Cognitive, Metacognitive, and Personality Manifestations of Gifted Pupils in Solving Word Problems

Kateřina Jůzová[1]

[1] Faculty of Education, Charles University, Magdalény Rettigová 4, Prague, Czech Republic; juzova.kat@gmail.com

This study focuses on the cognitive, metacognitive and personality manifestations of gifted first graders during word problem solving. A series of meetings with a group of gifted pupils aged 6–7 years ($n = 6$) were arranged, during which the pupils solved and commented on the solved word problems in a group discussion setting. The problems were selected and pre-tested to ensure clarity and appropriate difficulty. At the same time, they were selected with the aim of containing complicating elements, such as irrelevant information or unknown contexts. The methodology combined problem-solving interviews, group discussions and semi-structured group interviews. In terms of cognitive skills, pupils showed good memory and abstract reasoning skills. Pupils also demonstrated early metacognitive awareness and the ability to use advanced mathematical apparatus. Personality manifestations such as mindset and self efficacy were also observed. Manifestations of fixed and growth mindset and positive and negative self-efficacy were found. The findings suggest that word problems, when used in a structured and reflective environment, can serve as an effective tool for identifying and understanding the thought processes of gifted learners.

Key words:
cognitive abilities, metacognitive abilities, giftedness, self-concept, word problem.

Received 10/2024
Revised 5/2025
Accepted 6/2025

1 Introduction

This study deals with gifted primary school pupils. The variety of approaches to defining the concept of giftedness reflects the complexity of this phenomenon and its diverse manifestations across domains. When one refers to a gifted child, it is often expected that they will achieve outstanding academic success (Laznibatová, 2003; Renzulli, 2005). Frequently cited manifestations and characteristics of pupils in the literature include a rich vocabulary, perfectionism, flexibility and originality of ideas, ability to concentrate for long periods of time (Clark, 2002; Portešová, 2021; Winebrennen, 2001), early onset of reading (Laznibatová, 2003; Terman & Oden, 1959; Van Tassel-Baska, 1983) and advanced cognitive development in relation to their peers (Carter, 1985). Personality manifestations of gifted learners were also studied such as mindset (Dweck, 2017) and self-efficacy (Bandura, 1994). Little attention, however, was paid to gifted pupils in the early years of schooling.

The study builds on those and other studies which provide insight into the cognitive, metacognitive and personality manifestations we can expect to see in gifted learners. In the present study, word problems were used as a research tool to uncover such manifestations. Word problems are complex problems with high cognitive demands (Vondrová et al., 2019) and provide a good opportunity to observe pupils' thinking at different stages of their solution.

Thus, this qualitative study aims to describe the cognitive, metacognitive and personality manifestations of gifted individuals when solving word problems during common sessions. The research participants are six primary school pupils in the first grade, purposefully selected as previously diagnosed as gifted in an educational-psychological counselling centre. The study brings new insights into how young gifted pupils aged 6 to 7 reason in mathematics.

2 Theoretical Background

The main theoretical basis of the study is the concept of giftedness and its variability and related cognitive and metacognitive phenomena. Through mindset theory (Dweck, 2017) and self-efficacy (Bandura, 1994), attention is also paid to the personality characteristics of gifted learners, particularly younger ones. Lastly, the research instrument, word problems, is described.

2.1 Giftedness and Characteristics of Gifted Individuals

The concept of giftedness came to the fore in the early 20th century (Laznibatová, 2003), along with the intelligence tests introduced by Binet. They resulted in the measurement of IQ (intelligence quotient). An individual who was in the above-average range was identified as gifted. In 1983, Gardner introduced the theory of multiple intelligences and distinguishes several types of intelligence (linguistic, logical-mathematical, spatial, musical, bodily-kinesthetic, intrapersonal, interpersonal), thus refuting the view of intelligence as only a rational ability (Gardner, 1993).

There are many characteristics associated with giftedness. For example, Portešová (2021) mentions the ability to concentrate attention for a long time and the ability to work with abstract symbols. Urban (1990) also mentions above-average expressive skills, knowledge of complex words and the ability to decode even difficult tasks in a structured way. The early onset of reading is often an indicator of accelerated development (Laznibatová, 2003; Terman & Oden, 1959; Van Tassel-Baska, 1983). On the other hand, gifted individuals often experience dissatisfaction with their own performance and perfectionism (Clark, 2002). Socially, they may find it difficult to establish relationships with peers (Sutherland, 2008) and may be seen to get on better with adults (Machů, 2010).

The above-mentioned research focuses on different parameters of giftedness and over the years, various definitions of giftedness have been created. This study works with the definition of mathematical giftedness as "an extraordinary high potential to solve mathematically challenging questions and problems (compared to others of the same age)" (Assmus & Fritzlar, 2018, p. 59).

2.1.1 Cognition and Metacognition in Gifted Individuals

Piaget (1952) provided a theoretical basis for the interpretation of a pupil's cognitive development. His description of the development of mental abilities could provide a tool for delineating and identifying giftedness (Carter, 1985) in the event that significant differences were found between gifted individuals and their peers. A number of studies confirm that the gifted may progress through the stages of cognitive development differently or more rapidly (Cohen & Kim, 1999). Similarly, Carter (1985) demonstrated that the gifted can be accelerated in their development by up to two years compared to their peers (his research was conducted with 673 gifted pupils aged 10–16 years). In particular, the period of formal operations (Piaget, 1952), which is characterised by the ability to think abstractly, was manifested earlier. Good memory is another cognitive characteristic of gifted pupils (Krutetskii, 1976; Portešová, 2021).

For the concept of metacognition, "the prefix meta itself conveys that it is a phenomenon superior to our cognition" (Krykorková & Chvál, 2001, p. 186). Flavell (1979, p. 906) defined metacognition as knowledge and cognition of one's own cognitive processes. Krykorková and Chvál (2001, p. 185) talk about "thinking about our thinking". According to Straka (2021), it is a broad term that can be further classified into metacognitive knowledge and procedural forms of metacognition. This division is based on early work by Flavell and Brown (Brown, 1987; Flavell, 1979). According to Bransford et al. (2000), the concept of metacognition includes knowledge about one's own learning (e.g., knowledge about strengths and weaknesses) and "also includes self-regulation – the ability to orchestrate one's learning". (Bransford et al., 2000, p. 97).

This study is partly based on Anderson's (2008) model of metacognition. This model was originally related to linguistics. Given the use of word problems that are closely intertwined with language (Vondrová et al., 2019), it seems to be a suitable theoretical basis for observing metacognitive phenomena.

Preparation and planning is the stage where the learner "takes the time to prepare for learning and plan what needs to be done" (Anderson, 2008, p. 100). This involves, for example, activating prior knowledge. The selection and use of strategies lead to the selection of an appropriate strategy to achieve

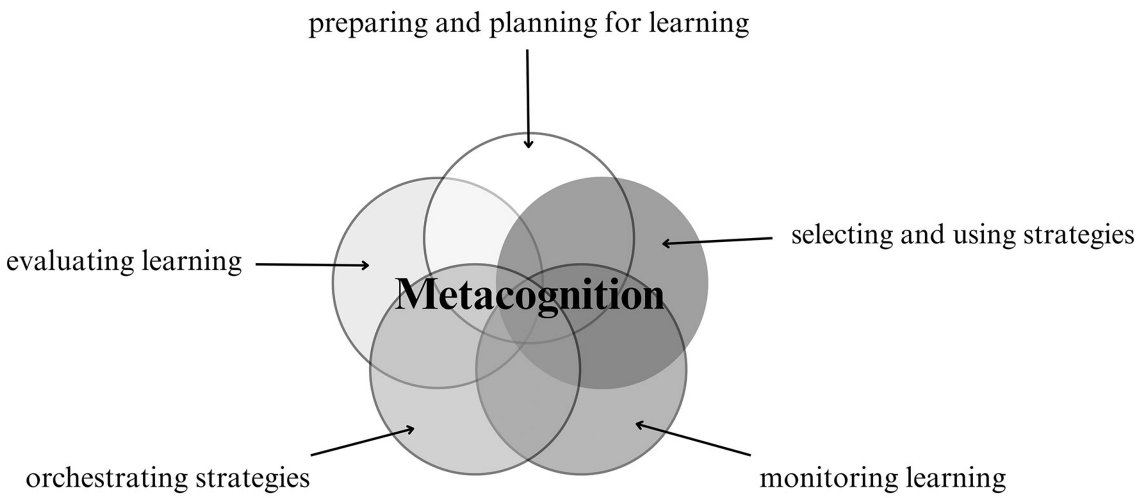

Fig. 1: Metacognition model (Anderson, 2008, p. 100)

a particular goal (in the case of the present study, to solve a word problem) and also points to an individual's skill to make decisions about their own learning process. The orchestration of strategies represents the selection and comparison of strategies, or the combination of strategies. The assessment of learning indicates whether the learner is able to evaluate the process of their own learning (Anderson, 2008). Monitoring learning has been mentioned above in the context of other research in a similar sense.

The link between intellectual giftedness and metacognition has been interpreted in different ways (Portešová, 2020; Straka, 2021). The first is based on the assumption that the gifted have a higher level of metacognitive abilities, and, thus, metacognition is one of the components of giftedness (Snyder et al., 2011; Sternberg, 1998, 2001). Some studies have also shown that children's metacognition develops along with their intellectual abilities (Berk, 2003). According to Alexander et al. (1995), a barrier to uncovering the link between giftedness and metacognition may be that gifted pupils can often solve tasks without using metacognitive strategies because the tasks are too easy for them. The myth that a gifted individual must excel in all areas, including metacognition, is also widespread (Moon, 2009). The second approach is the mixed model of Veenman et al. (2005, 2008), which shows only a partial relationship between intellect and metacognition level. Last, according to some authors, the metacognition and giftedness are mutually independent. For example, a study by Allon et al. (1994) uncovered a weak relationship between intellect and metacognition.

It is noteworthy, though, that the above studies (Allon et al., 1994; Snyder et al., 2011) involve older pupils. Studies with younger pupils are lacking.

2.1.2 Self-concept, Self-efficacy and Mindset in Gifted Children

Gifted children are associated with a number of myths unsubstantiated by research (Laznibatová, 2003), which are based on the concept of giftedness itself, which is often understood by society only in a positive sense and is associated with expectations from the society. However, a gifted child can also be negligent and unwilling to work, which often does not match the perceptions of teachers (Winebrenner, 2001). In this context, Hříbková (1994, p. 248) draws attention to some characteristics that teachers associate with gifted pupils. These include, for example, performance ("straight A pupil, best in class in everything"). These myths or expectations can influence the self-concept and thinking of the gifted.

Self-concept, i.e., "the idea of oneself, how an individual sees himself or herself" (Hartl & Hartlová, 2000, p. 524), in gifted individuals is influenced by the environment (Kong & Zhu, 2005), which may expect a positive self-concept because labelling these pupils as gifted may enhance their self-esteem. Other views assume a negative self-concept due to the high demands of the environment. According to some research, the self-concept of gifted pupils is also influenced by possible inclusion in special groups in which gifted pupils meet other gifted pupils (Miller, 1990). Pupils in such a situation are given a new comparison of their own performance with more able peers. The research findings in this area are not clear-cut. For example, Marsh and Parker (1984) showed that segregated groups of 6th grade pupils showed lower self-esteem but had slightly higher academic achievement and attainment than when gifted pupils were placed in mainstream classes.

Related to self-concept is the concept of self-efficacy, which represents "people's beliefs about their abilities necessary to achieve certain performances" (Bandura, 1994, p. 2). Both self-concept and self-efficacy can be considered crucial for enhancing pupils' intrinsic motivation (Bong & Skaalvik, 2003) and for mathematics performance (e.g., Smetáčková & Vozková, 2016). Higher levels of self-efficacy may be expected for gifted pupils given that they may experience a large number of achievements and awards, as suggested by a meta-analysis of studies (Albabbasi et al., 2023).

Self-concept can also be viewed through mindsets, which are "beliefs that people adopt" that strongly influence their lives. The influential division of mindsets is that of fixed and growth mindsets (Dweck, 2017, p. 14). A growth mindset learner believes that "the essence of success is striving to improve" (Dweck, 2017, p. 26). The learner seeks challenges and views criticism as a space to continue to work on themselves. They are more likely to identify their mistakes and correct them (Boaler; 2016). A learner with a fixed mindset "believes in the inflexibility of their qualities" (Dweck, 2017, p. 26) and prefers to avoid challenges. They take criticism as a sign of failure. They fear their mistakes and failure, and the success of others makes them feel threatened (Dweck, 2017).

Gifted pupils may be at risk precisely because of a fixed mindset. They may often hear from those around them that they are smart, gifted, and talented (Dweck, 2017). It is this 'labelling' that can lead children to believe that they must maintain such status and therefore not fail. Gifted students may not be willing to risk failing at challenging tasks (Siegle & Langley, 2016).

Research on mindset in gifted learners has not produced consistent results. For example, gifted pupils in the 7th grade have not been shown to tend towards fixed mindset (Esparza et al., 2014). Some even believed in the possibility of intelligence growth more than others.

2.2 Word Problem

Word problems "are seen as a link between mathematical concepts and everyday reality, and pupils are reassured of the usefulness of mastering mathematics through them" (Vondrová et al., 2022, p. 5). A word problem is a verbally formulated problem that is placed in a situational context and allows you to use mathematics in everyday situations (Verschaffel et al., 2020; Vondrová et al., 2019).

Solving a word problem is a complex process that can be divided into steps. For example, according to Reusser (1985), the learner must first process the textual input. To do this, they also use the skills acquired during the language learning such as understanding the text, syntactic structures, identifying key words, etc. The next stages, according to Reusser (1985), are the creation of a situation model; the creation of a mathematical model to which the learner applies calculation skills. Finally the answer is constructed and evaluated for correctness in the context of the task and reality.

Word problems are sufficiently complex and challenging for pupils because they make high cognitive demands (Vondrová et al., 2019). Problems can occur in any of the above steps (Reusser, 1985). If the learner does not know or cannot find a direct way to solve the problem, they can use heuristic strategies (e.g., systematic experimentation, trial-verification-correction, etc.) or perform experiments through which a deeper understanding can be achieved (Eisenmann et al., 2017). Moreover, working memory, that is, "our ability to remember and manage information" (Alloway, 2011, p. 1), also plays a role in the word problem solving process (Alloway, 2011).

2.2.1 Word Problem as a Diagnostic Tool for Metacognition

To the best of the author's knowledge, word problems have been previously used as a tool for research focusing on metacognition only for older pupils. Namely, Yulianto (2020) investigated the link between the mathematical ability and metacognition of upper secondary pupils in the context of word problem solving. He concludes that pupils with high mathematical ability showed indicators of metacognitive skills during the planning, monitoring and assessment stages. In contrast, pupils with lower levels of mathematical ability exhibited skills in the planning stage but not quite in the monitoring and evaluation stages. His research did not focus on other aspects of metacognition. Yulianto's results are supported by further research with lower secondary school pupils (Güner & Erbay, 2021) in which pupils with a good level of metacognitive skills were more successful in solving the word problem.

2.3 Research Question

The theoretical background offered different perspectives on the concept of giftedness regarding manifestations of giftedness, personality settings, and cognitive and metacognitive manifestations. Studies that have previously used word problems as a research tool for monitoring metacognition were presented. However, there is a lack of research on younger school-age pupils, as word problems require processing of textual input (Reusser, 1985) and younger pupils may be hindered by their lack of reading skills. Nevertheless, given the early onset of reading skills in gifted pupils (Laznibatová, 2003; Terman & Oden, 1959; Van Tassel-Baska, 1983), the study posits that it is possible to gain insight into the metacognitive processes involved in word problem solving in early school-age pupils (6–7 years).

The study aims to describe the thought processes of gifted learners and focuses on the areas of cognition, metacognition, personality expressions and advanced mathematical apparatus (given the age of the study participants and the content of the regular 1st grade textbooks). Based on this aim, the research question was formulated: *What signs of giftedness in terms of cognition, metacognition and personality manifestations can be observed in gifted pupils in the 1st grade of primary school through word problem solving and what advanced mathematical apparatus emerges in this process?*

3 Methodology

3.1 Context and Research Participants

The pupils were selected at an elementary school that runs a programme for gifted pupils. There are special groups in each grade for the lessons on mathematics and the Czech language and beginning in grade 3, also on science. In these subjects, pupils are educated separately while in the other subjects, they are integrated in their regular class. This means a partial form of segregation. In the gifted education programme at this particular school, both acceleration approaches (progressing more quickly through the curriculum) and extension approaches (pupils are offered additional topics outside the curriculum based on their interest, and topics are covered in greater depth and context) are used. The Feuerstein method of instrumental enrichment is also part of the school's curriculum, which, according to some authors, is one of the means for the development of metacognition (Krykorková & Chvál, 2001; Lokajíčková, 2014).

The participants were pupils aged 6–7 who were attending the first grade of primary school at the time of the study. All of them had been previously diagnosed as exceptionally gifted by the pedagogical-psychological counselling centre,[1] on the basis of which they were included in the programme for the education of gifted pupils in the subjects of mathematics and Czech language. At the time of the study, the author was also a teacher of these pupils in these two subjects.

Based on participant observation in the classroom (Hendl, 2023), six pupils out of this class were selected with the assumption that they would be motivated and show significant signs of giftedness. They were first divided into two homogeneous groups, i.e., groups of pupils with similar pace and attitude, as described in more detail below. The groups are designated as G1 and G2.

Group G1 is made up of pupils who typically progress more slowly in solving problems, require more time to think and produce more detailed written records, while also respecting the need of others to work at their own pace. Pupils in this group appear calmer and quieter in mathematics lessons. There were two boys and one girl in the group (Christopher, Sebastian and Jana). Acronyms are used for the pupils.

Group G2 includes pupils who focus on speed in their performance and are more likely to work without writing down their procedures, which may indicate a more intuitive and impulsive style of working. These pupils perform numerical operations quickly and prefer a more competitive approach. They sometimes find it more difficult to respect the slower pace of their classmates. There were also two boys and one girl in the group (Honza, Martin, Laura).

Before the main study was carried out, the pupils' experience with the topic of word problems was mapped. The author, the teacher of the pupils participating in the research, had a good overview of the word problems that the pupils had encountered in the school environment by then. In particular, they were problems with short text that corresponded to a typical 1st grade text (one sentence in length). They were often accompanied by a picture that provided additional explanation of the situation. As part of the enrichment curriculum, several problems with longer assignments (up to 4 sentences) were offered to the pupils during the lessons to check that reading skills would not be a barrier to involving them in the study. The assumption that the selected sample of pupils had sufficient reading skills was confirmed.

The participation of the pupils in the study was based on the informed consent of their legal representatives, who were informed about the aim of the research and also about its outline.

3.2 Research Design

The research tool consisted of word problems that were to be presented to the pupils for solution within task-based interviews (Maher & Sigley, 2014). Before using them with the research sample, their comprehensibility was checked with a group of 3rd grade pupils. Based on this experience, only minor language modifications were made. A substantial part of the problems was also taken from other research (Favier & Dorier, 2024; Havlíčková et al., 2023; Vondrová et al., 2019), where validation with a larger group of pupils took place. The problems represent the stimuli to which the pupils respond, and their responses and representations provide insight into their knowledge, cognitive structures and ways of thinking (Maher & Sigley, 2014).

Due to the age of the pupils, the main research method was group discussion (Hendl, 2023), which has the advantage of helping participants to overcome inhibitions, however, may lead to an uneven participation of the participants. Discussions were organised during afternoon meetings with the pupils.

A meeting scenario and time allocation (e.g., how much time would be given to pupils to work independently?) was prepared. During the meetings, the author was to be in the role of moderator. Pupils were to be provided with a word problem and given time to solve it individually and a group discussion should follow. Pupils were to be invited to respond to their classmates, e.g., What do you think of this solution? What do you like about this solution? These questions were used especially in the reflective part of the meetings. The aim was to support discussion among the group members as well. The meeting scenarios were written down in advance to avoid improvisation.[2]

The research methodology also includes focus groups (Prior, 2018) in which semi-structured interviews are conducted with several pupils at a time. They included questions to be asked in case the discussion would not occur spontaneously such as: Which task was more challenging for you? Why did you choose this particular task?

[1] A pedagogical and psychological counselling centre is a counselling facility that provides professional psychological and special education services to children and their parents (or teachers). It diagnoses school maturity, specific learning disorders, etc. and, in the Czech education system, also giftedness.

[2] There were also some inconsistencies in the organisation and deviations from the original plan. In the afternoon, in some cases, pupils showed signs of fatigue and it was necessary to start working as a group to boost their motivation.

3.3 The Selection of Problems and the Content of the Meetings

A common feature of all the problems offered was that they had to meet the conditions to be classified as word problems, that is formulated in words and with the presence of (real-life) context (Vondrová et al., 2019). The aim was to ensure that each problem contained some phenomenon that was new to the pupils and that reactions to unfamiliar situations could be observed in such cases. Based on research results, the following variables found to make word problems more difficult for elementary pupils were selected (e.g., Hembree, 1992; Vondrová et al., 2019, 2020, 2022): word problems with irrelevant information, inconsistent language problems,[3] and word problems set in an unfamiliar context. Such problems were complemented by other problems presumed to be more difficult for pupils and not allowing for surface strategies (such as a key word strategy), although this was not expected as the 1st grade pupils do not yet have a repertoire of learned algorithms.

Table 1 includes the English translation of the problems finally selected. Some sessions also focused on creating own word problems, but this is not part of the present study.

Irrelevant information	1.	There were 5 hens, 3 cows and 5 pigs on the farm. Together they eat 20 kg of feed a day. How many legs did they have together?*
	2.	Farmer Vodicka had 8 cows, 10 chickens and 4 horses. His neighbour had 5 fewer animals. How many animals did Farmer Vodička have in total?*
	3.	On the farm, there were 5 pigs, 4 cows, 5 chickens and 4 geese. How many wings do they have altogether?*
Inconsistent language	4.	Five people got on the tram, so now there are 21. How many people were on the tram before? (Hejný & Kuřina, 2001, p. 27)
	5.	The trams parked at the depot in the morning have a total of 10 trams. This is 4 more trams than there are in the depot in the afternoon. How many trams are in the depot in the afternoon?*
All combinations sought	6.	Jirka went to buy ice cream. There were 4 flavours to choose from: vanilla, chocolate, strawberry and pistachio. But Jirka could only buy two scoops. What different combinations of flavours can he have?*
Unfamiliar context	7.	Caspian had six coins in his pocket. They were coins worth two zeds and five zeds. He promised that if we could guess how many two-zeds and how many five-zeds he had, he would take us to Narnia for a while. He revealed that he had 18 zeds in all. How many two-zeds did Caspian have and how many five-zeds? (Vondrová et al., 2019, p. 391, originally for the grade 3)
	8.	The Star Empire's mothership has been attacked by an army of hostile fighter fauns. The Star Empire has deployed all defensive forces. The corvettes hit a total of 9 fauns, the frigate managed to take out 4 more. The battlecruiser destroyed as many fauns as the corvettes and frigate combined. How many fauns were destroyed in total? (Vondrová et al., 2019, p. 379, originally for grades 5 and 6, abridged)
Missing numbers	9.	Hansel and Gretel ate __heaps of gingerbread. Hansel ate __, Gretel ate __more than Hansel. (numbers: 1, 2, 3, 4, 5) (Havlíčková et al., 2023, p. 7, originally for grades 2 and 3)
	10.	Jonáš put __pieces of pastry for __crowns and one lemonade for __crowns in his basket. He paid __crowns at the checkout. (numbers: 22, 10, 4, 3) (Havlíčková et al., 2023, p. 21, originally for grades 2 and 3)[4]
Multiple solutions	11.	There were geese and pigs running around in the yard. They had 24 legs in total. How many pigs and how many geese were there?*
Focusing on strategy selection	12.	Each card in my deck represents either a triangle or a square. I pick 15 cards at random. I count all the sides of the figures drawn on the cards I picked and find 49. How many triangles and squares do you think I picked? (Favier & Dorier, 2024, p. 411, originally for the grade 2)

Table 1: Word problems used (problems marked with * are original)

Table 2 summarises the attendance of pupils at each meeting. Some pupils did not have the opportunity to build on previous experiences for some problems as they were not present at the meeting. The first letter of the pupils' pseudonym was used to identify them in Table 2.

Meetings were held regularly once a week with each group separately in the afternoon after school. Each group participated in at least 11 meetings of 45–60 minutes each (time had to be adjusted according to the difficulty of the word problem). Pupils were welcomed and the author attempted to create a relaxed atmosphere to encourage communication between pupils. The word problem was then presented to the

[3] Problems with cues in the role of distractors referring to an operation inverse to the one required for the solution (Vondrová, 2020).

[4] This type of word problems is inspired by the methodology of Kaur & Yeap (2009) and Singapore Mathematics.

Task number	Pupils present at the meeting					
		G1			G2	
1, 2, 3	J	S	Ch	L	H	M
4, 5	J	S	Ch	L	H	M
6	J	S	Ch	L	H	M
7, 8	J	S	Ch	L	H	M
9, 10	J	S	Ch	L	H	M
11	J	S	Ch	L	H	M
12	J	S	Ch	L	H	M

Table 2: Attendance of pupils at each meeting

pupils and read once together. The pupils were given time for independent reflection (according to the meeting plan, about 15 minutes). This section had to be adapted to the pupils' pace and also to the difficulty of the word problem. After the independent work, a group discussion took place where pupils talked about their progress, commented on the pitfalls they had encountered and interacted with each other.

3.4 Data and its Analysis

All the meetings were recorded on the videocamera. The recordings were transcribed into protocols and the protocols were supplemented with information related to non-verbal communication (such as facial expressions, etc.). In addition, written pupils' solutions were collected and field notes were taken during and after the meetings.

The meeting protocols were then subjected to coding and the individual codes were supplemented with pupil solutions if a written record was also made.

An inductive-deductive approach was used for coding. Based on the literature and an a priori analysis of the problems used (expected strategies, difficulties, mistakes, etc.), a preliminary code system was developed and supplemented with new codes in the open coding phase (Strauss & Corbin, 1999). Two people independently performed coding on a portion of the protocols (from two sessions). Thus, the first draft was subsequently added based on the discussion, resulting in a final list of codes, which were then grouped according to their meaning into categories.

The first category (*Personality*) brings together codes related to the personality of the pupils in Table 3. Specifically, it includes talk indicating self-efficacy, motivation, mindset, expressions of giftedness, and responses to a mistake.

Code	Description	Example
Self-efficacy	The pupil expresses their beliefs about their own abilities.	*It was terribly difficult. When I'm not good at something, I don't even enjoy it anymore.*
Mindset	The pupil's speech can be regarded as a manifestation of mindset.	*Because I have to think about it and that's what I enjoy.*
Mistake	The pupil reacts to their own or a classmate's mistake, or realises why the mistake happened.	The pupil made a mistake in the calculation and describes that she did not read part of the assignment and that is how the mistake occurred: *Yeah, I didn't read the part that the cruiser destroyed like a corvette and a frigate combined.*
Subcodes: Reaction to own mistake, Reaction to classmate's mistake, Search for the cause		

Table 3: Personality categories

The identified code categories are not completely disjunctive. For example, the response to a mistake appeared as a cross-sectional phenomenon. In some situations, the learner reacted to their mistake and related the comment to themselves (*Personality*). In other situations, they reflected on their mistake and directed their further action based on it. In this case, the situation would also fall into the category of metacognition.

Another category is represented by codes associated with cognitive functions (*Cognition*). A description of the codes and examples of statements are given in Table 4.

The last category (*Metacognition*) brings together codes related to metacognition (Table 5). These include situations where pupils talked about what would help them to find a solution, how they would be comfortable working, what they needed to do to solve the problem, searching for complicating phenomena in the assignment, and naming what made the problem difficult.

Code	Description	Example
Abstract reasoning	The pupil suggests independence from the concrete situation (context of the word problem).	The pupil reasons that the number of unknown words in the problem is not a problem for her: *Hey, it doesn't matter if you have Honza or Katka in there. Or if you've got a frigate in there, or if some pet killed something. Like a hedgehog killed so and so.*
Memory	Situations where working and long-term memory was demonstrated in solving/creating/reflecting on word problems.	Long-term: Situation where the pupil remembers from a meeting two weeks ago the data from the problem. Short-term: E.g., when the solution is only in the learner's mind and they do not feel the need to write it down.

Table 4: Cognition category

Code	Description	Example
Knowledge – conditions for learning	The pupil is aware of the conditions under which they work better (e.g. environment, organisation of work, time).	*Couldn't we just read it, Kate, and then go at our own pace?*
Metacognitive monitoring – pointing to complicating variables in the problem	Metacognitive monitoring – naming difficult phenomena in a problem. The pupil is aware of what influences the difficulty of the problem.	A pupil realises that one of the tasks is more difficult: *The first one because there were the pigs and the cows and they have 4 legs, so there were too many legs. I wouldn't want to count, for example, ants when they have 6 legs.*
Planning	The pupil plans the steps to solve the problem.	*I will draw the coins.*

Table 5: Metacognition category

The last phenomenon coded was the use of advanced mathematical apparatus (Table 6). Situations were coded where the student used a mathematical operation that was beyond the grade level, as determined, for example, by the content of the textbook (in this case, beyond grade 1).

Code	Description	Example
Multiplication/ division	Pupils use multiplication and division operations in calculations.	A pupil writes or comments on this operation, for example, the 3×5 is described as: 5 plus 5 is 10 and plus 5 is 15, so 15.
Decimals	The pupil works with decimals to solve a problem.	The pupil adds a decimal number to the problem with missing numbers: *For example, I would try 3.2 more gingerbread.*

Table 6: Use of advanced mathematical apparatus

4 Results

This study focuses on the manifestations of gifted pupils in solving word problems. Consistent with the study assumptions, characteristics falling into three categories (personality, cognition, and metacognition) were observed. Each is discussed separately.

4.1 Personality Manifestations

Mindset can be observed through pupils' comments and behaviours that are related to their commitment to more challenging problems. Such manifestations can often be considered in terms of metacognition. For example, comments that may indicate a growth mindset emerged for Sebastian, who in several situations preferred a more challenging problem or appreciated when the difficulty increased: "I want the hard one because it will be more fun." In situations where Sebastian was making mistakes, he was able to encourage himself to look for other solutions and possibly also modify his strategy: "This is wrong… I'll try from the end, maybe it will go better." This statement may indicate Sebastian's belief that he will be able to solve the problem on his next attempt. At the same time, such a comment can be evaluated as a metacognitive one, where Sebastian has evaluated his previous progress and comes up with a new strategy. It indicates the monitoring of learning and also his ability to select and use appropriate strategies. A similar situation, where the learner preferred a more challenging problem, occurred in the reflective part of one of the sessions, when Christopher also joined the evaluation. However, we can infer from his comment that he also welcomed a problem that challenged him:

> Sebastian: For me, when I'm not good at something, I enjoy it because then I figure it out, and I enjoy that.
>
> Christopher: I enjoy it too.
>
> Sebastian: Me too. Because I have to think about it, and I enjoy that.

Sebastian's statements again indicate a desire for challenges and a determination to tackle even the toughest problems.

Jana's reaction to similar situations was the opposite: "It was terribly difficult. For me, if I can't do something, then I don't even enjoy it anymore." When asked if they would like to solve one more problem, she answered: "Yes, but it must not be that hard." These statements may indicate a fixed mindset. At the same time, however, it may be a metacognitive manifestation of evaluating one's own learning, where Jana can judge that the problem is too difficult for her even thought she was able to solve it later with additional help and was motivated to continue solving the problem. It is possible that the difficulties occurred already at the stage of processing the textual input. This situation arose when solving Problem 7, where Jana expressed a lack of understanding of the concepts in the problem.

A trend that occurred repeatedly, but only in the group of Laura, Honza and Martin (G2), was the trivialisation of the problems in the reflective part of the meeting, even though pupils made mistakes in solving them. This situation occurred in the first meeting when the author asked the pupils how they worked with the problem. This was preceded by a solution where both Martin and Honza made mistakes but rated the problem as easy:

> Martin: It was terribly easy.
>
> Honza: Yeah, it was easy.

This situation was repeated in another meeting when Martin misunderstood the assignment and came to a different result. Martin also shows himself as a leadership type in regular classes, and here too it was possible to observe a certain influence on his classmates. The moment Martin made it clear that he found the problem easy, the other pupils felt the need to express a similar opinion:

> Martin: Yeah, it would be terribly easy for me, but I just didn't get it.
>
> Honza: Yeah, it's easy.
>
> Laura: That's easy.

From the point of view of mindset, we can consider a tendency towards a fixed mindset, where the pupil does not feel comfortable in situations in which they have to admit mistakes and do not even want to admit that they failed in solving the problem and at the same time admit it in front of their peers. It could also be a manifestation of perfectionism in relation to one's own performance, which is a possible manifestation of giftedness. It could also be an inability to adequately evaluate one's own learning process. We can observe the manifestations of self-underestimation and resignation, for example, in Honza, who answered my question why we cannot find another solution: "Because we don't have such a good brain."

A shift in the manifestations of mindset could be considered for Martin, for whom there were indications of growth mindset in the meetings towards the end of the study: "I want to figure it out myself; I would have found more, but I didn't want to copy it from Laura." Martin's shift can be further described in terms of a change in his mood. In the first two meetings he appeared to be out of tune, and when he made mistakes in the solution, he tried to hide it. In contrast, in the meetings in which Problems 11 and 12 were solved, he appeared confident and motivated. He was willing to find further solutions even though I disclosed to the pupils that there was no further solution to be found, suggesting his preoccupation. He also performed several experiments that he himself identified as incorrect and was willing to correct them. These phenomena might indicate a certain shift in terms of Martin's mindset. However, it is equally possible to consider the fact that the situation became familiar to the pupils over time and some nervousness may have subsided at the same time.

4.2 Cognition

In terms of cognitive functions, memory played a significant role. This could be observed from the course of the work itself in situations where a large capacity for short-term memory or long-term memory was evident.

Short-term memory was evident during the actual solving of the problem. Pupils were often able to solve the problem after the first reading. There were also situations where the pupil stated the result after the first reading without writing anything down. Long-term memory could be observed, for example, in Jana. In a combinatorial problem, which was supposed to represent a new situation for the pupils, she recalled the similarity with the problem from a regular mathematics lesson. Her description is appropriate given that it was also a problem where the pupils were looking for all possible combinations: "It seems to me that it's still similar to those penguin problems. How we were supposed to pair them up." Jana also referred to the strategy that was used in that situation. We assigned numbers to the different objects in the problem to facilitate writing down the solutions found and then wrote the different options in short form as two digits.

Good long-term memory was also evident in Sebastian, who referred to the assignment from the previous meeting and after a week still remembered all the information it contained (including the numerical information).

During the solving process, pupils also demonstrated the ability to think about data in the abstract, independent of context. For example, Laura, who was asked to explain the unknown concepts in Problem 8, replied, "We don't need to know that…" After a clarifying question, she added: "Guess why… because we only need to know how many they shot down." Similarly, Jana made it clear that she did not understand the problem statement (linguistically, because of the number of unknown words), but still said she could solve it.

The ability to think in the abstract can be further illustrated by the interview with Christopher and Sebastian, who found a connection between two problems (Problems 11 and 12). The problem with animals (Problem 11) had several possible solutions and the pupils' task was to find all of them. For the card problem (Problem 12), only one could be found. In the reflective part, Christopher and Sebastian were asked about the common elements of both problems:

> T (teacher): Which instruction would I have to remove from the problem in order to generate an awful lot of solutions?
>
> Sebastian: This number here (points to the number 15, which indicates the number of cards).
>
> T: And what does that say?
>
> Sebastian: How many cards I have to have in total. […]
>
> T: Do you notice if this and the backyard animal problem have anything in common?
>
> Sebastian: It's related… Because the pig is a square and the goose is a triangle.
>
> T: And is a goose a triangle?
>
> Christopher: No, because it has two.
>
> T: What is the similarity then? […]
>
> Christopher: Well two geese is one pig and here three squares is four triangles.
>
> T: What would I have to add to the backyard animal problem to make it only one solution too?
>
> Christopher: That there can only be a certain number of geese.
>
> Sebastian: A limited number of some animal.

Both Christopher and Sebastian name the similarities between the two problems they solved in successive meetings. They also point out which element in the assignment influenced whether there was only one solution or more than one. Again, long-term memory can be observed, as both Christopher and Sebastian were able to compare two problems that were solved within two weeks of each other.

4.3 Metacognition

The first theme in the area of metacognition is the beginnings of the manifestations of metacognitive knowledge, which represent pupils' awareness of the conditions in which they work well. This knowledge was manifested by Jana, who repeatedly commented on why she failed to solve the problem: "I'm very distracted today", "It was hard for me to concentrate", "I always had an idea and then I forgot what

I actually wanted to write there”. The demonstration of metacognitive knowledge was also evident in Honza, who indicated during the meeting that he would work better independently, “Can we just read it, Kate, and then we can go at our own pace?”

Another manifestation observed was metacognitive monitoring, specifically pupils’ ability to point out what makes problems difficult. In some cases, pupils identified the problem as difficult because a more difficult numerical operation had to be used. That was the case with Christopher: “This one, because there’s multiplication.” Laura identified the longer assignment and the number of steps leading up to the problem as problematic: “Because I didn’t read that up to *twice more*.” Laura started solving this problem (Problem 8) and skipped the last part of the assignment. For the task where more words were deliberately used that were unknown to the pupils, both Jana and Christopher revealed this difficulty: “Well we didn’t know what some of those things were.” “Some of the names were horrible and just weird.” Furthermore, for example, Honza mentioned a redundant piece of information in the problem: “Those 20 kilos! Because it wasn’t somehow in the problem that we were supposed to count it at all, so I don’t really understand why they would write it in there.” For this problem, Jana further commented on the increasing difficulty that came with the presence of animals with more legs: “The first one, because there were these pigs and cows and they have four legs, so there were too many legs. I wouldn’t want to count ants, for example, when they have six legs...” Furthermore, in the combinatorial word problem (Problem 6), where pupils found different combinations of four ice cream flavours, it was necessary to clarify in advance what options could be considered as different solutions. This was commented first by Martin and then also by Honza: “For me the second one was difficult. Because first we had to understand if I could, for example, have pistachio and pistachio.” “Also the order.” By order, Honza meant the placement of the scoops, and whether we would consider as different solutions the ones where the order of the flavours was just swapped.

The last phenomenon identified was the ability to plan the steps leading to the solution of the problem. Jana had such a plan when solving word problem with the unfamiliar context (Problem 7): “I will draw coins.” Then there was Christopher, who spontaneously highlighted some of the information in the problem. In the planning phase, Sebastian ticked what extra information in the problem was and came up with the strategy of trying the solution backwards.

4.4 Using Advanced Mathematical Apparatus

In the course of solving word problems, pupils used mathematical concepts beyond the curriculum for grade 1.

A spontaneous use of decimals occurred with Laura, Honza, Martin and Sebastian. In contrast, Jana expressed that she did not know how to work with such numbers: “I don’t know these numbers...” Martin added decimal numbers to Problem 9 (Fig. 2) in the order 0.9; 0.1 and 0.7 (in Figs. 2 and 3, the assignment of Problem 9 is in Czech). He did not fulfil the original assignment as the task was to use the offered numbers, otherwise it can be considered correct. At the same time, it can be observed that he wrote the decimal point as a period (in Czech, it is a comma), which he may have observed, for example, from a calculator or from foreign languages using this notation.

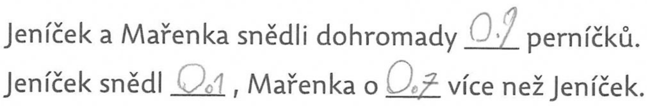

Fig. 2: Martin’s solution to Problem 9

Martin also came up with a solution where he used higher numbers than the numbers in the assignment (Fig. 3); this may be an attempt to make the problem harder. He added numbers in the order 58, 27 and 4 but did not comment on it further.

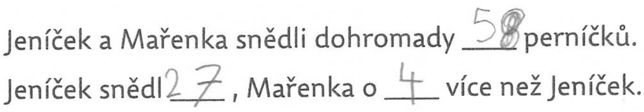

Fig. 3: Martin’s solution to Problem 9

A similar solution was also found for Laura (Fig. 4). In the subsequent discussion, however, she realised her failure to meet the assignment and commented, “I didn’t meet the assignment because the 0 is not there.” By this comment, Laura meant that there was no 0 among the missing numbers and therefore she could not write down 0.5 gingerbread.

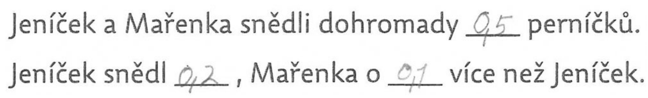
Jeníček a Mařenka snědli dohromady 0,5 perníčků.
Jeníček snědl 0,2 , Mařenka o 0,1 více než Jeníček.

Fig. 4: Laura's solution to Problem 9

Thinking about decimals could also be observed during the meeting, where Sebastian did not solve the offered problem, but spontaneously set a new mathematical problem related to the coloured copy lying on the desk in front of him. Sebastian began to consider how many colour copies I have per day as a teacher if I have 50 per month: "Wait, but what month? Some have 30, some have 31, and some have 28." So I chose January, which has 31 days. His calculation can illustrate his thinking about a problem that canot be solved in whole numbers: "31 times 2 is 62, so that's not right either, so it's going to be a whole something… That'll be one whole something." It is clear that Sebastian does not yet have the mathematical knowledge to solve this problem, but he can already guess what interval the result will lie in.

It was quite common for pupils to use multiplication. Some pupils performed only mental calculations. In such cases, a further question led to a check that they really understood the operation and they were asked to explain further. The pupils were able to justify their procedure by repeated addition. For example, Christopher explaining how he calculated the 3 times 5 example, "Five plus five is ten and plus five is fifteen, so fifteen." There was also a problem where Honza spontaneously used a multiplication table. "Look… ten plus ten plus ten plus ten is forty and then I add the threes… three plus three is six and six is twelve."

During the meeting, we also came across comments related to number parity. The pupils were given Problem 12 and immediately after finishing it, Sebastian came up with an idea: "We have to have an odd number of triangles in there because it's an odd number." He then answered the question of whether I can also get an even number out of the triangles. From his answer we can see that he is familiar with number parity: "Yeah, like twelve if there are four."

The pupils also showed a strategy to find all the solutions systematically. For example, Christopher commented that he had made "such an order". This strategy can be illustrated by Christopher's calculation when solving Problem 11. He also made a solution with six pigs, which he rejected: "No, that's not possible… I think I have all of them, 6 times 4 is 24 and that's not possible." This strategy appeared repeatedly among pupils and represented the most common argument for there being no more solutions.

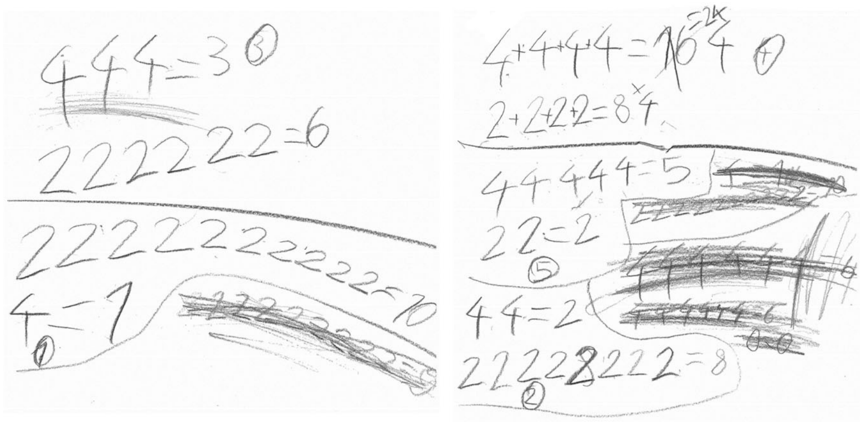

Fig. 5: Christopher's process of finding all the solutions

5 Discussion

The study presented in the paper focused on the use of word problems as a tool to analyse the mathematical reasoning of gifted pupils in primary school, to uncover phenomena related to their cognitive and metacognitive processes.

The first part of the results focused on *personality* manifestations. Some studies have expressed concern that a fixed mindset can stand in the way of gifted pupils' application of giftedness (Dweck, 2017; Siegle & Langley, 2016). In our research sample, there were indications of both mindsets (fixed and growth). The fact that only a small number of manifestations of mindset were observed in some pupils may have been due to the fact that this aspect was only observed in one specific situation and thus could not be described in detail.

In the results, we described a possible shift in the mindset of one of the boys, which may be tentatively attributed to the techniques suggested to be used for promoting the growth mindset (Dweck, 2017, p. 264). The pupils were encouraged and reassured by the author throughout the meetings that it was okay to make mistakes and the effort was important. This may have contributed to their gradual relaxation and effort to solve the problem independently, without worrying about whether they would solve it without mistakes and in the fastest way. However, this development may also be a reflection of initial uncertainty.

In the study, a *metacognitive perspective* was shown to be tightly connected with the manifestations of mindset. In some situations, the pupils trivialised the problems and were reluctant to admit that the problem was not solved on the first attempt. Such a situation could also have been assessed as a deficiency in the ability to evaluate one's own learning process (Anderson, 2008).

In terms of *cognition*, the pupils demonstrated good memory, which they used in problem solving, and the ability to reason abstractly (Portešová, 2021), which is consistent with the assumption that gifted children may move through cognitive development more quickly (Carter, 1985; Roeper, 1978). This was demonstrated in the study by the irrelevance of context for pupils' solving the problem and awareness of the connection between two problems, which some connected on the level of objects. These objects became only symbols representing numbers in the problem for them. Such pupils showed the ability to transfer what they had learned to a new mathematical situation (Haury, 1999). In such cases, the pupils benefited from a good capacity of their memory linked with their metacognitive ability to apply an appropriate strategy (Anderson, 2008).

According to a number of authors (Hrbáčková, 2009; Larkin, 2000; Perry & Drummond, 2002; Říčan, 2017), pupils can have a certain level of metacognition already at the elementary level. The gifted pupils in the present study showed signs of early stages of metacognitive knowledge when, for example, they expressed their views on how they would do well in their work. This may have been influenced by questions focusing on metacognitive knowledge about their learning during the meetings but also by the Feuerstein Method of Instrumental Enrichment (Krykorková & Chvál, 2001; Lokajíčková, 2014), which is part of their school experience.

According to Schofield (2012, p. 58), when "teachers focus on modeling and teaching metacognition, it has a positive impact on student success". Some research suggests that intellectually gifted individuals may possess the prerequisites for developed metacognition (Yulianto, 2020; Güner & Erbay, 2021). The participants in this study, as presented in the results, were able to search for similarities between the solved problems, to recognise challenging elements of the problems in the monitoring and planning phases. Transfer ability was also partially present, with pupils applying knowledge from previously solved problems to new situations, which also indicated their good memory. Thus, the inclusion of problems with a similar inner structure (isomorphic problems) could be considered as appropriate to determine whether the pupils show signs of giftedness. However, the study was not aimed at verifying whether such manifestations of metacognition are advanced compared to their peers.

In the study, situations were described where pupils demonstrated advanced *mathematical skills* by using operations such as multiplication and division, or working with decimals, quite spontaneously. The fact that they were able to apply these operations and also to explain their procedure shows their cognitive advancement. It may also reflect their interest in mathematics, as decimals had not been discussed in the class before. According to Sheffield (1994), gifted pupils need ample opportunities to solve more complex problems. In a regular first grade classroom, pupils might not get the opportunity to solve such problems and demonstrate these skills.

The study confirmed that word problems were a suitable diagnostic tool for younger school-age pupils, here in the first grade, provided that their reading skills are at a sufficient level. They represent a sufficiently complex problem with high cognitive demands for metacognition diagnosis (Vondrová et al., 2019). In solving them, it was possible to observe the whole required spectrum of metacognitive components (Anderson, 2008).

The pupils did not have enough experience with word problems, given their age, and often applied original strategies. In the initial phase of solving the problems, it was possible to observe how pupils worked with the text. The early onset of reading (Laznibatová, 2003; Terman & Oden, 1959; Van Tassel-Baska, 1983) and the ability to work with complex words (Urban, 1990) were confirmed for the study sample. The pupils planned and modified their strategies in the process. Compared to a mere mathematical operation, the process of solving a word problem has several stages that provide prompts for discussion. Equally, it provides an opportunity for pupils to seek out what stage of the process they erred in, if any. Word problems also provide a good basis for looking for similarities between the problems as they could be on the level of context, situational model, mathematical model, and others.

6 Study Limitations

The main limitation was the age of the study participants. As they were younger school-age pupils, fatigue and lack of concentration were sometimes evident in the afternoon. It was necessary to adjust the organisation of the meetings, which caused inconsistency in the results, for example, when in one group, the task was solved independently and in the other group, it was necessary to go immediately into group discussion without time for individual work. Therefore, it was not always possible to compare the results as the author deviated from the scenario. The course of the study was not disrupted, though, as comparison was not the aim.

Another organisational problem was the absence of some pupils. Thus, it was not possible, for example, to apply knowledge from meetings they were not present at. Moreover, it was not possible to describe all of the pupils' input knowledge as they often do mathematics in their home environment and leisure time.

In some cases, the pupils solved the problems immediately after reading without any notation and only expressed the result. It was difficult to determine and describe how they had thought about the task from their utterances and, therefore, it was not possible to observe some phenomena.

The number of pupils is also a limit. The observation was aimed at getting deep insight into their thinking. However, the results cannot be generalised to the gifted population.

The author was also a teacher in the group of pupils from which the sample was drawn. Although she sought to be as objective as possible in her treatment of the results, she may have been influenced by her experience of regular teaching. At the same time, however, she was able to gather more experience with the pupils from which she benefited in the preparation and implementation of the study. Different sociometric tools could have provided more objectivity in the selection of groups.

The selection of problems poses another challenge. The author chose a repertoire of different problems with different complicating phenomena in their assignment. Another option would be to focus on one particular type of word problems, which would have brought more consistency. Pupils would also have the opportunity to build on multiple prior experiences and demonstrate the ability to make connections between solved problems. This remains open for future research.

7 Conclusions

The study was guided by the following research question: *What signs of giftedness in terms of cognition, metacognition and personality manifestations can be observed in gifted pupils in the 1st grade of primary school through word problem solving and what advanced mathematical apparatus emerge in this process?* The study conclusions must be seen in the light of a small study sample and the context of word problem solving.

The results suggest that memory may be a strength of gifted individuals in the process of solving word problems. The assumption of an early onset of literacy was also confirmed as the pupils in the sample were able to work with word problem text including complex words and longer assignments.

The pupils showed an interest in topics not covered in the year group and not previously taught in school, particularly multiplication and division, when solving problems and were able to explain their procedures. Some also showed knowledge of decimals, which may indicate their interest in mathematics outside the school environment.

In terms of metacognition, some situations showed that pupils were able to name similarities between problems they solved and made transfer from these experiences helping them to solve the current problem. They were also able to point out complicating phenomena in the problems. There were several comments that could be considered as a manifestation of metacognitive knowledge, where pupils described what influences their learning or what conditions they prefer.

In terms of mindset, the results outlined situations that could tentatively be interpreted as a certain inclination towards a fixed or growth mindset. Some of the participants showed signs of fear of failure, fear of challenges, etc. Others showed enthusiasm for more challenging problems and were not afraid to take risks in the process of solving them. Some development could be observed in one of the pupils. In some situations, a possible link with metacognition was described. However, future research is needed with more situations in which mindsets can manifest themselves.

The results of the research showed some characteristics of gifted pupils in the process of solving word problems. A possible continuation of the research could be the implementation of a similar programme with pupils of regular first grades in order to compare in which cases the specifics of giftedness were involved.

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