

Michelle L2 94: You will count it. It can happen that you have a reminder. Do you feel like you understand it, girls?

Learners L2: Yes.

Michelle L2 95: If it happens that it does not work out, we will sit down together again. From what I have seen, I felt that you knew exactly what you were doing and when you were doing it. . .

Finally, learners in Michelle's class write a self-evaluation about their work, referring, if necessary, to the sample language. They leave their signed and dated work in the appropriate box at the station.

5. Discussion

Almost all principles of Montessori pedagogy correspond to the characteristics of personalization. In other words, principles of both personalization and the Montessori approach are responsive to diverse students' needs in classrooms. Therefore, teachers at Montessori schools have no obstacles to overcome in order to personalize. It is in accordance with Keefe and Jenkins (2000) who also saw Montessori education as one of the strategies for personalization. Watson and Watson (2016) likewise saw Montessori education as personalized because of the incorporation of student choice, student self-regulation, mastery-learning philosophy, portfolio assessments, and the teacher-as-guide approach.

This study showed that in Montessori classrooms, teachers offer the opportunity to self-select tasks, demonstration of materials, choice of resources, independent work while practicing and self-reflective feedback. All these attributes evince characteristics of personalized mathematics.

In my investigation I looked at teachers' beliefs and observed what characteristics of personalization were not included in teachers' statements and beliefs. I considered that personalization might be demanding on teachers' beliefs. "Teachers who are concerned about personalizing the learning process believe in teaching through genuine experience and thoughtful reflection." (Keef and Jenkins, 2002, p. 446).

The present research revealed that, in Montessori classrooms, teachers used detailed observation as a main source of information about childrens' progress. They followed the principles where Montessori teachers monitor all areas (level of physical, psychological, and sociological development) but did not use grades or tests. Personalized learning emphasizes the importance of different manners of analysing the relevant student-learning characteristics (Keefe and Jenkins, 2000).

In Montessori lessons, a lack of personalization was identified when selecting recourses for learners including the use of technology. It corresponds to the statement of Watson and Watson (2016) who said that Montessori limited the use of technology. Furthermore, "teachers who hold strong Montessori beliefs will most likely integrate technology in ways that align with the Montessori paradigm" (Jones, 2017, p. 18).

In both teachers lessons, I observed teacher and student interaction, attention to differences in personal learning styles, an assistant who was available during all the lessons, choices in personal goals, student ownership in setting goals and designing the learning process (Clarke, Miles, and McGee 2003) which I consider as a process able to overcome obstacles and is consistent with personalized learning.

My research, similarly, to the work of Mavric (2020), has shown that Montessori education as a child-centered approach, is one of the models that incorporates numerous aspects of a personalized approach and shares many common elements with personalized learning (Watson and Reigeluth, 2008). Both approaches em-

phasize independence and auto-education (The Office of Educational Technology, 2010; McFarland and McFarland, 2013). The goal of both personalized instruction and Montessori education is to build a learning environment that best suits the needs, developmental stage, and interests of each student (Keefe and Jenkins, 2002; Lillard, 1972).

The results of this study will make a positive contribution to the literature: firstly, studying the relationship between the two approaches brings new perspectives to both of them. Secondly, finding the characteristics of personalization in the Montessori approach proves that even though the method has been practiced for over one hundred years, it still uses modern, holistic ideas in the teaching of mathematics. Finally, this paper is one of the first studies to use individual data from the Czech Republic.

Limitations of my research

Several limitations of my research can cause that findings can not be generalized. Despite the maximum effort for objectivity, the researcher's personality is reflected to a certain extent, in the selection and evaluation of situations. To minimize this reality, I set criteria for coding.

Furthermore, to determine the characteristics of personalization, it is important to note that I was looking at different factors (such as principles and teachers' beliefs and real situations in the classrooms) but not all the factors could be included (such as learners' individual characteristics and their educational results, teachers' long-term planning or the influence of an assistant). I am aware that all these factors can have different causal interpretations. For example, the teachers' expressions during the interviews may not correspond to their true beliefs for various reasons.

Finally, the size of respondents for my research was selected as a sample for the approach. Some characteristics come from the approach itself or occur throughout the process and therefore were not identified repetitively. The teacher's personality is also clearly manifested in terms of the personality characteristics (temperament, introvert-extrovert, level of empathy, tendency to plan or react spontaneously, etc.).

On the other hand, it was the awareness of these facts that led me to a more comprehensive approach to the issue. I looked at several aspects of the educational process.

6. Conclusion

In the Montessori method, I found characteristics of personalization in the principles, teachers' beliefs, and teachers' practices. In some situations of one of the teachers, different principles prevailed. There wasn't much personalization missing, and I verified that Montessori gives opportunities to support personalization, as it is supported in all aspects of the studied environment.

With the help of tools, teachers provide learners the opportunity to move through certain aspects of the material in the order of their choosing, allowing learners to follow their interests. Personalization is supported in the Montessori environment. Teachers in the classrooms adjust things like seating and layout

to create an environment that supports a broader range of students and learning styles. By offering multiple options and organizing supplies in ways that are easily accessible to students, educators can help foster students' independence while setting them up for learning success. Characteristics of personalization (according to my interpretation) give us tools to develop responsibility and independence in learners' education.

To answer the first of my research questions, if and how any principles of the Montessori method did not correspond with personalization, I was looking at the principles which are presented in literature. All (except for one – mixed-age classrooms) principles of the Montessori method evince characteristics of personalization. My research question revealed that characteristics of personalization are included in beliefs and practices of the teachers using the approach. Even if it has been said that teachers' beliefs are crucial in using personalization regardless of the method, beliefs of teachers using the Montessori approach comply with the characteristics of personalization.

When considering: How teachers in Montessori elementary classrooms overcome obstacles to the implementation of a personalized approach to learning during mathematics lessons, the research findings showed that the kinds of activities of teachers using the Montessori approach are in accordance with personalization. For instance, Montessori teachers let student personalize learning objectives and they provide effective feedback on learning outcomes and monitoring of student's progress.

My study showed that personalization is not at all limited by the Montessori approach and also that the use of the approach itself does not dictate the use of personalization. However, literature confirms that personalization elements are beneficial for learners and teachers. Personalization incorporated in any approach brings results through application in various stages of the educational process and has a long-term effect on the learner's personality.

This research has shown that, while personalized instruction also suggests many strategies for implementation of the concept, Montessori education actualizes the principles of personalized learning.

References

- Adler, I.: 1972, *The new mathematics* (revised edition). New York: John Day and Co.
- Attwell, G.: 2007, Personal Learning Environments – the future of eLearning. *eLearning Papers*, 2(1), 1–8.
- Bautista, R.G.: 2012, Students' Attitude and Performance towards Algebraic Word Problem Solving through Personalized Instruction. In *Conference Paper: Proceedings of IATED-EDULEARN12*. IATED Barcelona, Spain, 3294–3301.
- Bentley, T., Miller, R.: 2006, Personalisation: Getting the questions right. In *Personalising Education*, OECD Publishing, Paris, 115. <https://doi.org/10.1787/9789264036604-9-en>.

- Bernacki, M., Walkington, C.: 2014, The Impact of a Personalization Intervention for Mathematics on Learning and Non-Cognitive Factors. In Stamper, J., Pardos, Z., Mavrikis, M., McLaren, B.M. (Eds.) *Educational Data Mining*, London, 80–87. <https://doi.org/10.13140/2.1.4342.1445>
- Bray, B., McClaskey, K.: 2015, Personalization vs Differentiation vs Individualization Report (PDI) v3. *Viitattu, 16*. Retrieved from <https://kathleenmcclaskey.com/personalization-vs-differentiation-vs-individualization-chart/>.
- Brooks, J.G., Brooks, M.G.: 1999, *In Search of Understanding: The Case for Constructivist Classrooms*. Alexandria, VA: Association for Supervision and Curriculum Development.
- Christou, C., Pitta-Pantazi, D., Pittalis, M., Demosthenous, E., Chimoni, M.: 2023, Personalized Mathematics and Mathematics Inquiry: A Design Framework for Mathematics Textbooks. In *Mathematical Challenges for All* Cham: Springer International Publishing. 71–92.
- Clarke, J., Miles, S. (Eds.), McGee, P.: 2003, “Changing System to Personalize Learning: Introduction to the Personalization Workshop”, The Education Alliance. <https://files.eric.ed.gov/fulltext/ED482970.pdf>.
- Deci, E.L., Ryan, R.M.: 1985, The general causality orientations scale: Self-determination in personality. *Journal of Research in Personality, 19*(2), 109–134. [https://doi.org/10.1016/0092-6566\(85\)90023-6](https://doi.org/10.1016/0092-6566(85)90023-6).
- Diamond, A., Lee, K.: 2011, Interventions shown to aid executive function development in children 4 to 12 years old. *Science, 333*(6045), 959–964. <https://doi.org/10.1126/science.1204529>.
- Fylan, F.: 2005, Semi-structured interviewing. *A Handbook of Research Methods for Clinical and Health Psychology, 5*(2); Jeremy, M., Paul, G. (Eds.); Oxford University Press: Oxford, UK, 65–78.
- Fynne, R.J.: 1924, *Montessori and her inspirers*. Longmans, Green and Company.
- Hanover Research: 2014, Best Practices in Personalized Learning Implementation. <https://www.hanoverresearch.com/media/Best-Practices-in-Personalized-Learning-Implementation.pdf>.
- Hiles, E.: 2018, Parents’ reasons for sending their child to Montessori schools. *Journal of Montessori Research, 4*(1), 1–13. <https://doi.org/10.17161/jomr.v4i1.6714>.
- Järvelä, S.: 2006, Chapter 2. Personalized Learning? New Insights into Fostering Learning Capacity. In *Personalising Education*, OECD/CERI (eds.), OECD Publishing, Paris, France, 31–46.
- Jeřábek, J., Tupý, J.: 2007, *Framework educational programme for basic education* (with amendments from 1. 9. 2007). <http://www.vuppraha.cz/wp-content/uploads/2009/12/RVPZV\2007-07.pdf>.

- Jones, S.J.: 2017, Technology in the Montessori Classroom: Teachers' Beliefs and Technology Use. *Journal of Montessori Research*, 3(1), 16–29. <https://doi.org/10.17161/jomr.v3i1.6458>.
- Keller, F.S.: 1968, “Good-bye, teacher...” *Journal of Applied Behavior Analysis*, Spring 1(1), 79–89. <https://doi.org/10.1901/jaba.1968.1-79>.
- Keefe, J.W., Jenkins, J.M.: 2000, *Personalized instruction: Changing classroom practice*. Eye on Education.
- Keefe, J.W., Jenkins, J.M.: 2002, A special section on personalized instruction. *Phi Delta Kappan*, 83(6), 440–448.
- Kendall, S.D.: 1992, *The development of autonomy in children: An examination of the Montessori educational model* (Doctoral dissertation, Walden University).
- Lillard, A., Else-Quest, N.: 2006, The early years: Evaluating Montessori education. *Science*, 313(5795), 1893–1894.
- Lillard, P.P.: 1972, *Montessori: A modern approach*. New York: Schocken Books.
- López, C.L., Sullivan, H.J.: 1992, Effect of personalization of instructional context on the achievement and attitudes of Hispanic students. *Educational Technology Research and Development*, 40(4), 5–14.
- Lopata, C., Wallace, N.V., Finn, K.V.: 2005, Comparison of academic achievement between Montessori and traditional education programs. *Journal of research in childhood education*, 20(1), 5–13. <https://doi.org/10.1080/02568540509594546>
- Marshall, C.: 2017, Montessori education: a review of the evidence base. *npj Science of Learning*, 2(1), 1–9. <https://doi.org/10.1038/s41539-017-0012-7>
- Mavric, M.: 2020, The Montessori Approach as a Model of Personalized Instruction. *Journal of Montessori Research*, 6(2), 13–25. <https://doi.org/10.17161/jomr.v6i2.13882>
- Mayring, P.: 2000, Qualitative Content Analysis. Forum: *Qualitative Social Research*, 1(2), 105–114. <https://doi.org/10.17169/fqs-1.2.1089>
- McFarland, S., McFarland, J.: 2013, Montessori Parenting. *Montessori Life*, 1, 30–39.
- McKinsey & Company: 2010, Klesající výsledky českého základního a středního školství: fakta a řešení. [Dropping results of the Czech basic and secondary schools: the facts and solutions.] [https://www.mckinsey.com/cz/\\$\mathrm{\sim}\\$\\$/media/McKinsey/Locations/Europe%20and%20Middle%20East/Czech%20Republic/Our%20work/McKinsey_pro_bono_skolstvi.pdf](https://www.mckinsey.com/cz/$\mathrm{\sim}$$/media/McKinsey/Locations/Europe%20and%20Middle%20East/Czech%20Republic/Our%20work/McKinsey_pro_bono_skolstvi.pdf)

- Meighan, R., Toogood, P.: 1992, *Anatomy of Choice in Education*. Ticknall: Education Now Publishing Cooperative.
- Miller, D.C., Kulhavy, R.W.: 1991, Personalizing sentences and text. *Contemporary Educational Psychology*, 16(3), 287–292. [https://doi.org/10.1016/0361-476X\(91\)90028-J](https://doi.org/10.1016/0361-476X(91)90028-J).
- National Council of Teachers of Mathematics (NCTM):. 2014, Principles to actions: Ensuring mathematical success for all. National Council of Teachers of Mathematics.
- Office of Educational Technology, U.S. Department of Education.: 2010, *Transforming American Education: Powered by Technology*. Retrieved from www.ed.gov/sites/default/files/NETP-2010-final-report.pdf.
- Parveva, T., Noorani, S., Ranguelov, S., Motiejunaite, A., Kerpanova, V.: 2011, *Mathematics Education in Europe: Common Challenges and National Policies*. Education, Audiovisual and Culture Executive Agency, European Commission. Retrieved from <http://eacea.ec.europa.eu/education/eurydice>.
- Strong, R., Thomas, E., Perini, M., Silver, H.: 2004, Creating a Differentiated Mathematics Classroom. *Educational Leadership*, 61(5), 73–78. <https://eric.ed.gov/?id=EJ716727>.
- Wasson, W.L., Boyles, D.R.: 1998, A democratic phenomenon: Emerging adolescent programs in Montessori Schools. *Philosophy of Education Archive*, 465–472.
- Watson, S.L., Reigeluth, C.M.: 2008, The learner-centered paradigm of education. *Educational Technology*, 48(5), 42–48. Retrieved from www.jstor.org/stable/44429608.
- Watson, W.R., Watson, S.L.: 2016, Principles for personalized instruction. In *Instructional-Design Theories and Models, Volume IV*, 109–136. Routledge.
- Wood, T., Cobb, P., Yackel, E.: 1991, Change in teaching mathematics: A case study. *American Educational Research Journal*, 28(3), 587–616. <https://doi.org/10.2307/1163150>.
- Yin, R.K.: 2003, Designing case studies. *Qualitative Research Methods*, 359–386.

Miroslava Brožová
 Faculty of Education,
 Charles University, Czech Republic
 e-mail: C.Mirka@seznam.cz