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DEVELOPING NUMERACY SKILLS OF A STUDENT WITH DOWN SYNDROME USING MATERIAL AND DIGITAL RESOURCES

Master's Thesis

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Abstract

Developing numeracy skills of a student with Down syndrome using material and digital resources

This action research aimed to develop the numeracy skills of a student with Down syndrome using material and digital resources and compare their effect on educational outcomes and motivation. The student's numeracy skills were assessed before and after teaching; motivational behaviours were evaluated during the teaching period. The student could calculate and solve word problems on numbers up to ten equally well with either resource but had difficulties learning number bonds and, therefore, needed additional visualisation. Digital resources caused more positive and less off-task behaviours; negative behaviours occurred similarly with either resource. The likely causes of mistakes on the tasks and differences in motivational behaviour are discussed, and suggestions for further teaching are given.

Keywords: numeracy skills, Down syndrome, material and digital resources, motivation.

Kokkuvõte

Downi sündroomiga õpilase arvuliste oskuste arendamine materiaalsete ja digitaalsete vahenditega

Selle tegevusuuringu eesmärgiks oli ühe Downi sündroomiga õpilase arvuliste oskuste arendamine kasutades materiaalseid ja digitaalseid õppevahendeid. Võrreldi õppevahendite mõju matemaatiliste oskuste arengule ja motivatsioonile. Arvulisi oskuseid hinnati enne ja pärast õpetamist, motivatsioonikäitumisi hinnati õpetamise ajal. Arvulised oskused, kümne piires arvutamine ja tekstülesannete lahendamine, arenesid võrdväärselt mõlema vahendiga. Suurimaks raskuseks oli arvu liitehituse mõistmine ja kasutamine, mistõttu vajas õpilane pidevat visualiseerimist. Motivatsioonikäitumistest esines positiivseid käitumisi rohkem ja kõrvalisi tegevusi vähem digitaalsete vahenditega, negatiivseid käitumisi esines võrdväärselt mõlema vahendi kasutamisel. Töös on lisaks arutatud ülesannete lahendamisel esinenud vigade ja motivatsioonikäitumiste erisuste võimalike põhjuste üle ning antud soovitusi edasisteks õpitegevusteks.

Võtmesõnad: arvulised oskused, Downi sündroom, materiaalsed ja digitaalsed õppevahendid, motivatsioon.

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Introduction

Down syndrome (hereinafter referred to as DS) is a chromosomal disability that causes a variety of intellectual and physical disabilities, distinct physical features and a number of health problems (Antonarakis *et al.*, 2020). The prevalence of DS in Europe is estimated to be 5.7 in 10 000 people (de Graaf *et al*., 2022).

Previous research (Charitaki *et al.,* 2015) and meta-analysis (Brigstocke *et al*., 2008) have shown that people with DS struggle mainly with prerequisite and basic mathematical skills. These skills, however, are essential for succeeding in life (Onnivello *et al.*, 2019).

Children with DS acquire visual information better than verbal information (Grieco *et al*., 2015). The use of digital resources has increased in popularity due to the numerous ways they allow for visualisation (Anderson & Putman, 2020), thus, the author decided to incorporate them into teaching mathematics. Using digital resources to teach numeracy skills to students with DS has been shown to have a positive effect. For example, after using a digital game, Lanfranchi *et al.* (2021) and Sella et al. (2021) saw an improvement in matching numerals to number words, counting, comparing and linking sets and numbers, number placement on a number line and solving mental additions and subtractions.

Besides visualisation, digital resources have been shown to increase motivation (Gilmore *et al*., 2015). According to Gilmore *et al*. (2015), children with DS exhibit similar levels of motivation as typically developing students in the same mental age group when measuring aspects of mastery motivation, such as curiosity, preference for challenge and persistence on optimally challenging tasks.

This research topic was chosen based on the need to teach numeracy skills to a student with DS in an educational and motivational way. The author compared observations made in mathematics lessons to the student's individual learning plan and work done in previous years. The student's skill level was uneven and previously learned skills and knowledge were not evident even after practice. Therefore, the author, who is also the student's mathematics teacher, needed to assess the student's numeracy skills and devise a teaching plan for developing the prerequisite skills necessary for further learning. As the student seemed to prefer using an iPad in other classes, the author thought using digital resources might add a motivational aspect to learning, in addition to enabling visualisation. Traditionally, mathematics has been taught using material resources. To compare academic achievement and motivational aspects when using material or digital resources, the author decided to alternate them during teaching.

Theoretical background

Cognitive and mathematical abilities of people with Down syndrome

Hannell (2005) has said that mathematical abilities are affected by a person's cognitive abilities, such as verbal and visuospatial skills, and memory. In order to develop a student's mathematical skills, it is essential to know what affects them. The cognitive abilities of people with DS range from mild to severe; most have mild to moderate disabilities (Liogier d'Ardhuy *et al*., 2015). Previous research has shown that, compared to typically developing people of the same chronological age, people with DS have lower mathematical abilities, such as basic number skills (Onnivello *et al.*, 2019). However, the development trajectory is the same, and their skills continue to improve throughout their life (Van Herwegen *et al.*, 2020). Difficulties with basic number skills and topics will cause problems in understanding more advanced topics (Emerson & Babtie, 2013).

Verbal abilities affect a person's understanding of mathematics and learning skills, such as the ability to count, compare and manipulate objects, in addition to planning steps and applying previously learned skills and information to solve problems (Hannell, 2005). Roch *et al.* (2021) reviewed research done on text comprehension of people with DS and noted that understanding text, especially if presented verbally, seems to be particularly difficult for people with DS. Poorer verbal skills and a greater likelihood of hearing problems in children with DS were noted in a review of research by Antonarakis *et al.* (2020).

According to Hannell (2005), visualisation in mathematics, such as using a number line or presenting information in diagrams, helps to understand the relationship between numbers. In addition, visuospatial skills affect how a person understands and can work with measurements and various geometrical shapes (Hannell, 2005). People with DS are more likely to have vision deficits (Antonarakis *et al.*, 2020), and their visual performance is lower even when using glasses compared to age-matched typically developed children (Little *et al.*, 2007). Channell *et al.* (2021) found that the visual abilities of people with DS depend on their cognitive profile and its variability. In addition to cognitive abilities, their basic number skills, such as counting, may also be affected by sensory difficulties (Porter, 2018).

Verbal information of calculations is stored in the verbal working memory, the ability to visualise and copy information is stored in the visuospatial working memory (Hannell, 2005). Lanfranchi *et al*. (2009) found that people with DS score lower than peers in their mental age group on tasks measuring verbal and visuospatial working memory, with higher results on visuospatial rather than verbal memory tasks. Godfrey and Lee (2018) noted in their

review of research that although children with DS perform worse than typically developing peers of the same mental age in verbal working memory tasks, the results on non-verbal working memory tasks vary and are in line with their mental age. Similarly to working memory, the short-term memory of people with DS seems to be poorer than that of their mental-age matched peers without disabilities, with better results on tasks measuring non-verbal short-term memory (Godfrey & Lee, 2018). Deficits in short-term memory might affect their counting skills (King *et al*., 2017). Noda Herrera *et al.* (2011) argued that the mistakes students with DS make and the strategies they use on addition and subtraction tasks might stem from deficits in short-term and sequential memory. Information on the basic mathematical operations and basic number facts are stored in long-term memory (Hannell, 2005). Godfrey and Lee (2018) noted long-term memory impairments in children with DS. They found that on long-term memory tasks, children with DS performed worse than their mental age-matched typically developing peers but also those with other intellectual disabilities. On tasks measuring visual long-term memory, children with DS achieved better results than those with other intellectual disabilities on tasks. However, due to the variety of data collection methods, no firm conclusions can be made (Godfrey & Lee, 2018).

Lanfranchi *et al*. (2010) found that compared to typically developing children of the same mental age, children with DS showed poorer results in their executive functioning abilities such as adapting to change within a subtest, problem-solving and spatial planning, inhibiting a response but not in their ability to produce words in the same category. Children with DS were able to solve the same number of tasks that measured their ability to sustain attention but made more mistakes than typically developing children and did not come up with task-solving strategies (Lanfranchi *et al*., 2010). Parent and teacher reports have also shown that children with DS have difficulties in planning and inhibition control, but not with their abilities to shift within or between tasks (Daunhauer *et al.*, 2014). Difficulties with executive functions might affect their ability to calculate (Lanfranchi, Aventaggiato, *et al*., 2015) or adjust to sudden changes in tasks (Monari Martinez & Pellegrini, 2010).

Chen *et al.* (2014) found that verbal working memory and cognitive planning were in a positive correlation with fine motor skills in students with DS. Daunhauer *et al.* (2020) found a correlation between fine motor skills and later academic achievement.

Besides the previously mentioned cognitive abilities, two mechanisms affect number sense – the approximate number system (ANS) and the object tracking system (OTS) (Feigenson *et al*., 2004). ANS is activated when perceiving groups larger than four and approximating their magnitude. Based on previous research, Feigenson *et al.* (2004) noted

that this system is already present in children as young as six months old, and is therefore not dependent on language abilities or knowledge of symbols. Later, when children have acquired knowledge of the symbolic number system, ANS is integrated into counting and calculation skills. Deficits in ANS seem to affect basic operation skills, dividing objects into two groups, comparison and counting skills (Feigenson *et al*., 2004). Previous research has shown that children with DS perform similarly to groups of the same mental age in counting (Sella *et al*., 2013). OTS is activated when perceiving groups of up to four and enables counting and calculations within that group. Deficits in OTS are presented differently in people when considering their cognitive abilities (Feigenson *et al.*, 2004). People with DS seem to have difficulty subitising and comparing groups of up to four, indicating deficits in OTS (Sella *et al.*, 2013). When reviewing previous research, Onnivello *et al.* (2019) noted that the skills of people with DS vary between being at the same level or poorer than for the typically developing children of the same mental age. Difficulties with addition and subtraction of smaller sets have also been noted (Lanfranchi, Berteletti, *et al.*, 2015).

Teaching numeracy through visualisation

When teaching new skills, one of the steps is to visualise the action at first by using concrete objects and then moving on to representatives such as schemes and symbols (Karlep, 1998). Visualisation is also one of the ways of adapting teaching to better suit the needs of the student with special educational needs (Erg & Kontor, 2013).

Concrete objects used for teaching range from the students using their own bodies to learn numbers (*e.g.*, two hands, two eyes) to cubes and real objects (Varol & Farran, 2006). Students with deficits in long-term memory count on their fingers when they have forgotten a number fact (Hannell, 2005). Concrete objects the student can to understand mathematical concepts better are also called manipulatives (Bouck & Flanagan, 2010).

Visual representatives are pictures and drawings of concrete objects that the student cannot move. Initially, abstracts – the numbers and symbols – are used together with concrete objects and representatives. The end goal is that the student understands what the numbers and symbols represent without using visuals (Agrawal & Morin, 2016).

One goal of this research is to compare material and digital resources to see if there is a difference between them – if one resource is somehow better from an educational or motivational standpoint. Material resources have been defined in different ways in research, such as “concrete” (*e.g.,* Bouck & Park, 2018), “physical” (*e.g.,* Sarama & Clements, 2016)

and "tangible" (*e.g.*, Pires *et al*., 2019). The author of this research will consider material resources as ones that are physical, presented on paper and are not digital. The terms "digital" and "virtual" have been used interchangeably in previous research (*e.g.*, Bouck & Park, 2018), therefore, the author will consider manipulatives, games, educational technology, and other resources used on a computer or tablet as digital resources.

Material resources

Concrete material resources used for teaching mathematics can be real-life objects, teacher-made or store-bought items made explicitly for teaching mathematics (Varol & Farran, 2006). Previous researchers have used base-ten blocks, Unifix cubes, Rekenrek, toy money, and real-life objects (*e.g.*, paper plates, popsicle sticks, beans and buttons) (Bouck & Park, 2018). Lanfranchi, Aventaggiato *et al.* (2015) taught number skills to adolescents with DS by visualising quantities with fingers, coloured beads, sticks and nuts, and a number line. Nye *et al.* (2005) used Numicon, a resource with multiple visualisation aspects, to teach basic number skills to children with DS. The basic number skills improved for all students who used the resource but more so for those who were just starting to learn basic number operations, found the resource interesting and were taught more regularly (Nye *et al*., 2005).

Representational resources may be pictures of manipulatives, tally marks, place value cards, hundreds-charts, number lines and graphics (Agrawal & Morin, 2016). For example, Bouck *et al.* (2017) taught monetary skills (calculating change) to students with intellectual disabilities by using toy money and pictures of the money, and saw an improvement in their skills after a two-week intervention. Although the students preferred using concrete objects and also made the least mistakes with them, it was emphasised that the end goal should still be that they are able to solve the task without visuals. However, the previous phases (concrete and representational) should be passed first (Bouck *et al*., 2017), indicating the importance of mastering the task through practical, hands-on activities before moving to more abstract visualisation to ensure the student fully understands what the visualisation represents.

In addition to manipulatives, games can also be considered a resource for teaching mathematics. Besides the educational aspect, games provide a motivational aspect (Maila, 2018). For example, Gaunt *et al.* (2012) used a variety of matching, counting and dice games to teach numeracy skills to teenagers with DS. Although numeracy skills improved for all students, it was emphasised that games alone do not develop their skills but rather provide an additional way to practice, as progress was biggest for those students who received additional teaching of numeracy concepts (Gaunt *et al*., 2012).

Digital resources

As with material resources, there are many digital resources that can be used to teach mathematical skills. Virtual manipulatives used in the concrete phase allow for an almost similar manipulation as the material counterparts and may often be digital representations of the material resources (Bouck & Flanagan, 2010). For example, previous researchers have used base-ten blocks or toy money, polynominoes (Bouck & Park, 2018) and other geometrical shapes such as colourful rectangles (Bouck, Shurr, *et al.*, 2020) to teach mathematical skills to students with intellectual disabilities. Some examples of representational resources are geoboards, mathematical tangrams, 3D shapes (Bouck & Park, 2018) and number lines (Bouck, Long *et al*., 2020).

Most applications used for teaching mathematics to students with DS are not specifically designed for them. For example, Ortega-Tudela and Gómez-Ariza (2006) compared the development of counting skills of students with DS when using material resources and software originally designed to develop the cognitive, emotional, and social skills of typically developing children in ages 1-4. More progress was made by students who used the digital resource (Ortega-Tudela & Gómez-Ariza, 2006). Similar results were seen by Agheana and Duţă (2015), who taught numeracy skills using an educational game on a tablet and compared the students' skill development with a control group taught using material resources. Sella *et al.* (2021) saw significant improvement in the number comparison and mental calculation skills of children with DS when using the computer game "Number race".

However, as people with DS also have specific educational needs, some researchers have developed applications considering the strengths and weaknesses people DS might have. For example, González *et al.* (2015) adapted a digital whiteboard program used for teaching additions and subtractions by changing and adding visual aspects to suit the students' visual and fine-motor skills, and altering and adding instructions to suit the students' verbal abilities. Although using visual assistance was optional, none of the students solved any calculations without it (González *et al*., 2015), which further illustrates the importance of visualisation. Porter (2018; 2022) designed computer games to develop comparison skills of students with DS. Although the results varied, more progress was made when using material resources (Porter, 2018), and skills gained from using digital resources did not always transfer to the material world (Porter, 2022). As the results varied and material resources seemed to be more beneficial to students with lower mathematical abilities, further longitudinal studies are needed to better understand how using material or digital resources benefits students with various levels of numeracy skills (Porter, 2022).

Tammur (2018) and Pihl (2018) have provided overviews of digital resources they use when teaching mathematical skills to Estonian students with special educational needs. Students with learning difficulties use more representational applications but also a smartboard which allows manipulation of various tools and objects (Tammur, 2018). Students with moderate intellectual disabilities use applications more suitable for their mental age, with most of them allowing for manipulation and having an additional game aspect (Pihl, 2018).

Digital resources have several benefits – added motivation (Maila, 2018; Pihl, 2018), flexibility (Bouck & Flanagan, 2010), feedback (Pihl, 2018), less stigmatization compared to using assistive material resources, and mobility – digital resources can be used at home and at school (Bouck *et al*., 2018). Although many digital educational applications, websites and games provide feedback, resources with constructive feedback benefit the student more than those that just say if the answer is correct or not (Tärning, 2018). When choosing and using digital resources, it is important to keep the special educational principles in mind – the teacher must check if the student understood the task, and if the language and font used are suitable for the student's needs (Tammur, 2018), guidance should be provided when necessary (Pihl, 2018), applications that provide additional instructions (Ok *et al*., 2020) and allow for scaffolding (Bouck & Flanagan, 2010; Porter, 2018) should be preferred. However, although there are several benefits to digital resources, excessive computer use might adversely affect their academic achievement, especially when considering that many students also use digital devices outside of the learning environment (Maila, 2018).

Motivation

Mastery motivation is what drives people to independently attempt mastering a task within one's proximal development zone while remaining focused and determined, no matter how many times they have previously failed at it (Morgan *et al.,* 1990). Mastery motivation is also tied to emotions such as joy, interest, hope, anxiety, shame, or anger (Barrett & Morgan, 2018). Therefore, motivational aspects should be considered when teaching anyone, especially children with special educational needs. As this research aims to compare resources, the author will observe the student's motivation and reactions to using the material and digital resources to see if they differ from a motivational standpoint.

Research by Gilmore and Cuskelly (2011) has shown that students with DS do not differ from typically developing students of the same mental age in motivation levels, except for persistence on an "impossible" task. Furthermore, Cuskelly and Gilmore (2014) reviewed

research on motivation in children with intellectual disabilities and found that observations done by researchers did not show any differences in the motivation of typically developing children and children with intellectual disabilities in the same mental age group on tasks that are optimally challenging. The opposite was true in teachers' and parents' observational reports (Cuskelly & Gilmore, 2014). However, Vlachou and Farrell (2000) found differences in the motivational behaviour of people with DS and people of the same mental age without DS. When faced with a challenging task, children with DS have been noted to show more off-task behaviour (Vlachou & Farrell, 2000). They tend to use more social strategies to divert attention from the task, such as doing things to catch the researcher's attention, looking at them or trying to socialise with the researcher (Jahromi *et al*., 2008; Kasari & Freeman, 2001). Compared to children with no intellectual deficits and children with other intellectual disabilities, mental age-matched children with DS exhibit more frustration when solving a task that is too difficult for them (Jahromi *et al*., 2008). They tend to stop working sooner than typically developing children of the same mental age (Wishart, 2001), although Jahromi *et al.* (2008) found that resignation occurred similarly to typically developing children.

Cuskelly and Gilmore (2014) hypothesised that frustration or disbelief in success might stem from earlier experiences that children with DS have. As task difficulty rises, they make more mistakes, might receive negative feedback and start comparing themselves with others who are more successful, thus inhibiting motivation (Cuskelly & Gilmore, 2014). Previous research has shown that they prefer solving easier tasks (Kasari & Freeman, 2001) and do not believe they will be successful when trying to solve a difficult task (Jahromi *et al*., 2008). To sustain motivation, it is essential to consider their individual strengths and interests to provide a learning experience that will also be meaningful (Cuskelly & Gilmore, 2014).

The goal of this research was to compare the development of basic mathematical skills and motivational behaviour when using material and digital resources to teach one student with Down syndrome.

Research questions based on the goal are:

- Does the student achieve better results when teaching using material or digital resources?
- Is there a difference in motivational behaviour when teaching with material or digital resources?

Method

Sample

The sample of this research is purposive. The sample consists of one student who has Down syndrome. The reasons for choosing this sample size were the student's unique educational and language background; and, since the author is the student's mathematics teacher, comparing motivational and effective teaching materials would also benefit the student's learning and provide useful information for his further studies.

During the time of the research, the student was 13 years seven months – 13 years 11 months old. He was studying in fourth grade at a school that follows the International Baccalaureate curriculum, which he had attended for four years, since first grade. The curriculum is taught in the student's home language - English. The student had previously attended a school for children with intellectual disabilities for five years in his home country. The decision for him to attend first grade at the school in Estonia was made based on his progress and assessments at the previous school that concluded that his social-emotional level of functioning is three to four years behind compared to his chronological age group.

The student was included in all classes with the help of a Special Educational Needs (SEN) teaching assistant, except in Mathematics, where he had one-on-one lessons four times a week (45 minutes per lesson). In addition, the student had Special Educational Support classes with an SEN teacher three times a week. He had an individual learning plan for both Mathematics and Special Educational Needs classes.

The student's cognitive abilities were assessed shortly before this research using a Wechsler Intelligence Scale for Children (WISC-V, UK version). His general cognitive abilities were estimated to be at a moderate disability level. His visual reasoning skills and working memory were estimated to be at the mild disability level, verbal comprehension at the borderline level of mild to moderate disability, and visual-spatial functions and processing speed at a moderate disability level.

The student has difficulties with fine motor skills, which affect his pace when writing or moving small items, such as the material and virtual counters used in this study. He wears glasses to compensate for his vision loss, which, with glasses does not seem to affect his ability to read, write or operate a computer or tablet. The child also has hearing loss, for which he has a cochlear implant. Although his hearing loss causes occasional difficulties in a large class setting, it does not affect the child's abilities in Mathematics lessons since those are taught individually in a separate classroom. The student's speech is affected by

macroglossia and coordination to produce speech sounds. An assessment done four years prior to this research concluded that his speech intelligibility to an unfamiliar listener is 60% in a known context and 30% in a foreign context. His language skills were estimated to fall below the expected range compared to students in his age group. Based on progress reports and observations, the student can follow single-step instructions and understand complex sentences with one dependent clause if it follows the independent clause. When reading, the student has difficulties understanding conditional and concession sentences and sentences with a complex structure (*e.g.*, fronting). The student reads fast, although he struggles with unfamiliar words and tends to guess word and sentence endings. When prompted with the subordinating conjunction, he can write complex sentences with one dependent clause.

Procedure

This research was conducted following action research principles and guidelines. Action research is cyclical and involves planning, acting, observing, and reflecting, and the researcher plays an active part (Löfström, 2011). As the author of this paper is also the mathematics teacher for the student in this study, the information gained allows for immediate applicability. Therefore, it benefits the student more than other research methods would. Due to the small sample size, the results cannot be generalised; however, as noted by Löfström (2011), the focus should be on the applicability or transferability of the findings.

Research phases and timeline

1. Planning – literature review, choosing the sample and asking for permission for the research from the student, his parents, and the school, finding the suitable virtual and material resources: September 2021 - October 2021

2. Gathering and analysing data to map the current situation – Designing and choosing material and virtual (respectively) non-standardised tests to assess mathematical skills, conducting a baseline assessment and analysing data to form an action plan, reviewing the literature: November 2021 - February 2022

3. Planning and implementing the action – Teaching using material and digital resources, assessing results, gathering data by recording and summarising the lessons: March 2022 - April 2022

4. Gathering data to assess the results of the action – Conducting a final assessment using non-standardised material and digital tests to assess the student's progress: May 2022

5. Analysing data – Analysing and categorising the results from the final assessment, discussing and drawing conclusions from significant findings: March 2022 - July 2022
6. Presenting findings – Formulating the thesis: July 2022 – January 2023

Data collection

Baseline assessment

The student's numeracy skills were assessed using non-standardised tests (see Appendix 1). The skills to assess were chosen based on the dyscalculia assessment described by Emerson and Babtie (2013). The non-standardised tests were devised and chosen based on the student's individual learning plan and report cards from from 2020/2021, and tasks solved in his notebook and on the educational platform IXL Learning (2022) (hereinafter referred to as IXL). The student had previously used counters and drawing pictures with guidance to visualise the information in word problems, and had tried to calculate using a number line. He had practised three-number additions up to 20 and briefly learned subtraction within 9. It was also noted that he had a good level of understanding of numbers from 1-50 and thus had begun practising skip counting. As the author was not the student's teacher in the previous school year, it is unclear what was meant by a good level of understanding and what amount of guidance or assistive resources were used.

As this research aims to see if the student's performance differs when using material or digital resources, analogical tests were conducted on paper (referred to as "material test") and on IXL (referred to as "digital test"). Knowledge was assessed in the following subjects: *estimation of sets between 20-90 items, number bonds in the range of 2-15, number sequencing in the range of 3-100, number and set comparison in the range of 1-85, counting up and down by one, two, five and ten in the range of 10-100, addition and subtraction within ten and solving addition word problems within ten.* When necessary, the student was offered accommodations by decreasing the level of independence gradually to find his level of proximal development. The levels of assistance were as follows: rereading the instructions, guiding questions, making an example and offering a simpler task. The student also had the opportunity to use material resources for assistance: drawing for visualisation, counters, a number line and a hundred chart.

Due to the substantial number of tests, the baseline assessment's tests were conducted on two separate days with one week between them. There were digital and material tests on both days, the same type of test was not performed on the same day (*e.g.*, Estimation tasks on

the material test were presented on the first week and the analogical test using digital resources was done on second week). The assessment took 53 minutes in the first week and 52 minutes in the second week, a 10 minute break was taken when switching between the material and digital test. Since the digital platform IXL changes task difficulty based on student's achievement and allows the student to solve multiple assignments on the same level, only the subtests that correlate directly with the assignments on paper are shown. The recordings of the assessments were transcribed, and the student's actions and mistakes were analysed descriptively, focusing on assessing his level of proximal development. Based on the results, an action plan (Appendix 2) was devised for the teaching phase in the fourth academic term (March 2022 – April 2022).

Teaching

During the teaching phase, the author kept a researcher diary that included analysing the lessons – the progress, preparing tasks for the next lesson, different approaches, the student's motivation levels, and notes about events that might cause the student to be more tired (*e.g.*, the extra effort put into other lessons).

The teaching phase consisted of two parts: Developing the student's skills of (early) addition and subtraction, learning the number's bonds by deconstructing and constructing the number and also calculating on a number line (23 lessons), and revising the learned skills (3 lessons), one week after finishing the initial teaching.

Principles of teaching

- **Choosing methods and topics based on assessment** (Gaunt *et al.*, 2012; Löfström, 2011) – A baseline assessment was done prior to the teaching phase to determine the student's current mathematical abilities. The teaching topics were chosen based on which fundamental skills the student needed to master.
- **Working in the zone of proximal development** (Gaunt *et al.*, 2012; Karlep, 1999) – Topics and skills taught were chosen based on what the student would be able to master with support or guidance. On the baseline and final assessment, the support provided started from minimum assistance (guiding questions).
- **Visualising information** (Grieco *et al.*, 2015; Karlep, 1999) – Visualisation was provided with the use of virtual and material manipulatives (counters), a number line, number cards, illustrating the information in word problems with drawing.

- **Scaffolding** (Karlep, 1999; Onnivello *et al.*, 2019) – Each skill was taught by using examples and explanations, working together with the student, allowing the student to practise, and providing additional support. Support from the teacher followed the principle of promoting independence by asking guiding questions, making an example, providing verbal guidance, working together with the student.
- **Practising new skills immediately** (Erg & Kontor, 2013) – Each skill or topic learned in the development phase was followed by practising it using word problems.
- **Sustaining motivation** (Cuskelly & Gilmore, 2014; Karlep, 1999) – The resources and teaching methods used were chosen based on the student's interests to keep the student motivated and provide a positive learning environment. The word problems used in the consolidation phase were written based on the student's interests and everyday life. The games chosen for the development and consolidation phase were chosen based on continuous assessment of what the student seemed to react to positively.
- **Following the student's pace** (Erg & Kontor, 2013; Kasari & Freeman, 2001) – A new number or skill was taught when the student had reached the goals set for the current one. Short movement breaks were taken either in the middle of the lesson or whenever the student seemed tired. If at some point the student was too tired to continue, the lesson was ended early.

Lesson phases

1. Introduction – Preparing for the lesson, revising the previous lesson or topic.

2. Development – informing the student of the topic and resource that would be used, learning, and verbalising the topic. The development face focused on learning one topic at a time, the skill was practised immediately after. Therefore, the lesson comprised of more than one development and consolidation phase.

3. Consolidation - The consolidation phase consisted of implementing the skill learned in the development phase. The skills were practised using word problems.

4. Conclusion – The topic of the lesson was summarised, the student received feedback.

Topics

The plan for topics to be taught was made based on the qualitative analysis results. The plan was to develop his numeracy abilities such as understanding how numbers relate to one another and the patterns within a number. The topics included early addition and subtraction,

making number bonds and addition and subtraction of numbers within ten. Each number was taught separately, the skills taught and practiced followed the same order throughout the teaching phase and when using material or digital resources.
Numbers 2, 4, 5, 8 and 9 were taught using material resources, numbers 3, 6, 7 and 10 were taught using digital resources. Sample lesson plans of using digital resources and material resources are presented in Appendix 3 and Appendix 4, respectively.

The choice of numbers taught using either resource was made randomly. The author considers the inconsistent pattern to be beneficial in providing an unpredictability for the student and therefore not affecting the motivational behaviour in an additional way.

Teaching phase

1. Making a number by adding one – early addition.

1.1. Visualising the addition sentence. The student was asked to put as many counters as was the previous number learned. He was then asked to add one more counter but leave a space between. After this, he was asked to count them. *Put three counters here. Add one counter. How many counters do you have now?* After counting, the student was asked to write or put numbers under the addition sentence and to read the addition. The first addend (set and numeral) were then compared to the sum, the suitable comparison sign " < " was written between the two sets and numerals and the conclusion that addition makes a number bigger was made using an analogy of " the bird wants to eat the bigger one, the bird's mouth is open towards the bigger number". To teach the student to understand the commutative properties of addition, the student was asked to follow the same procedure as before, but put one counter at first and then the amount of counters as learned previously. The results were then compared and the conclusion made that in addition the order of addends does not change the sum.

1.2. Solving addition word problems to practice the making of the learned number. The word problems were written by the teacher, the people and actions described were familiar to the student. The student was presented with a word problem and asked to read. The teacher asked what it was about, what they wanted to know, mark the question, and how he could find out the answer. *What was this word problem about? What do they want to know? What is the question? Mark it. How could you find out?* The student was asked to write down the information he already knew, guidance to find the information was provided by re-reading the word problem to the student, pointing to the sentences or phrases that contained the necessary information or pointing and reading the sentence. *What do you already know? Read from here. May I read it to you?* The action in the word problem was then discussed and the

student was asked what should be done next, if the amount was going smaller or bigger and what operation should be chosen. *What happened here? What did he do? He found a euro on the ground. Did he have more money or less money now? He had more money. The number was going bigger. What could you do to calculate how much money he has now? How do you make a number bigger? You could add the money he had and money he found.* The student verbalised and wrote the addition sentence down with the teacher's guidance. After solving the addition with the help of counters, the student was asked what the answer to the question was, to re-read the question if necessary and to provide an answer using a full sentence.

2. Making the previous number by subtracting one – early subtraction.

2.2. Visualising the subtraction. The student was asked to put as many counters as the number learned. He was then asked take away one counter and count how many he had now. *Put four counters here. Take one counter away. How many counters do you have now?* After counting, the student was asked how many counters he took away, and how many counters he had left. He was asked to visualise the subtraction by putting the initial set of counters, the counter he took away and the difference he got in a row while leaving gaps between the minuend, the subtrahend and difference. After verbalising the subtraction sentence, he was asked to write or put numbers under the subtraction sentence and to read the subtraction. The minuend (set and numeral) were then compared to the difference, the suitable comparison sign " > " was written between the two sets and numerals and the conclusion that subtraction makes a number smaller was made using an analogy of " the bird does not want to eat the smaller one, the bird's mouth is open towards the bigger number". To understand the difference between addition and subtraction, the student was asked if he could subtract the difference from the minuend using the counters for visualisation. The conclusion that you always subtract from the bigger number was made.

2.3. Solving a subtraction word problem. The subtraction word problem followed the same principles and steps as the addition word problem: the text was based on familiar people and actions, guidance was provided to solve the word problem according to the algorithm, the operation suitable for the action was chosen by discussing if there was more or less of something and if the number was going bigger or smaller. The relevant information was written down, as well as the subtraction sentence, which was then visualised and solved using counters. The answer for the word problem's question was written down using a full sentence.

3. Number bonds. Number bonds were taught according to the principle of increasing difficulty.

3.1. Deconstructing the number. The first step was to divide the set of counters that matched the number the lesson was focusing on into two sets as many ways as possible. An anchor chart with three circles, one for the whole set and two for the parts was used to visualise the division. To increase motivation, the student was asked what the counters in the whole set could be, to name the sets, and divide the counters between the two parts: Teacher: *What could these be?* Student: *Chocolates.* Teacher: *Count how many you have. You have five chocolates. Let's say you are feeling extra kind and give all your chocolates away. You give them to your friends. What could be their names?* Student: *Macy and Stenka.* Teacher: *How many chocolates are you giving to Macy? And how many are left for Stenka? Put the chocolates into their circles. Give all of them away.* After making a bond, the student was asked how many he gave to each person and to put or write the numeral next to the sets and to say what numbers can be used to make the number that was learned. *How many did you give to each of them? Put the numbers next to the groups. What numbers did you use? You used a two and a three to make five.* The student was then encouraged to try if he could divide them in another way. If the student made the sets using the same number, he was to give one amount to one person and then to see how many were left for the other. *Put the counters back in the whole. Stenka is feeling very hungry today. Could you give her more chocolate? How many will you give her? Give her two chocolates. How many can you give to Macy?*

3.2. Constructing the number.

3.2.1. Matching pictures and additions. Pictures of sets consisting of shapes in two different colours were presented. The task was to find sets that matched the number the lesson focused on and to match or write the suitable addition sentence. The student had to count how many shapes were in one colour and how many in the other and to write (material resource) or point to but not submit (digital resource) the addition sentence. *How many blue rectangles are there? How many green? What is the addition sentence? Choose/write the correct sentence.* He was then asked how many that made and, if necessary, was allowed to count all.: *How many rectangles are there? What number are we learning? Does this make five? So you made five with two and three.* When using the digital resource, he was asked to submit the answer. Addition sentences using 0 as one of the addends were also presented by using a picture that only had the shapes in one colour. The student was asked how many in one colour and how many in the other. If he said "none", he was asked what the numeral matches "none".

3.2.2. Choosing an addition sentence to match the number. The student was presented with addition sentences. If he knew which ones made the number that was asked, he had to circle the answer. If he did not know, he was asked to solve the additions using counters.

3.3. Word problems for deconstructing and constructing a number. Word problems followed the same principles and steps as in early addition and subtraction, but the instruction was to divide the number into two sets or make a whole set if only one of the parts is known. When using material resources, the word problem actions alternated between mentioning the whole set and one of the parts and mentioning the whole set but using the word "some" instead of saying one of the parts to allow the student to find different ways to deconstruct the number. When using the digital resources, the word problem mentioned the whole and one of the parts because the program needed only accepted one correct answer. Solving the initial task was followed by a discussion of alternative ways the set could be divided or constructed.

4. Calculating using a number line. The student was presented with addition and subtraction sentences in a random order, and a number line. He was instructed to find the first number and count on or back as many steps as indicated by the second number. *Read the sentence. Do you need to add or subtract? How could you solve this? Find the first number. Are you making the number bigger or smaller? Which way are the numbers bigger/smaller? Which way do you need to move? How many steps? Look at the second number. Count.*

Revision phase

The revision phase at the end of the teaching phase comprised of solving addition and subtraction sentences and word problems within ten throughout the lesson. Material resources were used in one half of each lesson and digital resources in the other half of each lesson. The tasks presented when using material resources were chosen based on the numbers that were taught using material resources. The same principle was followed for choosing the tasks for digital resources. The student was encouraged to solve the tasks independently, the teacher used guidance only when necessary.

Resources

Material resources

- **Counters –** Two-dimensional cardboard counters which had different coloured sides (one yellow and one red side), play Euro coins and game pins were used to teach early addition and subtraction and making number bonds.
- **UNO cards –** cards with numbers were used to match the numerals and counters when deconstructing the number.
- **Number line** - A ruler was used to represent the number line.

- **Two-dimensional pictures of counters –** Shapes such as circles or squares in two colours were drawn on paper in the ten-frame setting when teaching number bonds by constructing numbers.
- **Motivational aspect –** "Build a monster" game (Itsy Bitsy Fun, 2017). The option to build a monster using printed and laminated pictures of a monster's body, arms and legs, eyes, etc. was offered to the student in the consolidation phases of the lesson. He got to add something to the picture for each correct answer.
- **Additional resource for revision phase –** A modified boardgame (Simply Creative Teaching, 2016) was used to solve addition and subtraction sentences and word problems in a mixed order. The author of this paper created the tasks and word problems following the same principles as in the teaching phase.

Digital resources

- **Counters –** Five resources from three sources for virtual manipulatives were used.

- "Two-colour counters numbers" (Toy Theater, 2017) – virtual two-coloured manipulatives with auditive feedback for representing the addition and subtraction sentences. This resource was used when teaching or practising addition and subtraction sentences or word problems. This was also used as an assistive resource on the final assessment.
- "Compare" (Toy Theater, 2021) – a table, movable two-colour counters with auditive feedback and a virtual pencil is provided to enable comparison of sets and writing the comparison sign. This resource was used to compare addends and sums or minuends and difference.
- Part Part Whole Demonstrator from The ICT Games website (Barret, n.d.) – an anchor chart, a variety of movable counters, the option to add numerals next to the chart. No auditory or other feedback is provided. This resource was used when teaching or practising number bonds.
- "Make Another Number Sentence" application (Hengst & Egan, 2018a) – a table with four cells and movable counters are presented, the purpose is to construct the number in two ways. The resource provides written feedback. This resource was used when teaching or practising number bonds
- "Making Number Bonds" application (Hengst & Egan, 2018b) – An anchor chart with movable counters to deconstruct or construct the number. The application does not allow

the user to choose a specific number, but a range of numbers. Numbers are presented in a range of 1-5, 1-10 or 5-10. This resource was used when teaching or practising number bonds.

- **Website for tasks –** "Pink Cat Games" (Rodger, 2022). A website that allows teachers to design questions with answer choices and to choose a game to solve the tasks. The games provide auditory and visual feedback. This resource was used during the development and consolidation phase for presenting word problems, tasks for practicing constructing numbers and calculating on a number line during the teaching and revision phase. The topics of constructing a number by choosing the matching addition was used together with virtual manipulatives, matching pictures to additions was presented only on Pink Cat Games as well as calculating on a number line. A selection of tasks used for teaching is available under the user name "Example" at https://www.pinkcatgames.com/go/HnhK7jtH17meJwf61pkQ.
- **Number line –** A virtual number line (Didax, 2022) was used during the final assessment. Although the student was unfamiliar with the resource, it was chosen to provide a similar resource as the material number line.
- **Educational platform IXL** (IXL Learning, 2022) – This platform follows the Common Core State Standards curriculum and uses algorithms to generate questions and alternate difficulty levels based on the student's answers. The teacher can choose task categories with suitable difficulty levels but cannot choose easier or more difficult tasks or choose which numbers the tasks would be based on. The student can visualise the task by using a virtual marker, it also provides examples when the student requests one. The program has auditory and visual feedback. This platform was used to conduct the digital baseline and final assessment. The student was familiar with the program as he had used it in the previous years.

Final assessment

The final assessment was conducted ten days after teaching and revision. The student solved analogical addition and subtraction subtests on a test on paper and on the IXL platform using an iPad (see Appendix 5). The assessment was conducted on two consecutive days. The material and digital test for each day comprised of 10 addition and subtraction sentences presented in a mixed order and solving five addition and five subtraction sentences divided equally between the two days. The reason for this number of tests was to gather sufficient data on the student's skills and knowledge of the numbers learned in the teaching phase to make

valid conclusions. The reason for conducting the assessment on two days was that the number of tasks (a total of 40 addition and subtraction sentences and 20 word problems) would have exhausted the student and, therefore would have affected the results. On the first day, the assessment took 52 minutes; on the second day it took 48 minutes, a 10 minute break was taken when switching between the material and digital test. On both days, the student had a five-minute movement break in between the material and digital subtest

Assistance was provided by decreasing the level of independence and task difficulty and increasing teacher involvement. Levels of independence and task difficulty were: 1. Without additional resources, 2. Visualisation by drawing, 3. Visualisation by using counters, 3. Counting on a number line. Levels of teacher involvement were: 1. Guiding questions, 2. Guidance. The teacher provided visualisation resources when it was evident that the student would not be able to solve the task at the current level of independence. The student used material resources (drawing on the paper, counters, and a ruler) for the material test and digital resources (drawing on the IXL application, virtual counters and virtual number line on an additional iPad) for the digital test. On the first day, the student started with the material test (both number sentences and word problems); on the second day he started with the digital test.

Motivation

The student's motivation was assessed using a non-standardised checklist of behaviours to see if there are differences between using virtual or material resources. Since assessing motivation on all the topics would have been too time-consuming for this research, the author decided to choose one topic. After reviewing the recordings of the teaching phase, it was evident that the most challenging topic for the student was making number bonds.

To assess the student's motivation during learning number bonds, the author compiled a checklist of behaviours (see Appendix 6) that previous research has shown to indicate motivation. The behaviours were coded into three categories; category labels were adapted from previous research – positive behaviours (Vlachou & Farrell, 2000), negative behaviours (Jahromi *et al*., 2008) and off-task behaviours (Vlachou & Farrell, 2000).

Data analysis

Baseline and final assessment

Video recordings from the baseline and final assessment were transcribed and analysed qualitatively. To see if and how much the student's abilities in numeracy have improved, the author compared the results of the student's addition and subtraction tests and addition word problems. The findings, comparisons between the two assessment points as well as the student's strengths and weaknesses are described qualitatively and analysed using manuals on diagnosing mathematical difficulties by Chinn (2020), Emerson and Babtie (2013) and Hannell (2005). Since the number of tasks on the baseline and final assessment differed, the author compared the percentages of correct answers by subtest (addition, subtraction, addition word problems) and, in addition to descriptions, presented findings on charts made using Google Sheets.

Coding assistance levels

The student was also provided assistance, therefore the tasks solved independently, with assistance and tasks not solved were compared. by resource type. Although the levels of assistance are not mutually exclusive, since they also show how well the student can recall number facts, or perform operations, the percentages of assistance use by resource and subtest type were compared. The assistance levels were categorised as "guidance" – the author asked guiding questions, "visuals" – the student used drawing to visualise the operation, "visuals and guidance" – the teacher suggested he draw the operation and asked guiding questions, "counters" – the student used counters independently to visualise the operation, "counters and guidance" – the student solved the task with counters and with the help of guiding questions from the teacher, "number line" – the task was solved using a number line, "number line and guidance" – the student used a number line with the help of guiding questions from the teacher. Tasks solved independently and tasks solved incorrectly were categorised respectively as "independently" and "incorrectly".

Motivation

Motivation was assessed in lessons with the goal of developing skills not revision, therefore the revision lessons of the teaching phase were excluded. Assessment was done by rewatching lesson recordings and marking each occurrence of behaviour on the checklist in the suitable

subcategory slot using tally marks. If behaviours occurred simultaneously, both behaviours were recorded (*e.g.*, grunting and looking elsewhere).

Each lesson was assessed separately. Since teaching number bonds was one part of the lesson, the duration of the part assessed, as well the topic of the lesson (the number taught) and the type of resource used (material or digital) were marked.

As one of the research questions was to see if there is any difference between the use of virtual and material resources, the behaviours that occurred during the use of manipulatives (virtual or material) were marked and summarised separately for each subcategory. One type of counters was used when teaching with material resources. Three different digital resources for manipulatives were used, but since they all had similar qualities (no auditory feedback or a game aspect), all manipulatives used were categorised under one common denominator (Manipulatives). The behaviours that occurred during the use of the virtual game "Pink Cat Games" (2022) and the material resource "Build a monster" (2017) were marked between colourful brackets and categorised as "Games".

After the assessment, the assessor marked the total occurrence of behaviours for each category and subcategory. The behaviours that occurred during the use of manipulatives, games or both were marked separately for each subcategory.

Coding motivational behaviours

Indicators of *positive behaviour* were divided into two subcategories: belief in success by indicating or verbalising confidence (tries to solve task independently, sentences such as "I can do it!", "Watch me.") and expressions of happiness after successfully solving a task, such as vocalisations and verbalisations (*e.g.*, cheering, saying "Yes!").

Indicators of *negative behaviour* were divided into three categories: refusal to work by stopping during a task or refusing to start, verbalisations (*e.g.*, "I'm done!", "I won't do it."); verbalising disbelief in success (*e.g.*, "I can't do it.", "I don't know.") and expressing negativity towards the task but still continuing work (*e.g.*, vocalisations with a negative tonality, *e.g.*, grunts, groans, whines, saying "Not this again", "I don't like it.").

Off-task behaviours were divided into two categories: using social strategies to divert attention from the task, such as asking questions about the researcher or other topics (*e.g.*, "How are you?", "How are your pets?", "Have you seen this movie…?") or telling a story (*e.g.*, "Do you remember when…?", "One time, me and…") and other non-task related behaviours such as fidgeting with items on the table or the student's clothes, looking elsewhere, not listening so the author has to repeat instructions.

Analysis of motivational behaviours

Due to the small number of variables, no formal statistical analysis was performed and the data from the motivational behaviour assessment was analysed descriptively. Behaviours were summarised by category and subcategory for each number separately. Since the volume of lessons needed for teaching a number's bonds increased as the numbers grew larger, the durations of teaching a number's bonds were summarised and divided into 10-minute intervals. To calculate the average rate a behaviour occurred during a 10-minute interval, the summarised number of behaviour occurrences was divided by the number of intervals it took to teach that number's bond. Behaviour rates for material and digital numbers were summarised by context type and the mean occurrences by resource were compared. Average rates by resource type (counters, counters and game, game) were also compared to see if there is a difference in motivational behaviour when a different material or digital resource is used.

Reliability and validity of the motivation assessment

To increase reliability and assess the validity of the motivational behaviour assessment, the thesis supervisor watched and assessed motivational behaviour in 30% of the video recordings according to the checklist. Differences in assessment and understanding were resolved through discussions. To assess the level of agreement between the observers and the checklist's validity, Cohen's kappa (Cohen, 1960) was calculated for each subcategory separately based on the method explained by Watkins and Pacheco (2000).

In the *positive behaviours* category, kappa value for the *belief in success* subcategory was 0.82 and for *expressions of happiness* subcategory was 0.88. Kappa values for the category of *negative behaviours* subcategories were: 0.86 for the *refusal to work;* 0.93 for *disbelief in success* and 0.89 for *expressions of negativity.* In *off-task behaviours* category, kappa value for the *social strategies to divert attention* subcategory was 0.68 and for the *other off-task behaviours* subcategory was 0.79. According to Watkins and Pacheco (2000), values of 0.60 to 0.75 can be interpreted as representing a good agreement and values over 0.75 as representing an excellent agreement between assessors. The only kappa value below 0.75 was for the subcategory *social strategies to divert attention* in the *off-topic* category. This is likely caused by the student's speech intelligibility, which is lower to an unfamiliar person and/or on an unfamiliar topic, therefore, the author and thesis supervisor disagreed more on if the topic the student was talking about was off- or on-topic.

Research ethics

All research activities were conducted in a way that prioritised the student's welfare, rights, and safety. To ensure compliance with ethical requirements for research, informed consent was asked from parents and school administration. Assent was asked from the student after explaining the topic in a simple manner. All parties were informed that participation was voluntary, and consent could be withdrawn at any point.

To ensure high reliability in analysing the student's actions and motivation, the lessons conducted during the research were recorded and uploaded onto the IRIS Connect server (https://europe.irisconnect.com/). This password-protected server is, among other purposes, meant for educational research and complies with the General Data Protection Regulations. To further improve reliability, the thesis supervisor analysed 8 randomly selected videos shared by the author. The videos can only be shared within the server and cannot be downloaded. Other people besides the author or the thesis supervisor did not have access to them. Informed consent from the student's parents and the school administration was also asked for recording the lessons and sharing the videos with the thesis supervisor Assent was asked from the student after explaining the need for recording. The student's name or other personal information that would enable identification has not been shared anywhere in the research.

Results

Mathematical skills

The goal of this research was to compare the development of basic mathematical skills and motivational behaviour when using material and digital resources to teach one student with Down syndrome. Following the action research guidelines (Löfström, 2011), the author first assessed the student's numeracy abilities with a baseline assessment, based the teaching on its results, and later evaluated the intervention's effectiveness with a final assessment. Subtests were conducted using material and digital resources.

Baseline assessment

To understand which mathematical skills need development, the author first assessed the student's baseline level in numeracy. The baseline assessment protocol is in Appendix 7.

Estimation

On the material test, the student estimated sets of 20, 30 and 80 independently on the material test and sets of 40 and 70 incorrectly. To assist the student, the teacher showed how sets of 10 look like in the set of dots, but this did not help him in the following tasks. On the task on estimating a set of 80, he corrected his initial mistake of estimating it to be 40. On two tasks, the teacher had to ask the student to stop trying to count the dots and estimate instead. On the digital tests, he estimated sets of 70 and 80 independently, a set of 20 after the teacher read the choices out loud. Sets of 30, 50 and 90 were solved incorrectly, looking at an example of what ten dots look like did not help him. Mistakes were trying to count the dots and answering impulsively by choosing a random option (*e.g.*, choosing the options on the left).

Number bonds

The material test was on numbers up to 15. The student solved the task with early addition (+1), on the bond of 13, independently. The tasks on bonds of 7, 8, 10, 12 and 15 were solved incorrectly. The task was unfamiliar to the student and guidance on how to solve it and how to use counting cubes and partition strategies was necessary, although using counting cubes did not help him choose the correct answer. Mistakes were counting all the counting cubes together or answering all the bonds as the asked number (*e.g.*, after reading all the answer choices for a bond of 10, he said, “Those equal 10.”). On three of the tasks, the student wanted to stop the test. The digital test was on numbers up to 10. No tasks were solved independently. The student solved the task on the bonds of 10 correctly after the answer choices were narrowed down, and the task on the bonds of 6 after using counting cubes with guidance – the teacher gave him three cubes and asked him to count how many more he needed. The tasks on bonds of 2, 3, 4 and 5 were solved incorrectly. Mistakes were choosing the answer with the asked number, saying all the equations equal the asked number or choosing the wrong answer after using counting cubes (*e.g.*, on a task on the bonds of 4, he took four cubes, divided them into two piles but answered with 1+4).

Number sequencing

The first subtest was on positional words. All tasks on the word “after” were solved correctly. Both tasks on the material test on the word “before” were solved incorrectly. On the digital test, one task was solved correctly after the teacher told him which way “before” was on the number line, and one incorrectly. A common mistake on both tests was saying the number that came after instead of before (*e.g.*, “before 3”, the student answered “4”). Both tasks on

the material test on the word "between" were solved incorrectly. On the digital test, he solved one task correctly after the teacher pointed to the numbers on the ruler and asked what was between them, and one incorrectly. A common mistake on both tests was saying the number that came after or the last number in the question (*e.g.*, between 54 and 56, he said 56).

The second subtest was on counting on a number line up to 100 by filling out the gaps. On the material test, the student solved five tasks independently, one with guidance after the teacher asked him to look at the number line again, and six incorrectly. Mistakes commonly occurred when crossing the tens boundary (*e.g.*, …, 42, 41, 40, **44**; 69, **59**, 71, 72, …). He also mixed up the "-teen" and "-ty" endings or counted up by tens on the wrong tasks. The digital test was on numbers up to 30. He solved five tasks independently and one incorrectly. The mistake occurred when crossing the tens boundary (**30**, 20, 21, 22, 23).

Comparing numerals and sets

The material and digital tasks on comparing numerals up to 85 were too challenging, and the student seemed to choose answers randomly and compared numbers 39 and 46 on the material test and numbers 64 and 63 correctly on the digital test, although the answers chosen were on the left and no analysis by the student was visible. The material test involved using comparison signs, which the student had difficulty understanding, therefore the task was simplified (the teacher asked him to circle the bigger one in one column, the smaller in the other column). There was no digital equivalent for using comparison signs, the digital test was similar to the simplified version – he had to choose the bigger or smaller number. On the digital test, he also solved comparisons on 1 and 57, 2 and 3 correctly, but 6 and 6, and 8 and 41 incorrectly. This indicated that the task was too challenging, therefore, easier subtests – comparing sets – were included**.**

The subtest comparing sets up to 100 was only conducted on paper because there was no digital equivalent. The student compared a set of 20 to 30 independently, and a set of 40 to 60 after the teacher pointed and asked which one was bigger. The tasks on comparing equal sets and sets of 40 to 50 were solved incorrectly. To assess his skill level when comparing small sets, the author conducted a material and digital test on comparing sets up to 10. On the material test, he solved all tasks correctly but did so by counting all the dots. On the digital test, he solved three tasks independently, two of those without counting on numbers up to 4. Three tasks were solved incorrectly. Two mistakes occurred on tasks comparing a set of 4 to a set of 5 (after having counted both sets on one task) and one when comparing a set of 1 to 4 (after initially misreading the task – reading "which has more" instead of "which has less").

Counting up and down by twos, fives and tens.

The subtests were presented in an order of decreasing difficulty: (1) counting up and down without and (2) with a number line up to 100, and (3) counting up to 50 with pictures. The first subtest was on counting up or down without a number line. On the material test, he counted up by tens after examples and using a hundred chart with guidance. On one tasks, he counted up by tens but skipped "30" and mixed "-teen" and "-ty" endings. On the task on counting up by fives, he counted up to 10 independently, but up by ones from 10. He did not solve the tasks on counting down by fives or tasks on counting by twos. On the digital test, none of the tasks were solved correctly. However, he counted up by tens on two tasks – counting down by tens and counting up by twos. He wrote a random number ("0200") on the task on counting down by fives. Common mistakes on both tests were counting up by ones, skipping numbers, answering with the example the teacher made, counting by tens on the wrong task, and mixing "-teen" and "-ty" endings (*e.g.,* following an example of counting by tens from 30, he counted, "14, 15, …, 19" and wrote "91" as the answer).

Due to mistakes on the previous test, the following subtest, counting on a number line, was chosen. On the material test, the student solved two tasks on counting up by tens and one on counting down by tens independently, one on counting down by tens with guidance. One task on counting up by fives was solved with guidance, one incorrectly and none correctly when counting down. No tasks on counting by twos were solved correctly. On the digital test, he counted up by tens independently on two tasks but used a hundred chart with guidance to solve a task on counting down by tens. He solved one task on counting down by fives independently, although he mixed up "-teen" and "-ty" endings; the task on counting up and down by fives was solved incorrectly. No tasks on counting by twos were solved correctly. Common mistakes on these subtests were counting up by ones (*e.g.,* 56, 54, **55**, 50, 48), counting by the wrong number, and mixing "-teen" and "-ty" endings.

Due to errors in the number line test, the subtest on counting by sets of pictures was chosen. On the material test, he counted once by tens after an example and once after the teacher asked him to count by tens like on the previous subtest. He counted by tens independently on two tasks, although they were on counting by fives, therefore, tasks on counting by fives were not solved correctly, as were tasks on counting by twos. On the digital test, he counted by tens on the one task after guidance but skipped "30" and mixed "-teen" and "-ty" endings (10, 12, **14**, 15, 16). No tasks on counting by fives or twos were solved correctly. Common mistakes on both tests were counting the pictures by ones (*e.g.,* counting each skate picture separately instead of by pairs) and mixing up "-teen" and "-ty" endings.

Addition sentences

The addition sentences were on numbers up to 10. No tasks on either test were solved independently. On the material test, the student solved one task with a number line after the teacher made an example on how to add on it, two tasks using a number line independently, two tasks with the number line and the teacher's guidance, and one incorrectly, when he counted the second addend twice instead of adding the first and the second. On the digital test, he solved four tasks using a number line independently, one after the teacher asked him to use a number line and one incorrectly after an example on how to calculate with a number line. Common mistakes on both tests were failing to follow the one-to-one counting strategy and adding the wrong numbers (*e.g.*, the task was "1+9", the student counted nine steps from number 9).

Addition word problems

The word problems were on numbers up to 9, the student solved none of them. On one occasion, on the digital test, he found the question from the text but did not know how to solve the problem. He had difficulties understanding the text, following the algorithm, and choosing the correct answer. Common mistakes on both tests were saying a number in the text as the answer (*e.g., "*…. He has 6 red pencils and 3 blue pencils. How many pencils does he have?" The student answered "Six".), adding random numbers (*e.g.*, counting to five when the task had numbers 4 and 3) or choosing the first answer option on the digital test.

Subtraction sentences

The tasks were on numbers up to 9. No tasks on either test were solved independently. An example of how to subtract using a number line was necessary for solving two tasks on the material test and on one task on the digital test. He needed guidance to calculate using the number line on one task on the digital test, one task was solved incorrectly. The student used a number line correctly and independently on four tasks on both tests. Mistakes on both tests were initially reading the number sentence as an addition, adding instead of subtracting and starting to count from the wrong number (*e.g.*, the task was "6-3", he counted down from 5).

Conclusions

The student did not know any number's bonds and had difficulties understanding the concept, preferred counting to grouping or estimating and had difficulties understanding relationships between numbers, which, according to Emerson and Babtie (2013), show numeracy

difficulties. Knowledge of a number's bonds, understanding the relationships between numbers, the skill to count accurately, and the ability to apply learned knowledge in different settings are essential to becoming numerate (Emerson & Babtie, 2013). Therefore, the author decided the teaching phase should focus on developing the student's understanding of how numbers are made, teaching key number facts (bonds of 10) and applying the learned knowledge by solving operations and life-based word problems with numbers up to 10.

Final assessment

The final assessment was conducted after the teaching phase to assess if and how much the student's knowledge of key number facts (bonds of 10) and the ability to apply it when solving addition and subtraction operations, as well as his ability to solve simple word problems had developed. All subtests – addition and subtraction sentences and word problems - were on numbers up to 10, like on the baseline assessment. Besides developing the student's numeracy abilities, this research aimed to see if using different resources – material or digital – would affect the student's learning, knowledge retention and academic achievement. Similarly to the baseline assessment, analogical material and digital subtests were conducted. Results were analysed descriptively (see Appendix 8).

Addition sentences

Out of the 12 tasks on the baseline assessment, the student solved five using a number line independently, four with a number line and guidance from the teacher, and two incorrectly. The material test on the final assessment consisted of 10 tasks. The student solved one task independently ("1+1"), two with guidance (the teacher asked if he already knew the answer before using counters), six by visualising with drawing or counters, and one by using a number line, which was also the first task on the assessment. Mistakes that occurred were putting the wrong number of counters, failing to follow the one-to-one strategy when counting, circling the numerals of the addition sentence instead of drawing dots to visualise it, subtracting instead of adding, and initially guessing the answer wrong (*e.g.*, thinking "2 + 8" is 9 or 3). There were nine tasks on the digital test, three of which were solved independently (adding 0 and "6+1") and six by visualising the operation by drawing or using counters independently. The only mistake was initially guessing the answer wrong by thinking, "8 + 2 = 9". A comparison of the addition and subtraction sentences on the baseline and final assessment that were solved correctly or incorrectly, as well as the percentage of assistive resources used, is presented in Figure 1.

Subtraction sentences

The baseline assessment consisted of 12 tasks. The student solved four by using a number line independently and eight by using a number line with guidance and examples from the teacher. The material test on the final assessment consisted of 10 tasks. The student solved one task independently ("8 - 0"), eight tasks by drawing or using counters independently or with guidance, and one by using a number line with guidance. Mistakes that occurred were adding instead of subtracting (*e.g.*, solving "10 - 3" by adding three counters to 10), saying that when subtracting, he needs to make the number bigger, mixing up addition and subtraction (on the task "3 - 2", he initially added the circles he drew and then crossed off two from five) and subtracting the wrong number. On the digital test, he solved one of the 11 tasks independently ("7 - 0"), eight using either drawing or counters with guidance and two incorrectly. Mistakes that occurred were failing to understand what subtract all meant (*e.g.*, thinking "6 - 6 = 6"), adding instead of subtracting, subtracting from the wrong number, initially adding the numbers and then subtracting from the sum, and erasing the numeral instead of the counters when visualising (*e.g.*, erasing the numeral 2 from "3 - 2" and saying the answer is 3).

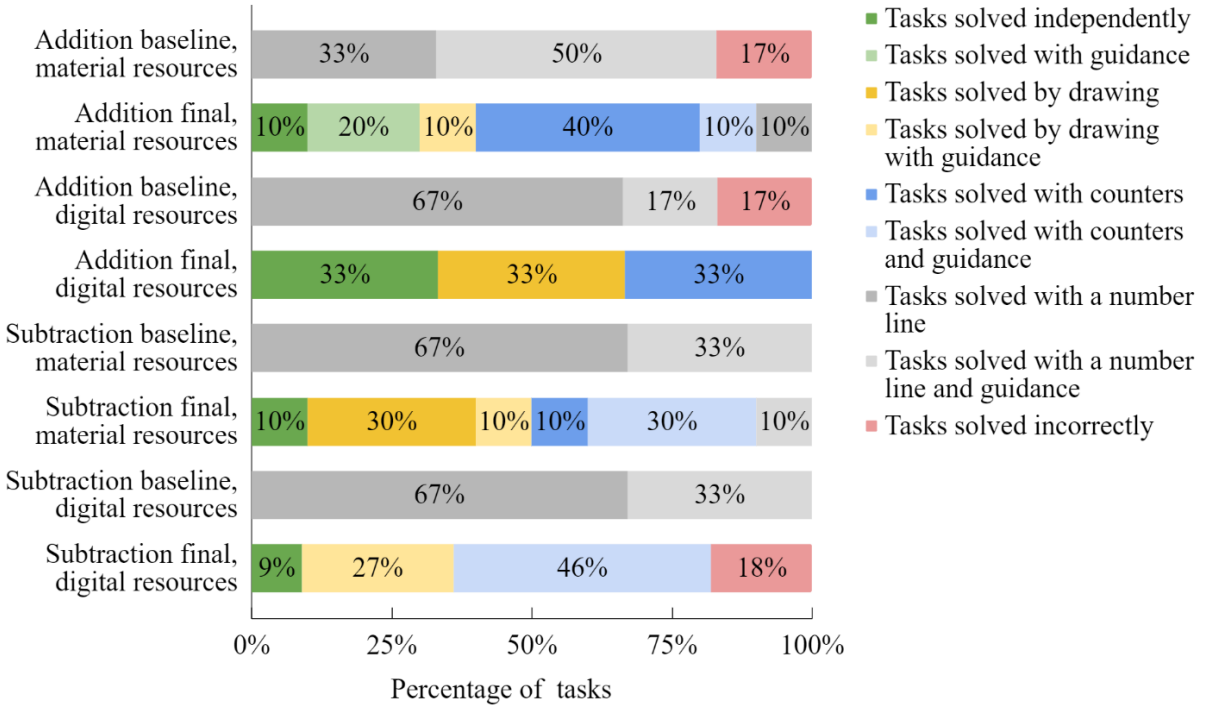

Figure 1. Results of the number sentence tasks solved on the baseline and final assessment.

Addition word problems

No addition word problems were solved correctly on the baseline assessment. On the final assessment's material test, the student solved all five word problems using assistive resources – visualising by drawing counters, counting on his fingers or calculating with counters either independently or with guidance. Mistakes that occurred were answering with the number in the text instead of adding the numbers (on the word problem "…. She bought three muffins and four cakes. How many things did Mary buy?", he said the answer is three.), thinking the word problem can be solved with a subtraction (*e.g.,* on the task "David has 2 dogs and 1 cat. How many pets does David have?" he said he has to subtract) and subtracting instead of adding after stating he needs to add to solve the task. On the digital test, he solved the five word problems with assistive resources by using either drawing or counters with or without assistance. The student needed the text to be simplified on one task, which was done verbally. Mistakes that occurred were misunderstanding the problem after it was simplified (although the original and simplified text had numbers 3 and 1 in it, the student initially answered "three" and then "zero"), initially guessing the answer wrong and failing to follow the one-to-one strategy when counting. On both tests, he needed guidance to answer with a full sentence. Comparisons of addition and subtraction word problems on the final assessment's material and digital test, as well as the assistance the student required, are shown in Figure 2.

Subtraction word problems

There were no subtraction word problems on the baseline assessment, therefore, no comparison of skill development can be made. On the material test, the student solved four tasks by visualising by drawing or using counters independently or with guidance and one task incorrectly. Mistakes the student made were answering with a random number (*e.g.,* the numbers in the text were nine and five, the student replied "six" and "three" before calculating), choosing the wrong operation, misunderstanding what subtract all meant (the task was about a dog eating eight of the eight sausages on the counter, the student initially thought the answer was nine, although he knew he had to subtract) and writing the wrong answer to the question (the question was "How many sausages were left?", the student answered "The dog eats zero sausages."). On the digital test, he solved one task using counters with guidance, one task using a number line and three tasks incorrectly, one of which was left unsolved. He needed the text to be simplified on four word problems. The student made mistakes such as choosing the wrong operation to solve the task, adding instead of subtracting (*e.g.,* saying, "5-2=7"), answering with a number from the text or choosing the

first answer option (*e.g.*, the options were 4, 1, 2 and 3, the student initially said the answer was 4) and subtracting from a previously added number (initially the student added 5 and 4 using counters, then subtracted four from the sum).

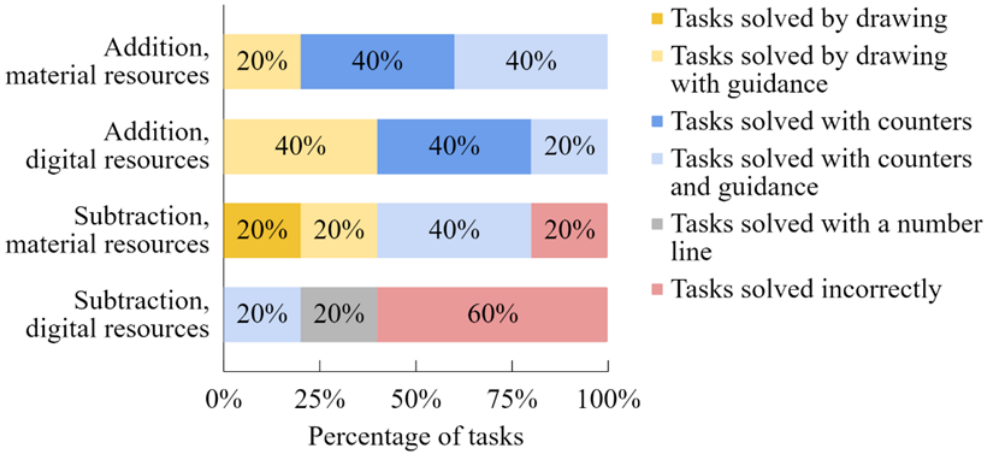

Figure 2. Results of word problems solved on the final assessment.

Motivation

The motivational behaviours when using material or digital resources were observed during the teaching phase when learing number bonds. When using material resources to teach a number and its bonds, the student exhibited 3.93-7.70 motivational behaviours per interval (M=5.52 (1.48)), the intervals for each number ranged between 1.02 and 8.15 (M=3.75 (2.79)). When using digital resources he exhibited 4.20-5.52 behaviours per interval (M=4.91 (0.61)), the intervals ranged between 2.08 and 11.02 (M=5.45 (3.87)). Table 1 shows that on average, he exhibited 2.8 times more positive behaviours per interval with digital resources. When learning with digital resources, the student showed *belief in success* (*e.g.*, saying phrases such as, “I can do this”, “Watch me” or “Trust me, I got this” when starting tasks) 2.7 times more per interval compared to when using material resources. *Expressions of happiness* (*e.g.*, cheering, saying “Yes!” when getting the answer right) occurred 2.8 times more per interval with digital resources.

Negative behaviours per interval occurred similarly when using either resource. The student expressed *refusal to work* (*e.g.*, saying, “I’m done”, “I don’t want to do this, don’t make me”, trying to close the application) 2.3 times more and *disbelief in success* (*e.g.*, saying “I can’t do it”, “I don’t know” or “It’s too hard” if he had previously answered incorrectly) 1.3 times more per interval when using digital resources. *Expressions of negativity* (*e.g.*,

grunting, sighing, saying, "I don't like this" when tasks seemed repetitive) occurred 2.8 times more per interval when using material resources.

Off-task behaviours per interval occurred 3.2 times more with material resources. He mainly used *social strategies* (*e.g.*, asking how the teacher or her pets are doing, reminiscing, making silly faces at the teacher). Those occurred 6.3 times more with material resources than with digital resources. *Other off-task behaviours* (*e.g.*, playing with the items (markers, counters) on the table, looking out of the window, talking to himself, not listening) occurred 1.7 times less per interval when using digital resources.

Table 1. Frequence of the motivational behaviors per interval.

Behaviour subcategories	**Material resources**			**Digital resources**		
	M	*SD*	Range	*M*	*SD*	Range
Positive behaviours						
Belief in success	0.43	0.40	0-0.98	1.17	0.32	0.96-1.63
Expressions of happiness	0.48	0.61	0-1.44	1.35	0.53	0.88-1.93
Total	0.91	0.54	0.22-1.44	2.51	0.38	1.99-2.89
Negative behaviours						
Refusal to work	0.23	0.31	0-0.65	0.54	0.30	0.27-0.96
Disbelief in success	0.45	0.34	0-0.96	0.58	0.44	0-0.96
Expressions of negativity	1.07	0.63	0.37-1.97	0.38	0.32	0-0.66
Total	1.74	0.56	0.86-2.39	1.50	0.34	1.20-1.99
Off-task behaviours						
Social strategies	1.83	1.11	0.48-3.02	0.29	0.22	0-0.48
Other off-task behaviours	1.05	0.49	0.48-1.75	0.61	0.57	0-1.20
Total	2.87	1.54	0.96-4.55	0.90	0.61	0.22-1.68

To see if the type of material or digital resource also affects the student's motivational behaviour, behaviours that occurred when using counters with and without the added game aspect, and behaviours he exhibited when using the PinkCatGames website or building the monster but not using counters were marked differentially.

Figure 3 shows that on average, out of all the positive behaviours per interval, most occurred when the student used the digital counters (M=1.05 (1.29)), although 69% of the behaviours were exhibited when learning the number 3, which was also the first time he used

them; therefore, he wanted to try using them independently and cheered when he was successful. When learning with the digital counters, per interval, he expressed *belief in success* on average 0.37 times (SD=0.41) and *expressions of happiness* on average 0.69 times (SD=0.89). 39% of the positive behaviours occurred when using the digital game without counters (M=0.97 (0.65)), with 34% of the behaviours occurring when learning the number 10. The student enjoyed the interactive website and showed *belief in success* (M=0.51(0.38) by saying "I got this" when presented with a new task and *expressions of happiness* (M=0.46 (0.33)) by laughing when the characters on the game danced or played music to reward him for answering correctly) approximately 7 times more than when putting different body parts on the monster picture when using material resources (M=0.07 (0.16); M=0.07 (0.16), respectively), which was also when, on average, least positive behaviours occurred: 0.70 times per interval and only when learning the number 5. The student did not express *belief in success* when using material counters with the added game aspect and showed *expressions of happiness* only when learning the number 4 (0.96 times per interval).

Out of all the negative behaviours per interval, most occurred when using digital counters (M=1.21 (0.41)). Compared to negative behaviours when using material counters (M=0.87 (0.78)), the student expressed *refusal to work* (M=0.14 (0.21)) 3.9 times more with digital counters (M=0.54 (0.30)). He would say he does not want to use those counters, try to close the application or just say he is done and stop working. No *refusal to work* was exhibited during material or digital tasks with the added game aspect with or without counters. Expressions of d*isbelief in success*, such as saying he does not know the answer or solve the task, saying the task is too hard, occurred most when using digital counters (M=0.41 (0.49)) only when learning numbers 3 and 6, and with material counters (M=0.40 (0.35)). Least behaviours of *disbelief in success* per interval occurred with the material game with and without using counters and only when learning number 8 (0.25 times and 0.12 times, respectively). *Expressions of negativity* occurred most when using material counters (M=0.33 (0.45)) and digital counters (M=0,26 (0.19)) when the student had placed the counters incorrectly, which resulted in him answering incorrectly and not wanting to use the counters, saying he does not like the task; and when tasks became repetetive (*e.g.,* deconstructing a number several times). Least *expressions of negativity* occurred with material game and counters, only when learning number 5 (0.35 times per interval).

Most off-task behaviours occurred when using material counters (M=1.54 (1.16)), 45% when learning number 5 (3.50 times per interval), and least when using digital counters and game (M=0.05 (0.09)). Most commonly, the student used *social strategies* when using

material counters (M=0.93 (0.92)), 53% of the behaviours occurred when learning number 5 (2.45 behaviours per interval). The student would ask the teacher questions about her or her family or talk about things that had happened at school or home. With digital counters, the student used social strategies only when learning the number 10 (0.27 times per interval). No use of *social strategies* occurred when using digital counters with the game, while 0.47 behaviours per interval (SD=0.54) occurred when using the material counters with the added game aspect. *Other off-task behaviours* occurred most when using material counters (M=0.61 (0.44)) and digital counters (M=0.50 (0.53)). Typical behaviours were fidgeting with objects on the table or his clothes (*e.g.*, taking off his socks), playing with the digital counters to hear the sound they made when erased and looking outside the window. Least *other off-task behaviours* occurred when using the digital counters and game – only when learning the number 10 (0.18 behaviours per interval) and when learning with the digital game without using counters when none occurred.

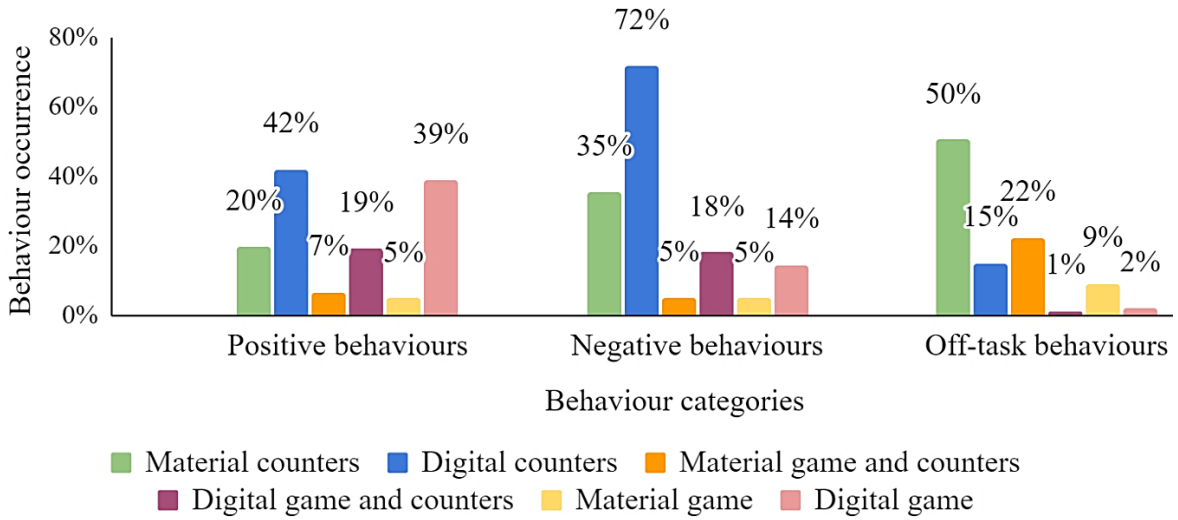

Figure 3. Motivational behaviours per interval when using material or digital resources.

Discussion

The goal of this research was to develop the basic number skills of one student with Down syndrome and to see if learning outcomes or motivational behaviours differ when material or digital resources are used for teaching.

The first research question was whether using material or digital resources would affect the student's knowledge and skills retention differently. The author conducted a baseline assessment to find the student's skill level before the intervention. Analogical tests were presented on paper and in the virtual educational platform IXL (2022) to see if the results were similar or possibly affected by the resource type. For the most part, results did not differ between the resources. A detailed analysis of the results is presented below.

Mathematical skills

Mathematical skills before the intervention

On **the estimation** subtest, the student estimated sets of 20 and 80 correctly on both tests, a set of 30 correctly on the digital test but not on the material test, a set of 50 correctly on the material test but not on the digital test. Sets of 40, 70 and 90 were solved incorrectly. These results might indicate that the student's sense of number is still developing in ranges of 30 and up (Chinn, 2020). Lanfranchi, Berteletti *et al.* (2015) noted that although children with DS performed better compared to typically developing children of the same mental age when estimating on a number line within 100, experience with numbers might affect the results. Sets of more than four objects are perceived using the ANS (Feigenson *et al.*, 2005). Therefore, mistakes might also be caused by problems in ANS, although this has been said to be developed better in people with DS than the OTS (Sella *et al.*, 2013). The scattered placement of dots, instead of being in rows of ten, might have made the task more difficult, as sets of ten were not easily distinguishable.

On the subtest on **positional words**, the student solved all tasks on the word "after", one task on the word "between", and one task on the word "before" on the digital test after guidance, but others incorrectly. This might be a sign of difficulties in language related to mathematical concepts on position and difficulties in visuospatial reasoning (Hannell, 2005). On both tests, the student would frequently say the number after instead of between or before. Lanfranchi *et al.* (2010) have noted that children with DS have difficulties switching between tasks, which might have caused the mistakes in current research since the tasks were presented in a mixed order.

When counting **up and down by ones on a number line**, the student solved most tasks on numbers up to 29, but larger numbers caused more mistakes. The mistakes were similar on the material and digital test and occurred mainly when crossing the tens boundary, when he would answer with a random number, count up instead of counting down, or count up by tens. Mistakes in crossing the ten boundary indicate difficulties in remembering the sequence and understanding base ten system (Chinn, 2020). On **step-counting tasks without pictures**, the student did better on the subtest that had a number line. He counted up by tens independently twice on the material and digital tests, once down by tens independently on the material test, and once down with guidance on the digital test. When counting by fives, the student solved one task on counting up on the material test after guidance and one test on counting down on the digital test. He solved no tasks on counting by twos. On several occasions, he would count by ones or count by tens on the wrong tasks. When **step-counting with pictures**, the student counted by tens after guidance but not by twos or fives. He would try to count the pictures by ones, possibly due to a preference for counting rather than using a strategy. The results and mistakes may have been caused by the fact that the student has yet to learn the strategies of counting by twos and fives. However, when considering that the student mixed "-ty" and "-teen" endings on several tasks on this subtest as well as others, he might have also counted up by "-teens" when counting up by tens. Such mistakes may be caused by auditory discrimination deficits (Emerson & Babtie, 2013), which his partial hearing loss might influence. On step-counting tasks, mistakes were more frequent when the tasks were on numbers over 20. When counting by ones, errors occurred more with numbers over 29, which might mean that his sense of larger numbers is not yet fully developed. Counting skills are affected by sequential and working memory (Emerson & Babtie, 2013) and verbal abilities (Hannell, 2020). Previous research has found that children with DS have poorer verbal and visuospatial memory (*e.g.,* Lanfranchi *et al.,* 2009); other researchers have hypothesised that difficulties with short-term memory may affect their counting skills (King *et al.,* 2017).

The **comparison** subtest also had tasks with decreasing difficulty: comparing numerals, large sets and small sets. On the material test on **comparing numerals**, he chose answers at random; on the digital test, he showed inconsistencies when comparing one-digit numbers or one-digit *versus* two-digit numbers. The comparison symbols and words needed to be explained on the material test; on the digital test, he did not know what "equal to" meant, which may be a sign of difficulties in understanding the mathematical language related to comparisons (Hannell, 2005). The student made mistakes in other subtests on numbers 30 and up, which further adds to the possibility that his sense of numbers over 30 is not yet fully

developed. Onnivello *et al.* (2019) have suggested that understanding symbolic number representations may depend on a person's ANS functioning. Although this seems to be better preserved than OTS in children with DS (Onnivello *et al.*, 2019), it is in line with their mental rather than chronological age (Sella *et al.*, 2013). Sella *et al.* (2013) found that people with DS solve digit-to-set comparison tasks on numbers up to 9 similarly to typically developing peers of the same mental age, the results seem to depend on how significant the difference between the two numbers is. However, the numbers in the present research were larger, which should be considered when forming conclusions. The tasks were likely too difficult, which may have caused anxiety and impulsive, non-reflective answering (Chinn, 2020) and additional mistakes when comparing smaller numerals. The subtest on **comparing large sets** of up to 80 in rows of ten was only conducted on paper due to the lack of a digital equivalent. The student compared sets 20 and 30 but needed guidance or made mistakes with sets of 40 and up and when comparing equal sets. The errors and results add evidence to the conclusions made on other subtests – his sense of number might not be as developed in numbers over 30, difficulties may stem from possible deficits in ANS. Although Sella *et al.* (2013) noted ratio-dependence, this was not evident in the current research. Task difficulty may have also depended on presentation. Onnivello *et al.* (2019) noted that children with DS might achieve better results when comparison tasks are presented sequentially rather than simultaneously, as was done in the current research. The last subtest was on **comparing small sets** of up to 10; the student solved most of them correctly. Tasks on the material test were solved by counting, and tasks on the digital test were mainly solved by comparing the pictures visually. Visual comparison may have been more difficult on the material test due to the placement of dots and the set size, as most sets were larger than four and, therefore, over the subitising range mediated by OTS (Feigenson *et al.*, 2004). Sets on the digital test consisted of up to five pictures and were in two rows. On the digital test, when numbers were up to four, he compared sets correctly if the other set was less than four, making only one mistake due to initially misreading. The results show that the student can correctly compare sets of up to four by subitising and sets of up to ten by counting. Although previous research (*e.g.*, Sella *et al.*, 2013) has found that students with DS have a poorer OTS and their results depend on difference ratio, this was not evident in the current research.

Most tasks on **number bonds** were solved incorrectly, except for an early addition task on the material test. Since he did not know any of the bonds of ten, the author simplified the tasks by narrowing down options or handing him counting cubes to solve the task. When using counting cubes, he needed guidance to visualise the addition tasks. He divided them

into two sets on one task but did not match the sets to numerical additions and would proceed to count all the cubes, which might be a sign of difficulties in linking objects to numerals (Chinn, 2020). Preference for counting rather than using a strategy might indicate difficulties understanding that numbers can be made of smaller numbers (Emerson & Babtie, 2013). An over-reliance on counters may mean that the student is still in the concrete operational stage (Chinn, 2020). On the material test, he also refused to continue on three tasks. Similar results – not knowing number facts, counting all visuals and refusal to solve the tasks – were also noted by Noda Herrera *et al.* (2011) in students who had learned to count 30 objects but did not understand place value and were only starting to learn calculations, and might indicate working memory deficits (Noda Herrera *et al.*, 2011).

The student solved all **number sentence calculations** with a number line, first with guidance and later independently. The number line was considered to be more difficult than using counting cubes based on previous information from the student's individual learning plan reports. It was noted that he had used counting cubes when calculating but had difficulties understanding how to use the number line.

Most **addition sentence** tasks were solved correctly; one mistake occurred on both tests. He added one number twice on the material test, possibly due to difficulties in verbal working memory (Hannell, 2005). The incorrect answer on the digital test was caused by failing to follow the one-to-one strategy when counting, a typical mistake on all calculation tasks, which might mean the strategy is still developing (Emerson & Babtie, 2013). The mistake may also be caused by memory deficits (Noda Herrera *et al.*, 2011), such as problems with short-term memory (King *et al.*, 2017), visuospatial and verbal working memory (Lanfranchi *et al.*, 2009) and problems with OTS, which is activated when perceiving small numerosities (Lanfranchi, Berteletti, *et al.*, 2015). Counting skills are also affected by a person's physical abilities, such as fine-motor skills (Onnivello *et al.*, 2019) and vision (Porter, 2019) and may have affected the results in the current research.

The student solved all but one task on the **subtraction** subtest correctly. The incorrect answer on the digital test was caused by the student calculating according to the author's example instead of the number sentence on the task, which indicates difficulties with working memory, that may also account for common mistakes on all the calculation tasks such as counting to and from the wrong number (Hannell, 2005). On the subtraction tasks, he would also try to add instead, which might be evidence of a poor understanding of the subtraction operation, working memory problems (Emerson & Babtie, 2013) and problems with executive functions (Lanfranchi, Aventaggiato *et al*., 2015).

In conclusion, the student did not know any number bonds and had difficulties calculating due to problems with following the one-to-one strategy, remembering what to calculate and choosing the correct operation. Children with DS seem to struggle with calculations (Daunhauer *et al.*, 2020; King *et al.*, 2017), likely due to poorer cognitive abilities such as executive functions, memory, and visual or motor deficits.

Addition word problems proved to be too difficult for the student, and he did not solve any of them. He answered with random numbers or with a number from the text; no differences between the digital and material subtest were noted. One strategy he tried to use was counting on his fingers, although the numbers were selected incorrectly. Similar mistakes were reported by Noda Herrera *et al.* (2011). Not knowing the strategy of how to solve a word problem might be caused by difficulties in verbal working memory and a lack of systematic practice with visualising the problems and using specific guidance and examples to learn the algorithm (Emerson & Babtie, 2013). Children with DS have been noted to have poorer verbal abilities (Roch *et al.*, 2021) and executive functions (Lanfranchi *et al.*, 2010), that may have made understanding and solving word problems more difficult.

The results of the baseline assessment indicated that the student's number sense is affected by his poorer cognitive and physical abilities, which cause difficulties in counting, understanding how numbers are made and working with concrete and abstract objects. This shows that he needs additional practice working with concrete objects and should learn how to make numbers within ten (Emerson & Babtie, 2013), which is what the teaching phase focused on. As difficulties were similar on the material and digital test, the context did not seem to affect results, so the two resources were used alternatingly during the teaching phase.

Mathematical skills after the intervention

The final assessment was conducted ten days after the teaching and revision phase. As the intervention focused on making numbers within ten and applying the learned skills to solve number sentences and word problems, only the learned skills were assessed. Analogical tests were conducted using material and digital resources to see if results differ between the two resources used for teaching,

The student showed an improvement in solving **number sentence calculations** after the teaching phase. He solved all **addition sentences** but used mostly counters or drawing for visualising, solving only one task using a number line on the material test. He knew one bond of 10 but wanted to initially solve the task with counters, which suggests that he is too reliant on them (Chinn, 2020). Most early addition tasks were solved independently on both tests. On

the material test, he asked for counters when solving an early addition task when the second addend was bigger than one but solved it after the teacher asked if he knew the answer already. On a similar task on the digital test, he preferred to use counters instead, indicating that he did not remember the commutative properties of addition. The student counted instead of subitising four counters on the material test, which may indicate deficits in OTS (Feigenson *et al.,* 2004) that have also been noted in earlier research (*e.g.,* Sella *et al.,* 2013). All tasks on adding zero were solved independently. He needed less guidance on the digital tests, which may be due to his preference for using the tablet but also because there were more early addition tasks as well as additions with zero.

Subtraction sentences seemed to be more difficult for the student, which has also been noted in previous research (*e.g.,* González *et al.*, 2015; Noda Herrera *et al.*, 2011). He solved none of the tasks by recalling number facts and needed to use visualisation on all tasks, including early subtractions. One task on both tests, subtracting zero, was solved independently, other tasks were solved by visualising with counters or by drawing, or with a number line, and two on the digital test were solved incorrectly. The number line was used once on the material test when solving an early subtraction. However, when using the number line on the digital test, he failed due to adding instead of subtracting. This may be explained by anxiety caused by previous failure on the task but also due to using the digital number line the first time. The other mistake was on a task on subtracting all, which he did not understand and would try to add instead, a common mistake on other tasks as well. Similar mistakes have also been noted by other researchers (*e.g.,* González *et al.*, 2015; Noda Herrera *et al.*, 2011), who argued that it may be caused by difficulties understanding the concept of subtraction (González *et al.*, 2015). Occasionally, he would initially add the counters or visuals and then subtract, which caused mistakes and frustration, although on most occasions, he solved the task after guidance. This type of mistake may have happened due to the way subtraction sentences were visualised in the teaching phase. As one part of teaching subtraction was visualising the sentence with counters similarly to the addition sentences, the student might have, on occasion, forgotten the concept of subtraction and remembered the visual representation. However, considering that on several occasions the student solved the subtraction task correctly and also verbalised his actions, no strong conclusions can be made. Verbalising one's actions shows reasoning, planning, and understanding (Hannell, 2005), which in turn, shows that he did not choose answers at random, as it might have been on some tasks on the baseline assessment.

There were also similar mistakes on both addition and subtraction tasks, such as choosing the wrong operation, possibly due to difficulties in switching between tasks, as the additions and subtractions were mixed. This, as well as problems with planning his steps to solve the task correctly, may be caused difficulties with executive functions (Lanfranchi, Aventaggiato *et al.,* 2015), which have been noted to be poorer in children with DS (Lanfranchi *et al.,* 2010). Another mistake the student made was adding or subtracting the wrong numbers, which may imply problems with verbal working memory (Hannell, 2005), which have also been noted in earlier research (*e.g.,* Lanfranchi *et al.,* 2009). The student's limited knowledge of number bonds may indicate difficulties in long-term memory (Hannell, 2005), which seems to be impaired in children with DS (Godfrey & Lee, 2018). His preference for using counters might be due to memory difficulties but also show a reliance on a strategy that is easier (Noda Herrera *et al.,* 2011). On the first day of the final assessment, he did not understand how to visualise by drawing and would refuse to try. After additional guidance on the second day, he used representations more than counters on both tests. It was evident that the student's level of independence declined, and more mistakes occurred on even simpler tasks after previous failures. This may have caused anxiety, which might have made the tasks seem more difficult and caused mistakes (Emerson & Babtie, 2013). The number line was used only when he had initially failed with other resources. Considering that he had difficulties working with objects, this should be counted as an improvement since representational resources, such as the number line, are used after the student has mastered using concrete objects and before working with symbols (Agrawal & Morin, 2006). Using representations and working with symbols before the student understands what set the symbol represents may inhibit understanding the relationship between numbers and cause gaps in number sense development (Emerson & Babtie, 2013). However, since the student still needed guidance when working with concrete objects, further practice may be necessary, although other strategies and the bonds of ten should still be learned since an overreliance on counters may inhibit further progress (Chinn, 2020). The use of digital or material resources for teaching or testing did not seem to affect the student's skills.

The student also showed an improvement in solving **word problems.** Although guidance and visualisations were necessary, he used the word problem algorithm and solved most of the tasks. All **addition problems** were solved correctly on both tests. He followed the algorithm independently on two of the material tasks and three of the digital tasks, although he needed guidance to answer with a sentence on one of the digital tasks.

Subtraction problems were more difficult, likely due to subtractions being more difficult for him and other children with DS (Noda Herrera *et al.*, 2011). Although he solved most of the tasks, one task on the material test and three on the digital test were solved incorrectly. The difference between the two tests may be due to the simpler sentence structure and the familiarity of situations (Erg & Kontor, 2013) on the material test. Since IXL (2022) provided the digital tasks, the wording needed to be simplified verbally, and the added strain to his verbal working memory made them more difficult. Simplification was necessary on all subtraction tasks but only on one addition task.

A mistake that occurred on all word problem subtests was choosing the wrong operation. This happened more on the material subtests, possibly due to addition and subtraction problems being presented in a mixed order and causing difficulties in switching between tasks caused poorer executive functions (Lanfranchi *et al.,* 2010). The mistake occurred most on the subtraction problems, when, on occasion, the student would explain which operation he would use, but solve using the opposite. Similar mistakes were noted by Noda Herrera *et al.* (2011) when students with similar number skills would solve subtraction word problems as additions due to seeing them as similar operations. It may also indicate difficulties with working memory or executive function but also show that the student does not yet fully understand the concept of subtraction. A mistake that occurred on the baseline and the final assessment was answering with a random number or a number from the text, which may show that he answered impulsively without analysing the problem (Noda Herrera *et al.,* 2011). It happened more on the subtraction tasks on the final assessment, possibly due to misunderstanding the problem (Hannell, 2005).

Additionally, typical mistakes that occurred throughout the teaching phase and on both assessments were failing to follow the one-to-one strategy and mixing up “-ty” and “-teen” endings. As mentioned earlier, mistakes in counting strategy may be caused by problems with memory (King *et al.,* 2017; Lanfranchi *et al.,* 2009; Noda Herrera *et al.,* 2011), difficulties with OTS (Lanfranchi, Berteletti, *et al.,* 2015) and also poorer motor (Chen *et al.,* 2014) and visual abilities (Porter, 2019). Confusion between number word endings might be caused by deficits in auditory discrimination (Emerson & Babtie, 2013), possibly caused by the student’s partial hearing loss.

Motivation

The second question in this research was if using material or digital resources would affect the student's motivational behaviour. According to Vlachou and Farrell (2000), mastery motivation should be measured during challenging tasks. The behaviours were assessed during the teaching phase when a number's bonds were taught since this was perceived as the most challenging. As material and digital resources differed between tasks, resource-related aspects which might have affected the outcome were also taken into account.

The time spent teaching a numbers bond varied, although it mostly grew as the numbers increased. In addition to the numbers increasing, the duration of teaching a number's bonds might have been affected by the student's energy levels but also projects in other classes, where he had to put in more effort than regularly. For example, during the week of learning number 8, he also worked on a lengthy project with a higher cognitive demand than usual, which might explain the reason why it took longer to learn the bonds. However, when looking at behaviours per interval, the numbers are comparable, and the differences between motivational behaviour when learning with material or digital resources are evident.

The student showed more positive behaviours when learning with digital resources, mainly when using counters or the Pink Cat Games platform without counters. Preference for digital resources has been previously noted by González *et al.* (2015) when students with DS chose to use a digital whiteboard over using a paper for practising. The results in the current research stayed the same in positive behaviour subcategories as well. The student showed more *belief in success* and *expressions of happiness* when numbers were taught using digital resources. Although the rates varied for numbers, there was a clear difference between the two resources. On average, *belief in success* was highest per interval when the student used the Pink Cat Games website without using counters. Task difficulty might explain the results, as this resource was used on tasks such as calculating on a number line or matching pictures to addition sentences, which the student might have seen as "easier" than deconstruction tasks and the construction task when matching additions to a number. However, most behaviours per interval were expressed when the student used the material or digital counters for the first time, when learning numbers 2 and 3, which may indicate curiosity for the novel resource. Most *expressions of happiness* per interval occurred when using digital counters and the website Pink Cat Games without the counters. The student liked the sound the counters on The ToyTheater website made and was interested in trying all the variations of counters on ICT games. The Pink Cat Games website had various characters and each game would reward

the student with visual and/or auditory feedback throughout the game, which made the student cheer and laugh. Similar results were noted by Agheana and Duţă (2015), where children seemed to be more interested and motivated by the auditory and visual aspects in addition to the feedback in the digital resources rather than the feedback they received from the teacher. In the current research, the visual feedback on "Making Number Bonds" and written feedback on "Make Another Number Sentence" applications used as digital counters did not seem to motivate the student as much compared to the other digital resources. Cuskelly and Gilmore (2014) have said that belief in themselves and experiencing joy when succeeding are aspects of motivation, which will keep the student engaged and actively participating in learning. Therefore, the student's interests and strengths should be considered when planning for activities. The results of the current research show that the student enjoyed the digital resources and the playful aspects and the visual and auditory feedback it provided more. As no differences in academic achievement were noted between the resources, the motivational aspect should be considered when planning future learning activities.

The differences between resources were not as clear when looking at negative behaviours. Overall, the student showed equal amounts of negative behaviour with either resource, which might also be explained by the challenging nature of the tasks, rather than be dependent on the aspects of either resource. Differences arose when looking at the behaviours by subcategory. Expressions of *refusal to work* occurred mostly when using counters and more frequetly when learning with digital resources. Children with DS's tendency to avoid a task that seems to be difficult for them has been noted by previous researchers (*e.g.,* Agheana & Duţă, 2015; Wishart, 2001). Agheana and Duţă (2015) also found that concrete material objects were seen as more difficult than digital resources, contrary to the findings in this research. However, the digital resource Agheana and Duţă (2015) used was an educational game with characters and the alternative, material resource was teacher directed learning with objects and no noted game aspects. In this research the student did not express any *refusal to work* when the game aspect was added, therefore the negative aspects of the counters must be considered. When working with the digital counters on ICT Games or "Making Number Bonds", the student would often place the virtual manipulatives in piles, which would also prevent correct counting, therefore he would get frustrated and want to stop. Occasionally, the student had difficulties moving the digital counters, which seemed to be affected by both the occasionally nonresponsive iPad screen but also due to the student's difficulties with fine motor skills. Difficulties, in addition to slowness occurred also when using material counters. Chen *et al.* (2014) have noted a correlation between the fine motor skills and verbal working

memory and cognitive planning, therefore the students physical and cognitive abilites may account for mistakes and negative emotions in the current research. *Disbelief in success* occurred slightly more with digital resources and also only when using counters. Working with counters (*e.g.*, dividing them into two sets, matching them to numerals) proved to be difficult even before the intervention. During the teaching phase, expressions of *disbelief in success* occurred more after the context (digital or material) was switched and most when first beginning to work with the counters. As the differences between resources were slight, task novelty and difficulty may explain the behaviours more than the aspects of the resources, as well as previous negative experiences in general. Cuskelly and Gilmore (2014) hypothesised, that children with DS have experienced more failures compared to those with typical development, therefore might not believe in their abilities as much. Emerson and Babtie (2013) have also pointed out, that anxiety in mathematics causes a loop – difficulties lead to failure, which results in anxiety for future mistakes, which, in turn, may cause a situation, where the student is unable to perform the simplest mathematical operations. Such a loop was also evident in both the teaching phase and the final assessments – on several occasions, if the student had initially failed, he would proceed to make mistakes in tasks he had previously solved without mistakes (*e.g.*, using counters incorrectly resulted in frustration and making mistakes on a number line). *Expressions of negativity* occurred more when learning with material resources and mostly when working with counters, but no pattern between the numbers emerged. Failures in solving a task due to misplacing counters and task repetition (*e.g.*, when deconstructing a number several times) seemed to cause more behaviours when either resource was used, although since the specific topics in the lesson were not measured, no strong conclusions can be made. In addition to misplacing the counters, the student needed to be reminded to use only the set amount of counters to prevent miscalculations. This occurred less with material resources, since only the necessary amount was on the table. In all of the digital resources, the number of counters was unlimited, so when constructing or deconstructing a number, the student would frequently take new counters instead of moving the original ones into a correct slot. Being asked to use only the set amount would occasionally frustrate the student and cause him to show various negative behaviours. In conclusion, negative behaviours occurred with both resources, although digital resources, specifically the counters seemed to frustrate the student more.

The biggest differences between resources occurred in off-task behaviours. The student either talked about irrelevant topics or focused on something other than the task three times more when learning numbers taught with material resources. Use of *social strategies*

occurred more than *other off-task behaviours*. The student would ask questions or talk about an event occurred mostly when learning with the counters, less when using counters with the added game aspect. Previous research has shown that children with DS tend to use social behaviour to avoid solving tasks which seem difficult (Jahromi & Kasari, 2008; Kasari & Freeman, 2001). Jahromi and Kasari (2008) found that, although children with DS showed similar amounts of negative expressions as did typically developing peers of the same mental age, unlike them, children with DS would interact with the researcher but not seek for assistance on the task, therefore the goal was not to relieve frustration towards the task. Similar behaviour was noted in this research, as the topics the student talked about had nothing to do with the task, counters or mathematics in general, and, although the student accepted assistance most of the time, he did not ask for it. This may indicate a lack of a coping-strategy, and to practice it, teachers and caregivers should provide the student opportunities to practice asking for help and learning from others situations that are mildly challenging (Jahromi & Kasari, 2008). Kasari and Freeman (2001) found similar task-avoidance strategies and argued that, although social skills are relevant and may benefit childen with DS in many aspects, being too social during challenging tasks may have an adverese affect, as this reduces the time that should be spent on learning. *Other off-task behaviours*, when the student was either looking elsewhere or played with items on the table, also occurred more when learning with material resources, mostly when using counters. Since no pattern between numbers was seen and the times and topics for when behaviours were expressed were measured, there may be many possible explanations to why they occurred. The tasks might not have been as challenging and therefore caused boredom (Cuskelly & Gilmore, 2014). The student's tiredness may also account for the behaviours. *Other off-task behaviours* would frequently co-occur with using *social strategies*, more during times when the student was tired, for example due to the time of day or mentally exhausting tasks in other lessons. Breaks were taken in the middle of the lesson or when it seemed like the student needed one, although on some days the student would still exhibit off-task behaviours afterwards, therefore some topics had to be continued and revised in the next lesson. Overall, off-task behaviours occurred least when the student was solving tasks with or without counters on the Pink Cat Games website, which may imply that the added game aspect allowed him to focus on the task even when tired.

Conclusions

The results indicated that the student's calculation skills and strategy use improved after the intervention but using material or digital resources did not provide a different outcome. He was able to use concrete and representational objects to solve calculations but did not remember most of the number facts. Addition tasks seemed to be easier than subtractions, both number sentences and word problems. Motivational behaviours seemed to be affected by task difficulty and the type of resource used – more positive and less off-task behaviours occurred with digital resources, negative behaviours occurred similarly with both resources.

Practical implications

Although memorising key facts might prove to be difficult due to the student's memory deficits, working with concrete and representational objects to visualise the bonds, applying the knowledge in various situations and discussing the relationships between the numbers should be done routinely. Dot patterns, such as dice patterns, will help visualise number bonds, develop the student's subitising and grouping abilities and number sense and will therefore help him progress to a more efficient strategy than counting items in small sets by ones (Emerson & Babtie, 2013). The student's interests should be considered when choosing resources. He showed less off-task and more positive behaviours when using digital resources, especially if it had a game aspect and provided visual and auditory feedback, therefore digital resources and games should be included in practicing learned skills to provide various experiences for practice. Based on the suggestions of Emerson & Babtie (2013), to develop the student's sense of larger numbers and counting skills, he should also practice counting various objects in large sets and match those to numbers. Making sets of ten with the objects will aid in understanding place value and developing the skill of counting by tens. Estimating the answer or set size should be done before counting or calculating to develop the student's number sense and the skill of assessing if the answer is sensible.

The student should also be encouraged to explain his thinking to limit impulsive answering, improve executive functions, and provide the teacher with valuable information on what skills might still need developing. To limit mistakes in auditory discrimination of numbers with "-teen" and "-ty" endings, the ending should be emphasised by the teacher and the student. This should be done when working with the numbers in general and during specific practice. As the student's skills were assessed only after a short time period had passed after the teaching phase, it is not possible to say if he retained the learned skills and

knowledge after a longer period. However, considering that he had worked on calculations in his previous studies but showed a limited understanding of them on the baseline assessment, it is also possible that calculation will always be complicated for him, as it seems to be for other people with DS (Daunhauer *et al.*, 2020). Learning how to use a calculator will be useful in everyday life and also when learning more abstract topics such as percentages or fractions, as was shown in the research by Monari Martinez and Pellegrini (2010).

Although this research focused on teaching one student whose educational and language background is untypical for the Estonian school system, the results might still benefit educators who are looking for additional resources that would be both educational and motivating. The main positive aspects of the digital resources were the auditory and visual feedback, so the language aspect of the programs might not affect usability as much, especially with the teacher's guidance. When considering the language aspect, it is important to note that there are also students in Estonia whose first language is not Estonian, newly arrived immigrants, for example. In addition, some students might not study in English but can still understand it, so using resources in English may also benefit them.

To the author's knowledge, there are no websites or applications in Estonian that provide virtual manipulatives or educational websites with game aspects that allow for such modifications as the resources used in this study, where the teacher could design the specific tasks based on the student's knowledge and interests and also see his progress. This information might be beneficial and inspirational to Estonian educational technologists, who might want to design digital resources that combine modifiability, games and manipulatives into one program.

Limitations

Typically to action research, the sample size was small and purposive, the research aimed to find answers to sample-specific questions and the student's unique educational and language background did not allow for a larger sample size or a control group. Therefore, no generalisations about a population can be made. An assessment after a longer period had passed from the teaching phase (*e.g.,* Lanfranchi *et al.,* 2021) could have shown how well the student retained knowledge and enabled more conclusions about the teaching phase's effectiveness on the student's number skills to be drawn. Other aspects of the research, the one-on-one teaching environment and the teacher's familiarity to the student may have affected the results. He had no one else to talk to, so although most interactions were not task-related, if there were other students in the class, off-task behaviours might have differed. As

the teacher was familiar with the student and worked with him daily, the student might have exhibited different levels of motivational behaviour if the teacher had been someone he was less familiar with. Although there were behaviour-rate differences between the numbers, considering the behaviours were measured throughout the teaching phase, and no pattern emerged, no clear explanations for the differences can be brought out. The student's behaviour may have been affected by his level of tiredness, distractions from outside of the classroom, the student's mood during the day and events that had happened or would happen that might affect his mood or focus. Conducting an interview with the student to assess his mood and tiredness levels may have provided insight if these aspects affect the student's motivational and academic achievement.

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Author's declaration

I hereby declare that I have written this thesis independently and that all contributions of other authors and supporters have been referenced. The thesis has been written in accordance with the requirements for graduation theses of the Institute of Education of the University of Tartu and is in compliance with good academic practices.

Sandra Soomann
/signed digitally/
06.01.2023

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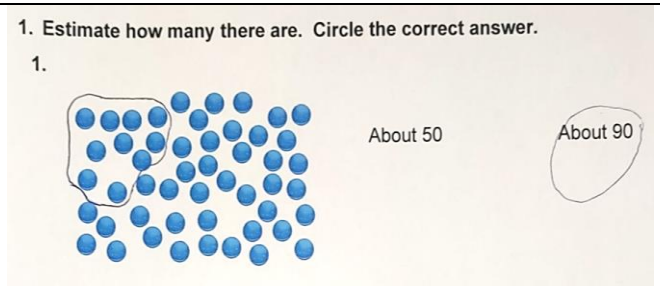
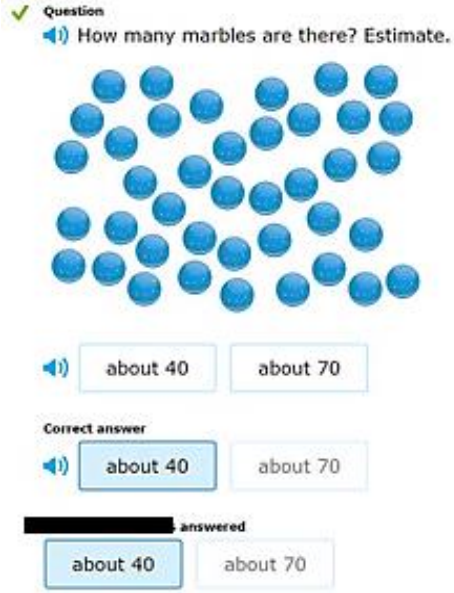
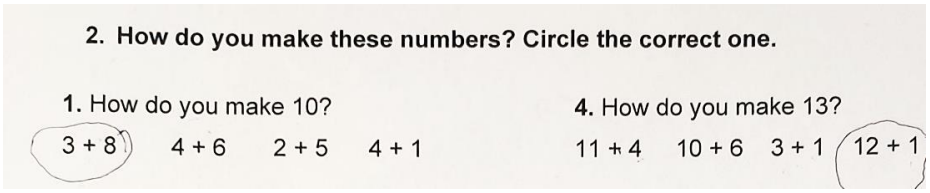
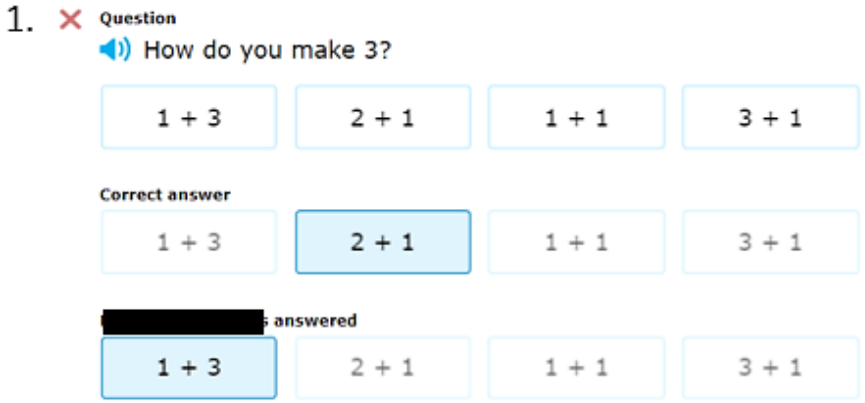
Appendix 1. Baseline assessment tests

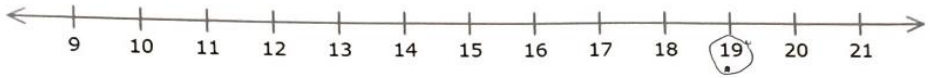
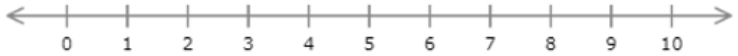
1. Estimation. This subtest aimed to see if the student could estimate the number of dots in sets of 20-90. The ability to estimate is to guess, without counting, how many items are in a set, therefore the student can guess the answer before calculating and assess if it makes sense (Emerson & Babtie, 2013). The material test was conducted in the first week, the digital test in the second week.

Test	Example	Tasks
Material test		**1.** 50 or 90 **2.** 20 or 70 **3.** 40 or 80 **4.** 60 or 30 **5.** 40 or 80 **6.** 70 or 30
Digital test		**1.** 30 or 80 **2.** 40 or 70 **3.** 30 or 90 **4.** 50 or 80 **5.** 50 or 90 **6.** 20 or 90

2. Number bonds. The purpose of this subtest was to see if the student understands that numbers can be made of different combinations or if he has a unitary concept of each number. The tasks were on making number bonds of 2-15. According to Emerson and Babtie (2013), knowing the bonds of ten facts is necessary as this knowledge will be used throughout the number system. The material test was conducted in the first week and the digital test in the second week.

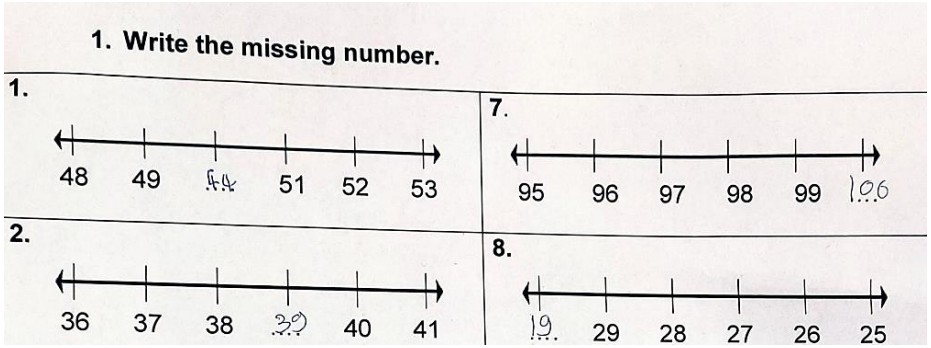
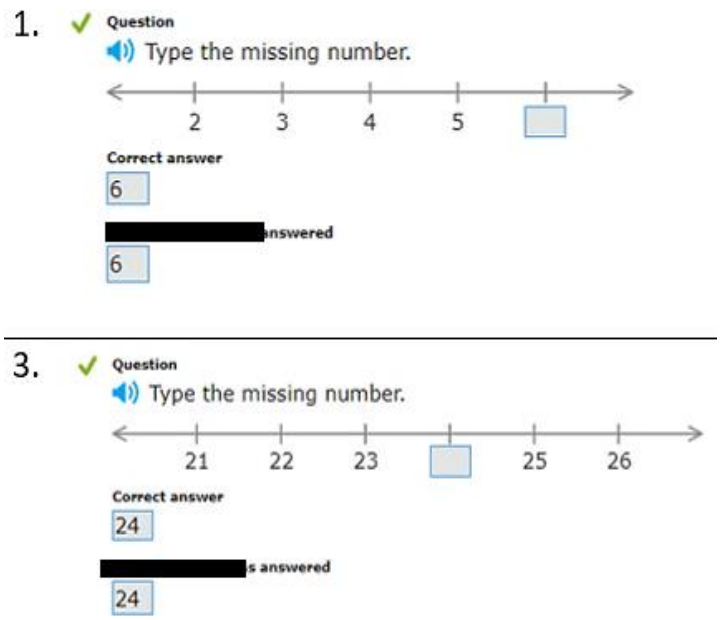
Test	**Example**	**Tasks** *(answer options)*
Material test		**1.** How do you make 10? *(3+8; 4+6; 2+5; 4+1)* **2.** How do you make 8? *(5+2; 3+6; 3+5; 9+2)* **3.** How do you make 7? *(3+8; 4+6; 2+5; 4+1)* **4.** How do you make 13? *(11+4; 10+6; 3+1; 12+1)* **5.** How do you make 15? *(2+10; 9+6; 13+5; 4+4)* **6.** How do you make 12? *(10+3; 8+6; 11+2; 8+4)*
Digital test		**1.** How do you make 3? *(1+3; 2+1; 1+1; 3+1)* **2.** How do you make 10? *(1+8; 3+7; 4+5; 3+6)* **3.** How do you make 5? *(1+3; 3+3; 4+1; 1+5)* **4.** How do you make 6? *(4+1; 3+3; 2+3; 1+6)* **5.** How do you make 4? *(1+3; 2+1; 1+1; 1+4)* **6.** How do you make 2? *(1+1; 1+3; 31; 2+1)*

3. Number sequencing. The subtest consisted of two tests: 3.1. Position words and 3.2. Sequencing on a number. The purpose of these tests was to find out if the student understands and can correctly use the position words “before”, “after” and “between” and knows the sequence of numbers in a range of 0-100. Emerson and Babtie (2013) say that sequencing, along with memory form the basis of learning mathematics. The material subtests were conducted in the first week and the digital subtest in the second week.

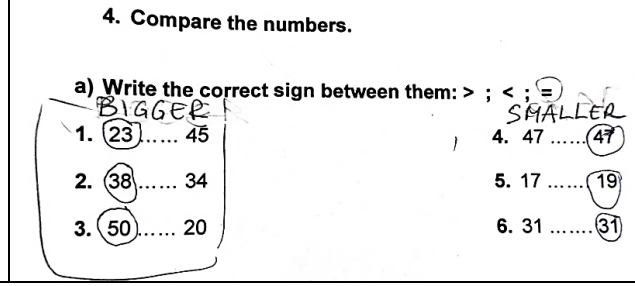
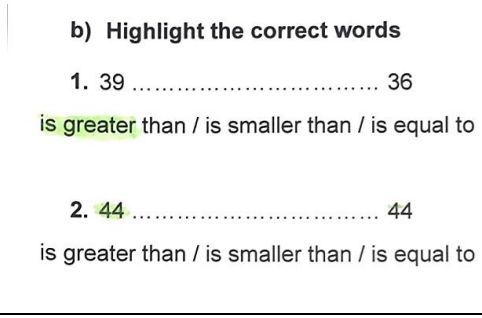
Test	Example	Tasks
3.1. Position words. *The student had to mark or type the number that was before, after or in between the numbers in question.*		
Material test	**4. Circle the correct answer.** **1.** Which number comes just after 18?  	**1.** “After 18” **2.** “Before 78” **3.** “Between 54 and 56” **4.** “After 99” **5.** “Between 29 and 31” **6.** “Before 40”
Digital test	3 ✕ **Question** Which number comes between 7 and 9?  **Correct answer** 8 [redacted] **answered** 10	**1.** “After 6” **2.** “Before 3” **3.** “Between 7 and 9” **4.** “After 21” **5.** “Before 28” **6.** “Between 17 and 19”

3.2 Sequencing on a number line.

The student had to fill the gaps in the number line by counting up or down by ones.

Material test		**1.** 48, 49, …, 51, 52, 53 **2.** 36, 37, 38, … , 40, 41 **3.** 72, 71, 70, 69, 68, …. **4.** 9, 10, …., 12, 13, 14 **5.** …., 20, 21, 22, 23, 24 **6.** 19, 18, 17, 16, …., 14, 13 **7.** 95, 96, 97, 98, 99, …. **8.** …., 29, 28, 27, 26, 25 **9.** 69, …., 71, 72, 73, 74 **10.** 44, 43, 42, 41, 40, …. **11.** …., 56, 55, 54, 53, 52 **12.** 85, …., 83, 82, 81, 80
Digital test		**1.** 2, 3, 4, 5, …. **2.** …., 5, 6, 7, 8 **3.** 21, 22, 23, …., 25, 26 **4.** …., 20, 21, 22, 23 **5.** 13, …., 15, 16, 17, 18 **6.** 24, 25, 26, 27, …, 29

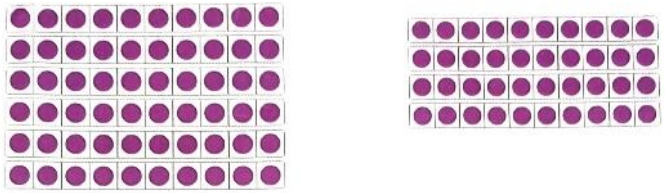
4. Number comparison. These subtests were conducted to see if, and on what level the student can compare numbers or sets. The ability to compare is a basic skill, a part of a developed number sense, and the student who is unable to compare numbers or sets, should not work on more complex tasks like addition and subtraction (Emerson & Babtie, 2013). The initial subtests (4.1 and 4.2) were on comparing numbers up to 85. Tasks on comparing (smaller) sets were prepared in case the student does not solve the initial subtests (4.3 and 4.4). The digital tests were conducted in the first week and the material tests in the second week.

Test	Example	Tasks
4.1 Comparing numbers in a range of 17-50 using the comparison sign. *The initial task was on writing the correct comparison symbol between the two tasks. As the student did not understand them, the material test was simplified and he had to circle the bigger/smaller number. There were no comparable digital tests since the IXL did not have this level separately and the student did not reach a high enough level on the 4.2 digital task.*		
Material test		**1.** 23 *vs* 45 **2.** 38 *vs* 34 **3.** 50 *vs* 20 **4.** 47 *vs* 47 **5.** 17 *vs* 19 **6.** 31 *vs* 31
4.2 Comparing numbers in a range of 1-85 by choosing the correct phrase. *The student had to highlight or choose the suitable phrase that would make the comparison sentence true.*		
Material test		**1.** 39 *vs* 46 **2.** 44 *vs* 44

Digital test	3. Question Which words make this statement true? 6 ____ 6. is greater than / is less than / is equal to Correct answer is greater than / is less than / is equal to [redacted] answered is greater than / is less than / is equal to	**1.** 64 *vs* 63 **2.** 82 *vs* 85 **3.** 6 *vs* 6 **4.** 2 *vs* 3 **5.** 1 *vs* 57 **6.** 8 *vs* 41

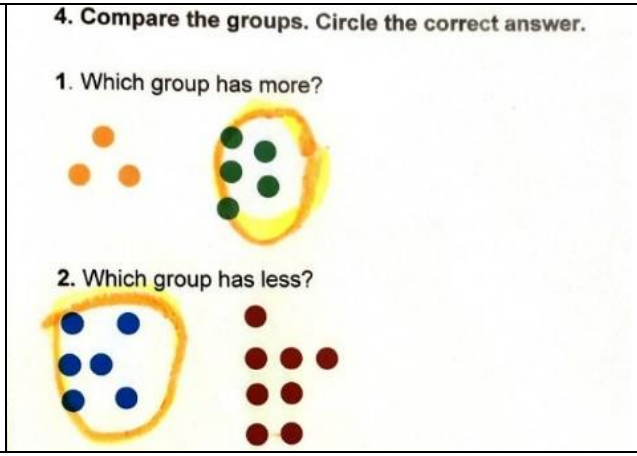
4.3 Comparing sets in a range of 20-80.

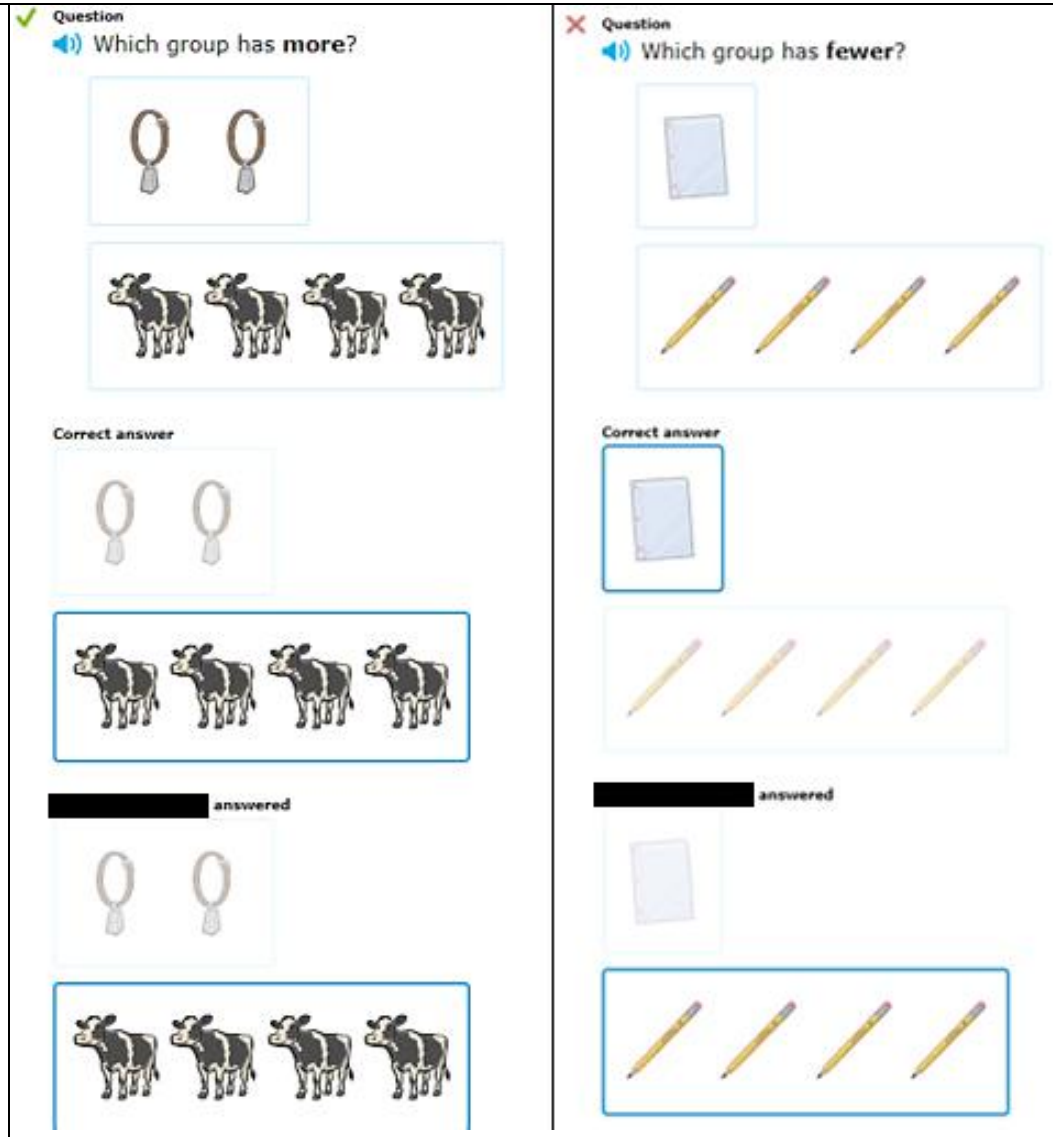
The student had to highlight the correct comparison phrase. This subtest does not have an IXL comparison, since the student did not reach a high enough level on a combined test and because there are no separate tasks with comparing sets over 10.

Material test	**4. Compare the groups. Highlight the correct words.** **1.**  is greater than / is smaller than / is equal to	**1.** 60 *vs* 40 **2.** 80 *vs* 80 **3.** 30 *vs* 20 **4.** 40 *vs* 50

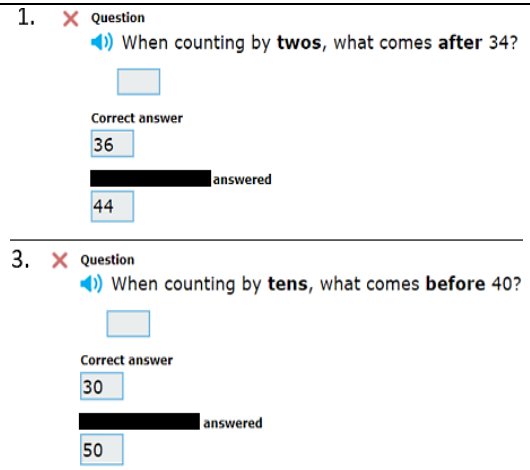
4.4 Comparing sets in a range of 1-10.

This was considered the easiest task level for the student and also the subtest which would show his ability of comparing small sets He had to circle or choose the set that has more or less.

Material test		**1.** Which group has more? 3 *vs* 5 **2.** Which group has less? 6 *vs* 8 **3.** Which group has more? 5 *vs* 4 **4.** Which group has less? 7 *vs* 10

Digital test		**1.** Which group has more? 4 *vs* 2 **2.** Which group has fewer? 1 *vs* 4 **3.** Which group has fewer? 3 *vs* 2 **4.** Which group has more? 4 *vs* 5 **5.** Which group has fewer? 5 *vs* 4 **6.** Which group has more? 2 *vs* 5

5. Counting. The purpose of this subtest was to assess what kind of counting skills the student has. According to Emerson and Babtie (2013), counting is the foundation of numeracy that helps students understand the "spoken number system." The skill to count by tens, fives and twos is a calculation strategy (Emerson & Babtie, 2013). The subtest (5.1) had alternatives with easier levels of difficulty, which were used in an order of decreasing difficulty: 5.2 followed by 5.3. The digital subtests were conducted in the first week and the material subtests in the second week.

Test	Example	Tasks
	5.1 Counting up and down by tens, fives, and twos.	
	The purpose of this subtest was to see if the student can count up and down by tens, fives, and twos without using a number line. The student had to write the number that comes before or after the said number while counting in sets.	
Material test	**1. Write the correct number.** 1. When counting by **tens,** what comes after 20? 40 2. When counting by **fives,** what comes after 10? 20 3. When counting by **twos,** what comes after 16? 17 4. When counting by **fives,** what comes before 25? 35	**1.** Counting up by tens from 20 **2.** Counting up by fives from 10 **3.** Counting up by twos from 16 **4.** Counting down by fives from 25 **5.** Counting down by twos from 12 **6.** Counting up by tens from 30 **7.** Counting down by twos from 14 **8.** Counting up by twos from 12
Digital test		**1.** Counting up by twos from 34 **2.** Counting down by fives from 90 **3.** Counting down by tens from 40

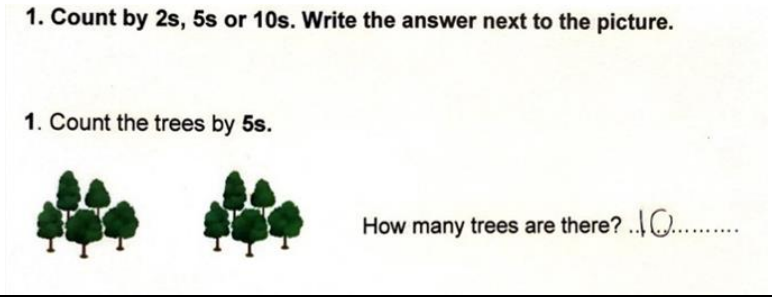
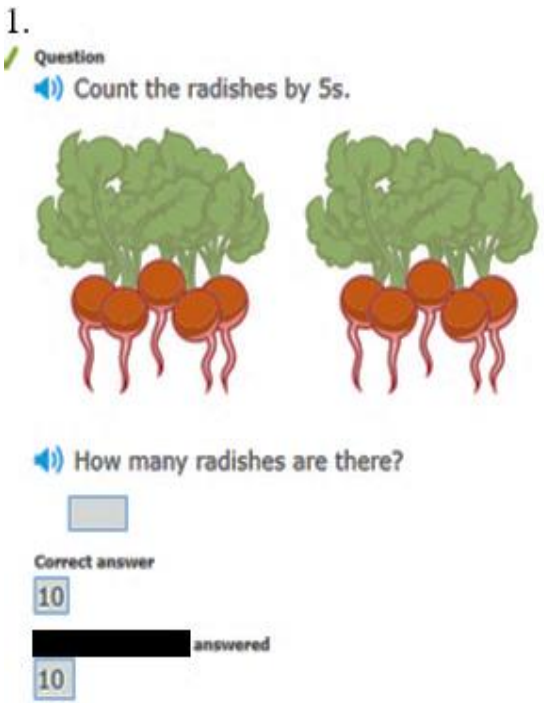
5.2 Counting up and down by tens, fives, and twos on a number line.

The student had to look at the number line and figure out by how many he needed to count by, and, if he needed to count up or down.

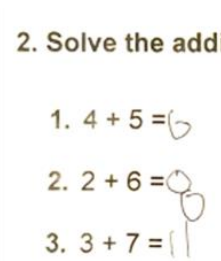
Material test	**1. Write the missing number.** **2.** 48, 50, 49 , 54, 56 **3.** 35, 14.., 45, 50, 55	**1.** Counting up by twos *48, 50, ..., 54, 56* **2.** Counting up by fives *35, ..., 45, 50, 55* **3.** Counting down by tens *60, 50, 40, 30, ...* **4.** Counting down by twos *56, 54, ..., 50, 48* **5.** Counting down by tens *...., 30, 40, 50, 60* **6.** Counting down by fives *65, 60, 55, 50, ...* **7.** Counting up by fives *10, ..., 20, 25, 30* **8.** Counting up by tens *...., 40, 30, 20, 10* **9.** Counting up by twos *24, 26, 28, ..., 32* **10.** Counting down by fives *35, ..., 25, 20, 15* **11.** Counting up by tens *40, 50, ..., 70, 80* **12.** Counting down by twos *20, 18, ..., 14, 12*
Digital test	1. ✓ Question Type the missing number in this sequence: [ ], 75, 80, 85, 90 Correct answer 70, 75, 80, 85, 90 [redacted] answered 70, 75, 80, 85, 90 3. ✗ Question Type the missing number in this sequence: 2, 4, 6, 8, 10, 12, [ ] Correct answer 2, 4, 6, 8, 10, 12, 14 [redacted] answered 2, 4, 6, 8, 10, 12, 13	**1.** Counting down by fives ... *75, 80, 85, 90* **2.** Counting up by twos *50, 52, 54, ..., 58* **3.** Counting up by twos 2, 4, 6, 8, 10, 12, …. **4.** Counting up by tens 40, 50, …., 70, 80 **5.** Counting up and down by fives …., 65, 60, 55, 50, … **6.** Counting down by tens 80, 70, …, 50, 40, …. **7.** Counting down by twos 66, …, 62, 60, …, 58 **8.** Counting up by tens 40, 50, 60, 70, …

5.3 Counting by twos, fives, and tens with pictures.

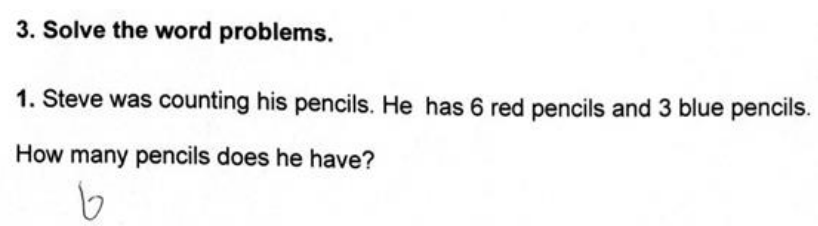
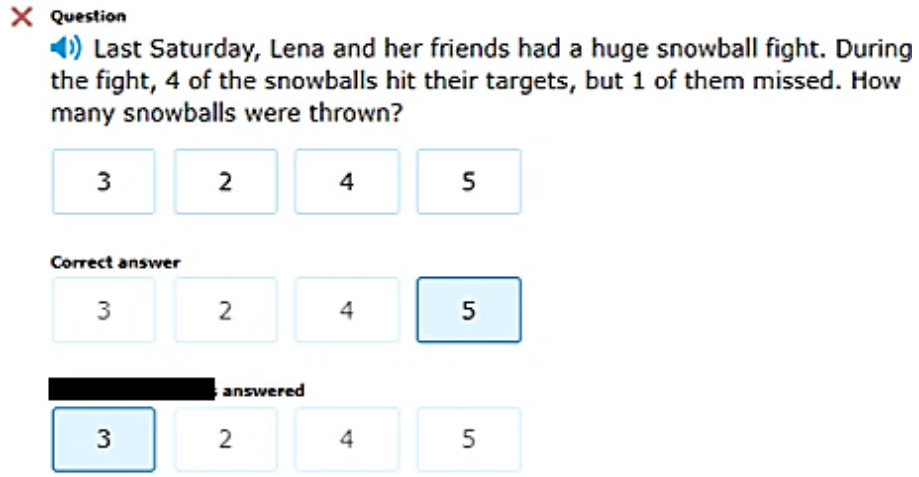
The purpose of this test was to materialise the numbers and give the student visual aids when counting. The student had to read the instruction and count the items by sets of two, five or ten accordingly.

Material test		**1.** Counting by fives *2 sets* **2.** Counting by tens *3 sets* **3.** Counting by tens *4 sets* **4.** Counting by twos *5 sets* **5.** Counting by fives *5 sets* **6.** Counting by twos *6 sets*
Digital test		**1.** Counting by fives *2 sets* **2.** Counting by fives *5 sets* **3.** Counting by tens *5 sets* **4.** Counting by twos *4 sets*

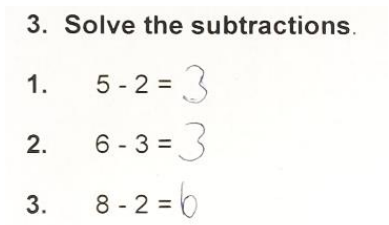
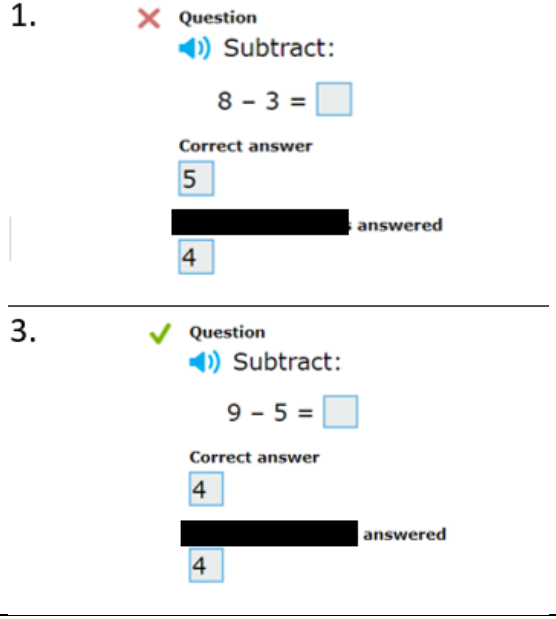
6. Addition. The purpose of this test was to see if, and with what level of help the student can add numbers in a range of 10. Addition is one of the four arithmetic operations that require factual knowledge, understanding of numbers, calculation proficiency and memory (Emerson & Babtie, 2013). Initially, the student tried to solve three-number additions, but as those were too difficult, only the two-number additions are shown. The digital subtests were conducted in the first week and the material tests in the second week.

Test	Example	Tasks
Material test		**1.** 4 + 5 = **2.** 2 + 6 = **3.** 3 + 7 = **4.** 4 + 3 = **5.** 5 + 5 = **6.** 1 + 9 =
Digital test		**1.** 2 + 8 = **2.** 2 + 7 = **3.** 4 + 3 = **4.** 7 + 2 = **5.** 3 + 3 = **6.** 5 + 4 =

7. Addition word problems. The purpose of this subtest was to find out if the student knows the algorithm for solving a word problem and can find the necessary information from the text. Since the student could solve additions involving two numbers, word problems with adding two numbers were chosen for this part of the test. The digital subtests were conducted in the first week and the material tests in the second week.

Test	Example	Tasks
Material test		**1.** Steve was counting his pencils. He has 6 red pencils and 3 blue pencils. How many pencils does he have? **2.** Mary went to a bakery. She bought 4 muffins and 3 cakes. How many sweets did Mary buy? **3.** Dave asked for Pokémon cards for his birthday. He got 5 from Amy and 3 from Steve. How many cards did he get?
Digital test		**1.** Last Saturday, Lena and her friends had a huge snowball fight. During the fight, 4 of the snowballs hit their targets, but 1 of them missed. How many snowballs were thrown? *Answer options: 3 2 4 5* **2.** Abby only feeds her dog two kinds of treats. Last year, Abby fed her dog 1 peanut butter treat and 4 carrot treats. How many treats did Abby feed her dog last year? *Answer options:* 4 2 5 3 **3.** Billy had 3 letters. Then 2 more came in the post. How many letters does Billy have now? *Answer options:* 4 3 2 5

8. Subtraction. Previously, the student had only briefly learned subtraction. These tests were necessary to see if the student understands the idea of subtraction, the words used (subtraction, minus) and what subtraction technique he uses. According to Emerson and Babtie (2013), to solve additions and subtractions, one must understand the operation's concept, as well as know how to calculate. The material test was done in the first week and the digital subtest in the second week.

Test	Example	Tasks
Material test		**1.** 5 – 2 = **2.** 6 – 3 = **3.** 8 – 2 = **4.** 9 – 7 = **5.** 8 – 5 = **6.** 6 – 6 =
Digital test		**1.** 8 – 3 = **2.** 9 – 4 = **3.** 9 – 5 = **4.** 8 – 4 = **5.** 7 – 5 = **6.** 7 – 2 =

Appendix 2. Action plan

Time

- Teaching phase: 09.03.2022 – 14.04.2022 (4 lessons per week, 23 lessons).
- Revision phase: 21.04.2022 – 22.04.2022 (3 lessons).

Lesson times

- Teaching phase: Monday (10.40-11.25), Wednesday (10.40-11.25; 12.15-13.00), Thursday (11.30-12.15).
  Duration and lessons needed for teaching each number are presented below.
- Revision phase: Thursday (10.40-12.15), Friday (10.40-11.25).

Duration and lessons needed to teach the numbers

Number	Resource	Time	Number of lessons
2	Material	9.03	1
3	Digital	9.03 - 10.03	1.5
4	Material	10.03 - 16.03	2.5
5	Material	16.03 - 17.03	2
6	Digital	21.03 - 23.03	2
7	Digital	23.03 - 24.03	2
8	Material	28.03 - 31.03	4
9	Material	4.04 - 6.04	3
10	Digital	7.04 – 14.04	5

Topics taught and resources and assistance used are presented below. Assessment was done by observing the student's progress in the lesson, the next topic was chosen if the student achieved the goal.

Goals, assistance and resources for teaching numbers

Topic	Goal	Assistance	Resources
Teaching phase			
1.2 Comparing part and whole	The student compares the first addend to the sum using the correct comparison symbol and verbalises that addition makes a number bigger.	Putting the counters in the correct order or places, guiding questions to decide which is bigger, comparing the counters in side-by-side lines, choosing and writing the correct symbol and using the “birds mouth analogy”.	M: counters, notebook, pencil. D: “ToyTheater counters and comparison table”, iPad.
1.3 Commutative properties of addition	The student understands that the sum stays the same if the addends are switched.	Putting counters in the correct order, asking guiding questions when reading the addition sentence, guidance choosing or writing the correct symbol in the correct place.	M: counters, notebook, pencil. D: TT counters, iPad.
1.4 Addition word problem	The student reads the word problem, finds the question, chooses and solves the correct operation and writes or says the answer using a full sentence.	Guiding questions and guidance to understand the problem, finding the question, choosing the operation, visualising the problem with counters, answering with a full sentence.	M: printed task, counters, notebook, pencil, glue. D: task on PCK, TT counters,, iPad, laptop.
2.1 Making the previous number with early subtraction	The student places counters in one line, leaves gaps between counters to visualise the subtraction sentence, reads the sentence and writes correct numerals and symbols “-”, “0”.	Putting counters in the correct order, guiding questions when reading the subtraction sentence, guidance choosing or writing the correct symbol in the correct place.	M: counters, notebook, pencil. D: TT counters, iPad.
2.2. Comparing part and whole	The student compares the minuend to the difference using the correct comparison symbol, verbalises that subtraction makes a number smaller, knows he must subtract from the bigger number.	Putting the counters in the correct order or places, guiding questions to decide which is bigger, comparing the counters in side-by-side lines, choosing and writing the correct symbol and using the “birds mouth analogy”.	M: counters, notebook, pencil. D: TT counters, iPad.

2.3 Subtraction word problem	The student reads the word problem, finds the question, chooses and solves the correct operation and writes the answer using a full sentence.	Guiding questions and guidance to assist in understanding the problem, finding the question, choosing the operation, visualising the problem with counters, answering with a full sentence.	M: printed task, counters, notebook, pencil, glue. D: PCK, TT counters, iPad, laptop.
Number bonds	The student understands that numbers can be made of smaller numbers.		
1. Deconstructing the number.	The student shows the number's bonds with counters.	Guiding questions and guidance to divide the counters into two sets, writing/choosing the number to match the sets.	M: Counters, notebook or comparison sheet, pencil or markers, UNO cards. D: counters on "ICT Games", "Make Another Number Sentence" or "Making Number Bonds", iPad.
2. Constructing the number.			
2.1 Matching addition sentence to picture.	The student finds the addition sentence that matches the two-coloured counter picture.	Guiding questions and guidance to count the two-coloured sets separately.	M: Printed pictures of two-coloured sets in a ten-frame setting, addition sentences, pencil. D: Pictures of two-coloured sets in a ten-frame setting, addition sentences on PCK, iPad.
2.2. Constructing the number by choosing the matching addition sentence for the the number.	The student chooses the addition sentence that the number is made of independently or by using counters.	Guiding questions on choosing the correct addition sentence, guidance on using the counters.	M: Printed addition sentence options and numbers, counters. D: Addition sentence options and numbers on PCK, counters on "ICT Games", "Make Another Number Sentence", iPad.

3. Word problems for deconstructing and constructing a number.	The student solves addition or subtraction word problems either with guidance or by using counters.	Guiding questions and guidance to assist in understanding the problem, finding the question, choosing the operation, visualising the problem with counters, answering with a full sentence.	M: printed tasks, counters, notebook, pencil, glue. D: PCK, counters on "ICT Games", "Make Another Number Sentence", iPad, laptop.
Number line calculation	The student uses a number line with minimal guidance to solve the number sentences.		
3. Addition on a number line	The student calculates using a number line by counting up from the first addend.	Guiding questions and guidance on finding the number to count up from, guidance to count the correct amount.	M: Printed tasks, ruler, pencil. D: Task with a number line picture on PCK.
Subtraction on a number line	The student calculates using a number line by counting down from the minuend.	Guiding questions and guidance on finding the number to count down from, guidance to count the correct amount.	M: Printed tasks, ruler, pencil. D: Task with a number line picture on PCK.
		Revision phase	
Solving addition and subtraction sentences and word problems in a mixed order	The student can solve addition and subtraction sentences and word problems with minimal assistance.	Number sentences: Guiding questions when reading the number sentence and choosing how to solve it, guiding questions and guidance when using counters. Word problems: Guiding questions and guidance to assist in understanding the problem, finding the question, choosing the operation, visualising the problem with counters, answering with a full sentence.	M: Printed game board, word problem and number sentence tasks, markers, counters, pencil. D: PCK, TT counters, iPad, laptop.

* M = material, D= digital
PCK= Tasks on Pink Cat Games website, TT counters = "Two-colour counters numbers" on Toy Theater website.

Appendix 3. Sample lesson plan (digital resources)

Time: 21.03.22 10.40-11.25

Topic: Making the number 6

Learning objectives

- The student makes the number 6 with counters by adding 1 to 5. The student compares the addend and the sum by using counters and uses the correct comparison symbol.
- The student makes the number 5 with counters by subtracting 1 from 6. The student compares the minuend to the difference with counters and uses the correct comparison symbol.
- The student deconstructs number 6 with counters.

Resources

- iPad and laptop

iPad applications and websites:

- Virtual two-colour counters at https://toytheater.com/two-color-counter-numbers/
- Virtual two-colour counters and comparison table at https://toytheater.com/compare/
- Virtual counters and anchor chart at https://www.ictgames.com/mobilePage/partPartWhole/index.html
- Virtual games and tasks at www.pinkcatgames.com (check using the link https://www.pinkcatgames.com/go/HnhK7jtH17meJwf61pkQ and choosing “Example”)
- Word problems up to six

Lesson phase Work method	**ACTION**		
	Teacher activity and speech	*Student activity and* speech	Resources Assistance
Introduction Preparation	Let's start. Are you ready for math?	Yes.	
Revision	What number did we learn last week?	Five.	Assistance: Saying one of the bonds, saying a number in the bond.
Revising the bonds of five.	Yes, we did. Do you remember any bonds of five? Four and one, that's right. One and two make a three. But two and three make a five as well.	Four plus one. One and two.	
Development Introducing the topic	What number are we going to learn this week? That's right. And instead of the notebook, we'll use your iPad.	Six.	*Resources:* iPad, Virtual two-colour counters at Toytheater.com,
Making the number six with counters using *Virtual two-colour counters at Toytheater.com.* Visualising the first addend	*Opens Toytheater 2 colour counters website.* Please put five red counters up there.	*Puts five counters on the board while counting.*	Assistance: Directing to count to six. Asking him to add one counter and then to count the row.
Early addition, adding one . Visualising the second addend	How many do you need to add to make six? Add a yellow counter.	One. *Adds one counter.*	Pointing to where to add the counters, digits. Making an example. Adding the counters/numbers with the students's hand.
Visualising the sum	You added one. How many are there now? Add the answer here also. *Points to the end of the page.*	*Counts.* Six *Puts six counters (five red and one yellow)*	

Matching the numerals to sets	Put the numbers under the counter sets also.		
	How many here? Count.	Five. *Puts the numeral 5 under the set.*	
	How many yellow?	One. *Puts the numeral 1 under the group.*	
	And how may total?	Six. *Puts the numeral six.*	
	That's right.		Guiding questions: What is the addition sign? Do you use a plus or a minus sign?. Instructing to use the plus sign. Pointing to the correct sign.
Adding the operation symbols	Now you need to make the addition sentence. What signs do you use?	Plus. Equals. *Adds the + and = signs.*	
	Good job!		
Reading the addition sentence	Read the sentence.	*Reads 5+1=6*	
	So, to make a six you need to add five and one.		
Visualising the commutative properties of addition			
Adding counters to make six.	What if we do this… I'll put one counter here. How many yellow counters to make a six?	Five. *Adds five counters.*	Guiding question: How many red counters did you put before? Directing to count the red counters in the previous task. Counting with the student's hand.
Visualising the answer	How many do you have now?	*Counts.* Six.	
	Add counters to the answer also.	*Adds the same amount to the answer part.*	
Matching the numerals to sets	That's right. Put the numbers under there also.	*Adds numerals.*	
Adding the operation symbols	Now add the signs.	*Adds the + and = signs.*	

Reading the addition sentence	Read the addition. You made a six with one and five. One and five are addends. Six is the sum.	One plus five equals six.	
Summarising the commutative properties of addition	So it does not matter which one you add first.		Resource: Virtual two-colour counters and comparison table at Toytheater.com
Comparing the addend and the sum with counters using *Virtual two-colour counters and comparison table at Toytheater.com* Comparing the numerals Visualising the numbers with counters. Dividing the counters into boxes Matching the numerals to sets Comparing the sets	Now we are going to compare. *Opens Toytheater.com Compare* *Writes the addition sentence (5+1=6).* Which is bigger? Five or six? Let's put the counters also *Adds counters..* Put the five counters here. *Points to the box on the left.* And put the six counters here. *Points to the box on the right.* Write the numbers also. Which one is bigger?	Five. *Puts the counters in the boxes.* *Writes the numbers "5" and "6".* *Points to the group of six.*	Assistance with adding the counters to the boxes (1. Example, 2. Using the student's hand). Assistance: Writing the numbers. Assistance: Lining the counters in two rows, asking the student to point to the bigger one. Pointing to the bigger one. Assistance with putting the counters back in the boxes. Using the "bird mouth" analogy to

Writing the comparison sign	Write the comparison sign. That's right.	*Writes the sign < between 5….6*	write the correct symbol ("Which one does the bird want to eat? The bigger or the smaller? His mouth is open to the bigger one"), making an example of the sign. Using the student's hand to write the sign. Guiding question: You added a counter. Did the set go bigger?
Summarising the principle of addition	So when you're adding, are you making a number bigger or smaller? Yes, adding makes a number bigger.	Bigger.	
Consolidation **Solving a word problem** using *PinkCatGames on the computer and counters on the iPad.* Motivating action – adding something to a picture on Pink Cat Games	Now let's solve a word problem. *Opens "Word problems up to six" on Pinkcatgames.com on the computer and Toytheater.com Two-coloured counters on the iPad* What do you want to add to the picture?	*Looks at the game and chooses something to add to the picture.*	Resources: "Word problems up to six" on computer at Pinkcatgames.com, virtual two-colour counters on TheToytheater.com
Reading the word problem. Finding the question. Visualising the information with counters. Adding the operation signs	Read the word problem What is the question? How do find out? Use the counters to help you. Put the signs there also. What do you need to put?	*Reads the word problem.* *Reads the question.* I add. *Uses counters to visualise the information*. *Adds the + and = sign.* Five and one is six.	Assistance: Reading the word problem. Pointing to the question. Guiding questions: How many does he have in the beginning? And what else do you know?. Assistance with finding the information in the text. Assistance with putting the counters and signs in the correct

			places.
Answering the question	What was the question? What is your answer? Use a full sentence. Now press the answer button.	*Reads the question and answers. Presses the correct answer button.*	Starting the sentence so the student would answer using a full sentence.
Naming the operation	And what did you do? You added five and one to make six.	Added fine and one.	Guiding question: Did you add or subtract? What numbers did you add?
Development Introducing the topic **Making the number five with counters** using *Virtual two-colour counters at Toytheater.com.*	Now let's look at subtracting.		Resources: iPad, Virtual two-colour counters at Toytheater.com Assistance:
Early subtraction, subtracting one . Visualising the action with counters	Put six counters here. Now pull one counter here. You take one off.	*Puts six counters.* *Pulls one away.*	Pointing to where to add the counters. Making an example of how to pull a counter away.
Counting the remaining counters. **Visualising the subtraction sentence.**	How many do you have now? That's right. Lets show the subtraction sentence.	Five.	Asking the student to count. Making an example of how to count. Using the student's hand to count.
Visualising the minuend	You started with how many?	Six.	
Visualising the subtrahend	And you took away how many? You subtracted one. Put one here.	One.	
Visualising the difference.	How many did you end up with?	*Puts counter.* Five.	Assistance with choosing digits

Matching the numerals to sets	Put the numbers under there also.	*Writes numbers.*	and the correct spot.
Adding subtraction signs.	Put the signs.	*Adds – and = signs*	Guiding questions: What is the subtraction sign? Do you use a plus or a minus sign? Instructing to use the minus sign. Pointing to the correct sign.
		Six minus one equals five.	
Reading the subtraction sentence.	Read the subtraction sentence. You subtracted one from six.		
Naming the parts of the subtraction sentence.	Six is the minuend. Where you start to subtract. One is a subtrahend. And five is the difference.		
Principle of subtraction	Can you take one from six?	Yes.	
	Try it.	*Tries.* There's none.	
Visualising the subtraction rule of always subtracting from the bigger number.	You can't. You always subtract from the bigger number.		
Comparing the minuend and difference with counters ***Opening the comparison table website***	Does the number go bigger or smaller when you subtract from it?	Bigger.	Resource: Virtual two-colour counters and comparison table at Toytheater.com
	Let's see. *Opens Toytheater.com Compare.*		
Visualising the subtraction sentence	You did six minus.. ? *Pulls six counters in the box on top.*	One. *Puts the one counter next to it.*	Assistance with adding the counters to the boxes (1. Example, 2. Using the student's hand). Guiding questions to write the numbers/signs: "How many are here? What sign do you use for subtraction?". Naming the correct signs. Writing the signs/numbers with the student's hand.
Subtracting	Minus one. Lets put that here also.	Five. *Pulls five counters.*	
	And what is six minus one?		
Writing the symbols for subtraction	That's right. Write the numbers under the counters. Draw the signs also.	*Writes 6-1=5 under the counters.*	

Comparing the minuend and difference using counters	Now in the beginning you had six. Lets put that here. *Pulls the counters into the box on the left.* You took one off and then you had five. Put those counters here. *Points to the right box.*	*Puts the counters in the right box.*	Assistance with adding the counters to the boxes (1. Example, 2. Using the student's hand).
Writing the digits to match the set	Write the numbers in the box also. *Points to the boxes on the left and right.*	*Writes the numbers.*	
Comparing the sets	Which is smaller? Six or five?	Five.	Assistance: Lining the counters in two rows, asking the student to point to the bigger one. Pointing to the bigger one. Assistance with putting the counters back in the boxes.
Writing the comparison sign	Write the comparison sign also. Remember the bird? That's right.	The bird eats the bigger one. He eats six. *Writes the ">" symbol.*	Using the "bird mouth" analogy to write the correct symbol ("Which one does the bird want to eat? The bigger or the smaller? His mouth is open to the bigger one"), making an example of the sign. Using the student's hand to write the sign.
Principles of subtraction	So, subtracting makes a number bigger or smaller?	Smaller.	Guiding question: "Did you make six bigger or smaller?"
Consolidation **Solving a word problem on subtraction** *on PinkCatGames.com, using the two-coloured counters on*	Now let's look at the next word problem. And then we'll take a break. *Opens computer again.*		Resources: "Word problems up to six" on computer at Pinkcatgames.com, virtual two-colour counters on Toytheater.com, laptop, iPad

ToyTheater			
Motivating action – adding something to a picture on Pink Cat Games	What do you want to add?	*Chooses what to add.*	
Reading the word problem	Read the word problem	*Reads the word problem.*	Assistance: Reading the word problem. Pointing to the question. Guiding questions: How many does he have in the beginning? And what else do you know?. Assistance with finding the information in the text.
	What is the question? How do find out?	*Reads the question.* I subtract.	
Visualising the information with counters.	Use the counters to help you.	*Uses counters to visualise the information.*	
Adding digits to match the sets	Pull the numbers there also.	*Pulls matching numbers.* *Adds the - and = sign.*	Assistance with putting the counters and signs in the correct places.
Adding the operation signs	Put the signs there also. What do you need to put?	*Six minus one is five.*	
Naming the operation	Did you add or subtract?	Subtracted.	Guiding question: “Did the number go bigger or smaller? Which sign did you use. Is this an addition signt? Or a subtraction sign?
Answering the question	What was the question? What is your answer? Use a full sentence. Now press the answer button. That’s right!	*Reads the question and answers.* *Goes in the hall to do a*	Starting the sentence so the student would answer using a full sentence.

Movement break	Time for break.	*movement break.*	
Development Deconstructing the number using *ICT Games* – choosing the counters	*Opens ICTgames for anchor chart.* Which counters do you want?	*Chooses counters.*	Resources: Virtual counters and anchor chart at ICTgames.com, iPad
Putting the counters and matching numerals in the anchor chart	What number have we been learning? Put the number in the top bubble. Now put six counters here.	Six. *Puts the number in the bubble.* *Puts counters and counts.*	Assistance: Arranging counters so they are not covering each other.
Dividing counters into two groups without knowing one number	Let's say you give some to your friend. How many will you give him? Put one counter here. *Points to the circle on the left.*	One. *Puts number one and one counter in the circle.*	Assistance: Guiding and pointing to use the counters left in the "whole" circle.
Counting the counters	How many do you have left for yourself?	*Counts*	
	Put the rest of the counters in here. *Points to the circle on the right.*	Five. *Puts number next to it.*	
Counting the counters Saying the number bond	How many did you put? So six is made with…? *Points to number one.*	One and five.	Assistance: Guiding question: "What numbers did you use?" Pointing to the digits.
Dividing counters into two groups in a different way	*Puts the counters back.* So you still have six here. Now. Your friend is very sad. He only got one chocolate. He wants more. Give him more.	*Counts and puts six counters in the left circle.*	Guiding question: "What is bigger than one?" Guidance: "Put one

	How many will you give to him?	*Puts the numeral next to it.* Six.	counter more."
Counting	How many are left?	None. It's zero.	Guidance: "Count how many in the big bubble." Pointing to the circle, starting to count. Pointing to the counters, the student counts.
Saying the number bond	So a six is made with..?	Six and zero.	Guiding question: "What numbers did you use?" Pointing to the digits.
	Let's do one more.	Okay.	Guidance: "Count how many in the big bubble." Pointing to the circle, starting to count. Pointing to the counters, the student counts.
	Put all the counters back in the big bubble.	*Puts all the counters back.*	Assistance: Arranging counters so they are not covering each other.
Counting all	How many do you have?	Six.	Guidance: "Count how many in the big bubble." Pointing to the circle, starting to count. Pointing to the counters, the student counts
Dividing counters into two groups when knowing one part	Now put four in there.	*Counts and puts 4 counters in the left circle. Puts the numeral next to it.*	Assistance: Guiding and pointing to use the counters left in the "whole" circle.
Counting the other part	How many counters are left? Put those in the other bubble.	Two. *Puts the numeral next to it.*	Assistance: Guiding question: "What numbers

Saying the number bond	So what makes a six? That's right. **Making as many number bonds as possible until the end of the lesson.*	A two and a four.	did you use?" Pointing to the digits.
Conclusion Summarising the subject Naming number bonds Feedback Finishing the lesson	So what number did we learn today? Do you remember bonds of six? Yes. That's right. Do you remember any others? We also did 4 and 2 and 3+3. I think you worked very hard. Good job! We can go back to class now.	Six. 6 and 0? 5 and 1? Thanks. *Goes to class.*	Assistance: Showing the bonds of six on the application.

Appendix 4. Sample lesson plan (material resources)

Lesson time: 28.03.2022 at 10:40-11:25

Topic: Making the number 8

Learning objectives

- The student makes the number eight with counters by adding one to seven.
- The student compares the addend and the sum by using counters and uses the correct comparison symbol.
- The student makes the number seven with counters by subtracting one from eight.
- The student compares the minuend to the difference with counters and uses the correct comparison symbol.
- The student answers independently to the questions “Does adding make a number bigger or smaller?”, “Does subtracting make a number bigger or smaller?”.

Resources

- Two-coloured counters,
- squared notebook, pencils, glue, coloured markers,
- UNO cards,
- laminated “Build A Monster” kit from https://www.itsybitsyfun.com/blog/free-printable-build-a-monster/#more-3461

Lesson phase Work method	**ACTION**		
	Teacher activity and speech	*Student activity and* speech	Resources Assistance
Introduction Warm-up Revision: Revising the bonds of the previous number learned. Naming the bonds of seven.	Let's start. Are you ready for Math? Do you remember what number we learned last time? We did learn seven. Do you remember any bonds of seven? One and six make a seven. And three and four.	Yes. We learned seven. Today we learn eight. *Says bonds of seven*	Assistance: Showing a number card. Showing number cards that make a seven (first one card, then another).
Development Introducing the topic. Writing the digit for the number they'll learn. **Early addition, adding one** Visualising the first addend Counting . Visualising the second addend	We are going to learn eight. Please take your notebook. Let's write the number. Write the number. Take seven counters. Put them here. *Pointing to the page.* How many did you put? How many do you need to add to make eight? Add a yellow counter. Put that here.	*Takes notebook.* *Writes eight.* Eight. *Takes seven red counters and lines them in a row while counting.* *Counts again.* Seven. One. *Adds a counter.*	Resources: Two-coloured counters, squared notebook. Assistance: Finding the next empty page in the notebook. Pointing to the beginning of the page. Pointing to where to add the counters. Making an example. Adding the counters with the students's hand. Pointing to a spot while leaving a gap between the previous set.

Visualising the sum	How many counters do you have now? Put this many counters here.	*Counts.* Eight.	Pointing to where to add the digits. Making an example.
Writing digits to match the set	Now write the number under each group. How many did you have in the beginning?	*Puts eight counters.* *Writes the digits.*	What is the addition sign? Do you use a plus or a minus sign?. Instructing to use the plus sign. Writing the plus and minus sign, pointing to the correct one.
Writing the addition sign	Yes. What sign do you use for adding? Add "equals" too.	Plus. *Writes + and = sign.*	
Reading the addition sentence	Yes. Read the addition sentence. Good job!	Seven… plus one equals eight.	
Addition principle	What if we try this. Put one counter here. *Points.*	*Puts one counter.*	
Visualising the first addend	Now put seven counters here.	*Puts seven counters.*	
Visualising the second addend	How many do you have now?	Eight.	
Visualising the sum Writing the addition sentence	Write the addition sentence. Perfect! And now read it.	*Writes 1+7=8 under the counters. Reads.*	
Comparing the sum to the previous one.	Is it the same as before?	Yes	
Summarising the commutative properties of addition	So it does not matter which one you add first, the answer stays the same.		
Comparing the addend and the sum	Did you make the set bigger or smaller? Yes!	Bigger.	

Visualising the addition sentence with counters. Matching the sets to digits Comparing the sets Comparing the number Writing the comparison symbol	Put seven counters here. Put eight counters there. Let's write the numbers too. Write here. So which is bigger? Write the sign also.	*Puts the counters.* *Writes the numbers.* Eight. *Writes < sign between 7…. 8*	Guiding question: How many red counters do you have? Directing to count the red counters in the previous task. Counting with the student's hand. Assistance: Lining the counters in two rows, asking the student to point to the bigger one. Pointing to the bigger one. Using the "bird mouth" analogy to write the correct symbol ("Which one does the bird want to eat? The bigger or the smaller? His mouth is open to the bigger one"), making an example of the sign. Using the student's hand to write the sign.
Summarising the principle of addition	So when you're adding, are you making a number bigger or smaller? Yes, adding makes a number bigger.	Bigger	Guiding question: You added a counter. Did the set go bigger?
Consolidation	Now let's try a word problem.	A word problem?	Resources:

Solving a word problem on early addition			Paper with word problems, scissors, glue.
Preparation	*Takes scissors and paper with word problems.* You can cut. *Puts glue on the paper slip.* Put it here. *Shows the empty space in the notebook.*	*Cuts out word problem.* *Puts the slip in his notebook.*	
Reading the word problem out loud	Could you read it out loud?	*Reads the word problem*	Reading the word problem. Pointing to the question. Guiding questions: How many does she have in the beginning? And what else do you know?. Assistance with finding the information in the text.
Writing down the data	What is the question? Mark it. How do find out? Use the counters to help you.	*Chooses pencil. Underlines and reads* Eight. *Reads the question.* I add. *Uses counters to visualise the information.*	
Choosing the suitable operation	Put the signs there also.	Adds the + and = sign. Writes 7 1	Assistance with putting the counters and signs in the correct places.
Writing the operation	So what's the answer to the question? *Writes "*Answer:"	*Writes* + *and* = 8	
Answering the question	Use the full sentence. Read the question again. So the answer is…	Eight. *Reads question.*	Starting the sentence so the student would answer using a full sentence.

using a full sentence	Write the full sentence.	*Writes the answer.*	
		A body and mouth.	
Motivating action	*For motivation:* Now you can start building your monster. What do you want to add? *Reads choices.* Here you go. *Gives the student the parts he asked for.*	*Uses sticky tack to attach parts.* *Yawns and asks about his iPad.*	
Development Visualising subtraction with counters			Resources: Counters, notebook
1. Making the minuend with counters	Now. Take eight counters.	*Takes eight counters and counts the same time.*	
Setting the counters in a ten-frame setting	*Arranges the coins in ten-frame setting.*	*Asks questions about the author.*	Assistance: Arranging counters to allow for better perception.
2. Removing the subtrahend from the group	Now pull one counter away to here. *Points to a spot on the notebook.*		
Counting the difference	So. How many counters do you have in this group now?	*Counts.* Seven.	
Writing the numerals to match the sets	Write the numbers also.	*Writes 8-1=7*	
Comparing the numbers	Do you think you have more or less now? Let's use the counters to show the subtraction sentence.	More.	
Visualising the number	How many counters did you have in the beginning? Look at the sentence.	Seven.	

sentence with counters	Put eight counters here. How many did I take away? Put that one counter here. *Points to a spot leaving a gap.* And that equals? You can use these counters.	Eight. One. *Puts the counter in the spot.* Seven. *Puts seven counters after the one.*	Assistance: Using counters to show the difference between groups.
Comparing sets	Now you had eight here. And you made seven here. Lets compare those. *Puts the two groups next to each other.*	This one. *Points to the group of eight.*	Guiding questions
Lining the counters for length comparison	Which one has less? Let's see. Let's put them in two lines. I'll put one group. You put the other. *Lines up eight.* Yes. One is missing. Which group is smaller?	*Lines the seven counters next to the other line.* We need one more. *Points to the group of seven. Yawns.*	Assistance: Arranging counters in two lines to visualise the difference.
Counting the sets and matching the numerals to sets	We'll finish with this and then take a break, okay? So. How many counters in the bigger group? *Puts UNO card with 8 next to it.*	Yes. *Counts.* Eight.	
Writing the numbers Using "bird mouth" analogy to write the comparison sing	Write eight here. And how many in the smaller? *Puts UNO card with 7 next to it.* Write seven. Now write the sign in the middle. The bird mouth. Which one does the bird want to eat? That's right. Very good.	*Writes 8.* *Counts.* Seven. *Writes seven.* Smaller. *Writes the > sign between 8… 7*	Assistance: Referring to the "bird mouth" analogy for writing the comparison sign.
Subtraction principle Movement break	So when you're subtracting, do you make the number bigger or smaller? Yes. Subtracting makes a number smaller.	Bigger. I mean smaller.	

	Let's do a little stretch before the word problem.	*Stretches.*	
Development Informing the student of the activity and plan	Now let's do the word problem. And then we'll take a longer break. You may cut the word problem out. *Puts glue on the paper.* Glue it here.	Fine. Okay. *Cuts out the word problem.*	Resources: Paper with word problems, scisssors, glue, laminated monster picture with parts, notebook
Reading the word problem	Could you please read it?	*Reads the word problem out loud:* Julia has eight euros. She buys a cookie from the bake sale. The cookie costs one euro. How many euros does Julia have left?	
Solving the word problem using the algorithm	Do you already know the answer? How could you find out? What do you already know?	No. I don't know. Euros.	Assistance: Guiding questions to solve the word problem.
Writing down the information	Read. Write that here. Like before. Do you know anything else? Write that here also.	She has eight. *Writes "She has 8 euros."* *Reads:* She spends one euro. *Writes She spends 1 euro.*	Assistance in finding where to write. Directing the student to read the information.
Marking the question	What do they want to know? Read. Mark the question.	Eight. *Reads the question. Yawns.* How many euros does Julia have left? *Underlines.*	
Naming the operation for solving the problem	How could you find out? What do you need to do? Add or subtract? When you buy something, do you have less money	I don't know. Add. Less.	Guiding questions to understand which operation to use. Making an analogy for better

	or more?		comprehension.
Visualising the word problem with counters	So you need to… That's right! Let's try with counters. Julia has eight euros. *Points to the info in the notebook.* Put eight counters. How many euros did she spend? Take one off. Buy the cupcake. How many are left?	Subtract. 8-1= *Writes.* Equals eight. *Puts eight counters.* One. *Takes one off. Counts.* Six.	Using counters to visualise the information. Directing to recount.
Answering the question with a full sentence.	Count again. Yes. So what's the answer? Who has seven? Seven what? How would the whole sentence be? How many euros did Julia have left? *Points to the question.* Julia has..	*Counts.* Seven. Seven. Julia. Euros. Seven euros.	Guiding questions to answer with full sentence. Pointing to the question.
Writing the answer with a full sentence.	Yes. Let's write the whole sentence also. Julia has seven euros left.	Seven euros left. *Writes.*	Starting the sentence.
Motivating action: adding items to the monster picture	What do you want for your monster? *Gives the student the parts for his monster.*	Umm.. legs.	
Movement break	Wow. That's a cool monster. Now let's take a short break.	*Chooses the legs for the monster and attaches them.* *Takes his jump rope and goes to jump in the hall for five minutes.*	
Consolidation Introduction to activity Drawing anchor chart to	Let's continue. Number eight can also be made from different groups.		Resources: Notebook, markers, counters, UNO cards.

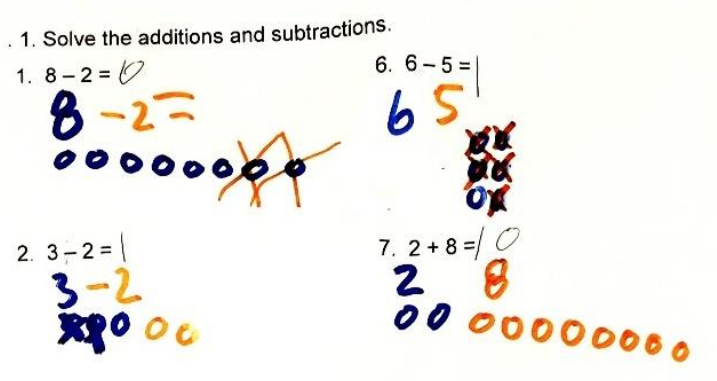
visualise number bonds	*Draws anchor chart in notebook.* *Writes "part, part" by the circles below and "whole" by the circle on top.*		
Putting the counters and numeral for the number they'll deconstruct	Put eight counters here. *Puts UNO card with 8 next to it.* You have eight counters.	*Puts eight counters in the circle.*	
Deconstructing a number by dividing counters into two sets	Now put the counters into the two circles. Some to the left and some to the right. *Points to the circles below.*	*Puts 1 counter in the left circle.*	Assistance: Repeating the other half of the direction.
	Put the others here.	*Puts seven counters in the other one.*	
Counting the counters	How many did you put here? *Points to the left circle.*	One.	
Matching the set to numeral	So what number card do you need? *Puts UNO card with 1 next to it.*	One.	
Counting the counters	How many did you put here? *Points to the right circle.*	Eight. *Counts.* Seven.	
Matching the set to numeral	Count. What number card do you need?	Seven.	Directing to count.
Verbalising the number bond	*Puts UNO card with 7 next to it.*		
Counting all the counters	So one and seven make an..	Seven.	
Visualising the commutative property of adding	How many counters did you have in the beginning? Count all the counters.	Many. *Counts.* Eight.	Directing to recount.
	You used one and seven to make an eight. Does a seven and a one make eight too? Yes.	Mhmh.	

Counting all counters	These are bonds of eight. Let's put these cards here. *Puts the number cards next to the notebook.* Put all the counters back. How many counters do you have?	*Counts.* Eight.	
Deconstructing when knowing one number Diving counters	You have eight. Now put two counters here. *Puts UNO card with 2 next to it.*	*Puts two counters in the circle on the left.*	
Matching numeral to group	Put the other counters here.	*Puts six counters on the right.*	
Counting the counters	*Points to the circle on the right.* How many did you put here?		
Matching numeral to set	Count.	*Counts.* Six.	
Verbalising the number bond	So what number card do you need? So you used what numbers to make an eight? What makes an eight? A six and a… *Points to the numbers.* Yes. Say it with me. Two and six make an eight. Or six and..	*Puts card next to the counters.* A six. And a two. *Repeats.* Two.	Pointing to the numeral.
Making a whole number Deconstructing the number	*Puts the cards under the other ones.* Last one for today. Put the counters back in the whole bubble again.	*Yawns.* *Puts the eight counters back.*	
Choosing the numeral to match the set	Now put four counters on the left.	*Counts and puts four counters.*	
Making the other part with counters and counting	Choose the card. *Shows cards with 4, 5, 2, 1.* Now put the other counters on the right.	*Chooses 4.* I choose four. *Puts the card next to the counters.* *Puts the counters in the right circle.*	

Matching the numeral to the sets Verbalising the number bond	How many did you put here? What number card do you need? A four again. So what numbers also make an eight? A four and a four make an eight. That's right! *Puts the cards under the other ones.* These are all bonds of eight.	*Counts.* Four. A four. A four and a four. Make an eight.	
Conclusion Summarising the lesson Naming the bonds of eight Motivating action: adding items to the monster picture Feedback Ending the lesson	What number did we learn today? Do you remember any bonds of eight? You can take things for the monster for each bond. Look at the bonds over there. That's right! And what do you want for your monster? *Gives the student arms for the monster.* Can you say another one? And what do you want for your monster? *Gives the student horns for the monster.* And four and four also. But that's okay. That is a very cool monster. I think you did great today. You can go to class now.	Eight. *Looking at the bonds made with the cards:* 7 and 1. I want arms. horns. *Attaches the arms to the monster*. 6 and 2. I want the horns. *Attaches the horns to the monster*. I'm done. No more. Thanks! *Goes to class.*	Resources: laminated monster picture with parts, Assistance: Directing to look at the number cards next to his notebook.

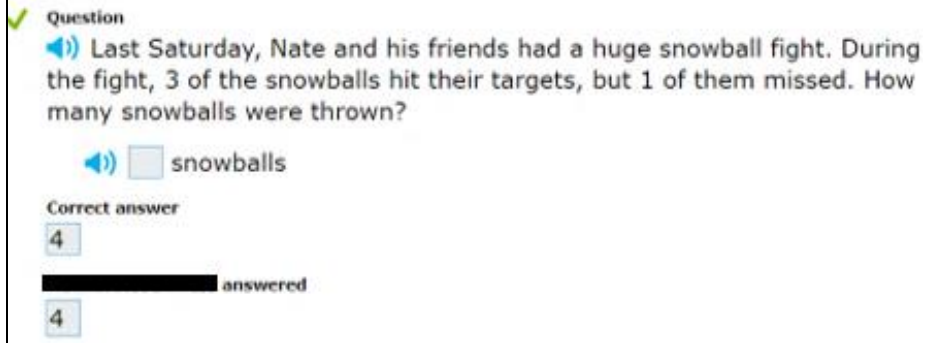
Appendix 5. Final assessment tests

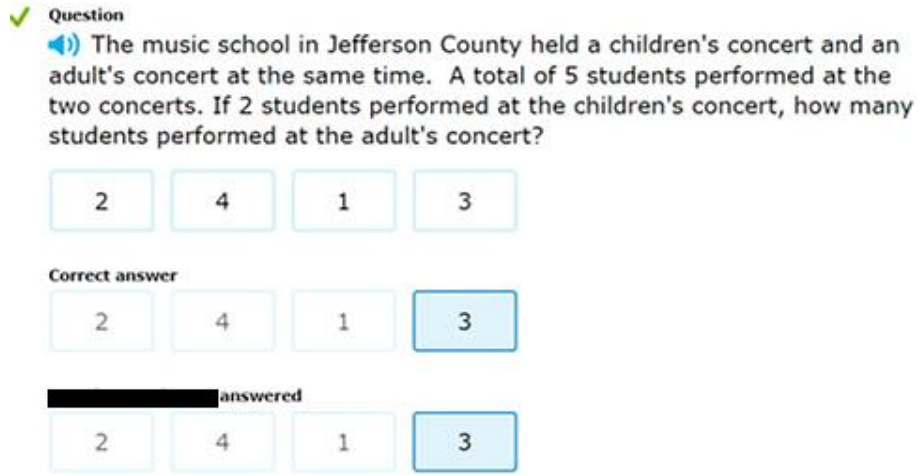
1. Addition and subtraction sentences. The purpose of this subtest was to assess how well the student could add and subtract within ten after the teaching phase, and to see if there was any difference between numbers taught using material or digital resources. The operations were presented in a mixed order. The material test was comprised by the author in a way that would allow the student to show his knowledge of all the numbers learned in the teaching phase. The IXL program chose the digital tasks, therefore the author had no way to affect if the student would be able to solve tasks on all numbers from 2-10.

Test	**Example picture**	**Tasks**	
Material test		**Day 1** **1.** 2 + 3 = **2.** 6 + 3 = **3.** 4 + 4 = **4.** 2 + 2 = **5.** 2 – 1 = **6.** 10 – 3 = **7.** 5 + 4 = **8.** 6 – 3 = **9.** 2 + 5 = **10.** 8 – 0 =	**Day 2** **1.** 8 – 2 = **2.** 3 – 2 = **3.** 5 + 5 = **4.** 4 – 3 = **5.** 1 + 2 = **6.** 6 – 5 = **7.** 2 + 8 = **8.** 9 – 7 = **9.** 1 + 1 = **10.** 5 – 4 =
Digital test		**Day 1** **1.** 6 – 6 = **2.** 6 – 1 = **3.** 2 – 1 = **4.** 6 + 3 = **5.** 9 – 9 = **6.** 0 + 2 = **7.** 1 + 4 = **8.** 4 + 5 = **9.** 9 – 2 = **10.** 4 – 4 =	**Day 2** **1.** 4 – 1 = **2.** 2 – 2= **3.** 2 + 5 = **4.** 3 + 0 = **5.** 8 + 2 = **6.** 6 + 4 = **7.** 3 – 2 = **8.** 7 – 4 = **9.** 7 – 0 = **10.** 6 + 1 =

2. Addition and subtraction word problems. The purpose of this subtest was to see if the student has learned and can solve the word problem according to the algorithm, can understand the operation he needs to solve and if he knows how to add or subtract within ten. On the first day, the student solved 3 addition and 2 subtraction word problems on and on IXL. On the second day, the student solved 2 addition and 3 subtraction word problems on paper and on IXL. On paper, the student solved word problems in mixed order to assess how well he understands the signs used and adapts to changes in operation type. However, since the IXL program doesn't have mixed operation word problems with numbers up to ten, the student solved addition and subtraction word problems separately.

Test	Example	Tasks
Material test	2. Emma has 10 euros. She spends 4 euros on a toy. How many euros does Emma have left? Emma have 6 euros. 3. Dave asked for Pokemon cards for his birthday. He got 5 from Amy and 3 from Steve. How many cards did Dave get? Dave has 8 Potemon cards.	**Day 1** **1.** There are nine kids in the class. Five of them are girls. How many boys are in the class? **2.** Emma has 10 euros. She spends 4 euros on a toy. How many euros does Emma have left? **3.** Dave asked for Pokémon cards for his birthday. He got 5 from Amy and 3 from Steve. How many cards did Dave get? **4.** Mary went to a bakery. She bought three muffins and four cakes. How many things did Mary buy? **5.** Steve was counting his pencils. He has 4 red pencils and 2 blue pencils. How many pencils does he have? **Day 2** **1.** There are five cupcakes in the cafeteria. John eats three of them. How many cupcakes are left?

		2. David has 2 dogs and 1 cat. How many pets does David have? **3.** Julie is picking flowers. She picks one yellow flower and three red flowers. How many flowers did she pick? **4.** James has 7 euros. He buys a movie ticket for 6 euros. How many euros does he have left? **5.** There are eight sausages on the counter. The dog comes and eats eight of them. How many sausages are left?
Digital test		**Day 1** **1.** Last Saturday, Nate and his friends had a huge snowball fight. During the fight, 3 of the snowballs hit their targets, but 1 of them missed. How many snowballs were thrown? **2.** A school bus made a stop and 1 child got off the bus. However, 4 children stayed on. How many children were on the bus just before the stop? **3.** The basketball team lost a game. They scored 1 point, but they needed 3 more points to win. In total, how many points did the team need to win? **4.** Mark has a total of 5 letters. He has opened 4 of them so far. How many letters does Mark have left to open?

		**5.** The music school in Jefferson County held a children's concert and an adult's concert at the same time. A total of 5 students performed at the two concerts. If 2 students performed at the children's concert, how many students performed at the adult's concert? (Answer options: 2 4 1 3) **Day 2** **1.** Seth needs to stand on 5 pillows to reach the biscuit jar. He takes 2 pillows from the bed. How many more pillows does he need to reach the biscuit jar? **2.** Last week, Tina practised a song 5 times. If she practised the song 3 times on her own, how many times did she practise the song in front of others? *(Answer options: 4 1 2 3)* **3.** Mrs. Grey's class raised a total of 5 silkworms, and 3 of them turned into moths. How many silkworms did not turn into moths? **4.** Mandy and Sue collected shells on the beach. Mandy found 5 shells and Sue found 3 shells. How many shells did they collect in all? **5.** A husband and wife are on the Oregon Trail. Bugs get into their food and ruin 2 cups of wheat and 2 cups of cornmeal. How many cups of grain does the couple lose?

Appendix 6. Motivational behaviour assessment

Motivational behaviour assessment

Assessor: Sandra

Date and time (duration) of the lesson: 31.03 11.30-12.15 (1.10-1.25) 10min 15s

Topic of the lesson: Number bonds of 8

Type of resource used (underline): Material / Digital

Protocol: Mark each occurrence of behaviour in the slot using tally marks: 1= | , 5=𝍸

Circle or highlight the tally marks for when manipulatives (M) were used with green. *Material manipulatives are two-colour counters. Virtual manipulatives are on Toytheater, ICT Games, Making Number Bonds, and Make Another Number Sentence.*

Additional protocol for game aspects (G): Mark the time Pink Cat Games (PKG) or "Build a monster" was used between pink brackets: [ ]. *Example: Belief in success:* 𝍸|| *or* [|||]

Summary: Mark the totals of occurrences for each category and subcategory and how many times behaviour occurred when manipulatives were used (1.). Additionally, mark manipulatives used with game aspects (G) (2.) and use of PCG or "Build a monster" without manipulatives (3.).

1. Positive behaviours: ..1..

1.1 Belief in success: ..1... 1. M: ..... 2. M and G: ..... 3. G: .....

1.2 Expressions of happiness: ..... 1. M: ..... 2. M and G: ..... 3. G: .....

2. Negative behaviours: ..1..

2.1 Refusal to work: ..... 1. M: ..... 2. M and G: ..... 3. G: .....

2.2 Disbelief in success: ..1... 1. M: ..1... 2. M and G: ..... 3. G: .....

2.3 Expressions of negativity: ..... 1. M: ..... 2. M and G: ..... 3. G: .....

3. Distractive behaviours: ..3..

3.1 Social strategies: ..2.. 1. M: ..1... 2. M and G: ..... 3. G: .....

3.2 Inattentive behaviours: ..1... 1. M: ..... 2. M and G: ..... 3. G: ..1...

Behaviour category Behaviour description	**Occurrence** (mark with tally marks) *Manipulatives*, [*PCG /Build a monster*]
1. Positive behaviours	
1. Belief in success – Student tries to solve the task independently, verbalises confidence (e.g., "I can do it", "Watch me")	|
2. Expressions of happiness solving the task - vocalisations and verbalisations of joy and pleasure (e.g., cheering, saying "Yes!").	
2. Negative behaviours	
1. Refusal to work – stops during the task or refuses to start, verbalisations (e.g., "I'm done!", "I won't do it.")	
2. Disbelief in success – verbalisations (e.g., "I can't do it.", "I don't know.")	|
3. Expressions of negativity – vocalisations that indicate negativity towards a task but still pursuing work (e.g., "I don't like this.", negative tonality in expressions)	
3. Off-task behaviours	
1. Social strategies to divert attention - Asking questions (about the researcher, other topics), telling a story.	| |
2. Other non-task related behaviours – looking elsewhere, not listening (e.g., the author has to repeat instruction due to the student not listening), fidgeting.	(|

Motivational behaviour assessment

Assessor: Sandra 2.25-16.29

Date and time (duration) of the lesson: 13.04. 10:40-11:25 22-36 42 (28min 62s)

Topic of the lesson: Bonds of 10

Type of resource used (underline): Material / Digital

Protocol: Mark each occurrence of behaviour in the slot using tally marks: 1= | , 5=𝍸

Circle or highlight the tally marks for when manipulatives (M) were used with green. *Material manipulatives are two-colour counters. Virtual manipulatives are on Toytheater, ICT Games, Making Number Bonds, and Make Another Number Sentence.*

Additional protocol for game aspects (G): Mark the time Pink Cat Games (PKG) or "Build a monster" was used between pink brackets: [ ]. *Example: Belief in success:* 𝍸|| *or* [|||]

Summary: Mark the totals of occurrences for each category and subcategory and how many times behaviour occurred when manipulatives were used (1.). Additionally, mark manipulatives used with game aspects (G) (2.) and use of PCG or "Build a monster" without manipulatives (3.).

1. Positive behaviours: 6

1.1 Belief in success: 4 1. M: 2 2. M and G: ..... 3. G: 1

1.2 Expressions of happiness: 2 1. M: 1 2. M and G: ..... 3. G: 1

2. Negative behaviours: 6

2.1 Refusal to work: 1 1. M: 1 2. M and G: ..... 3. G: .....

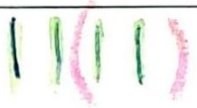
2.2 Disbelief in success: 1 1. M: ..... 2. M and G: ..... 3. G: .....

2.3 Expressions of negativity: 4 1. M: 2 2. M and G: 2 3. G: .....

3. Distractive behaviours: 4

3.1 Social strategies: 4 1. M: 2 2. M and G: ..... 3. G: 1

3.2 Inattentive behaviours: ..... 1. M: ..... 2. M and G: ..... 3. G: .....

Behaviour category Behaviour description	**Occurrence** (mark with tally marks) *Manipulatives* [*PCG /Build a monster*]
1. Positive behaviours	
1. Belief in success – Student tries to solve the task independently, verbalises confidence (e.g., "I can do it", "Watch me")	
2. Expressions of happiness solving the task - vocalisations and verbalisations of joy and pleasure (e.g., cheering, saying "Yes!").	
2. Negative behaviours	
1. Refusal to work – stops during the task or refuses to start, verbalisations (e.g., "I'm done!", "I won't do it.")	
2. Disbelief in success – verbalisations (e.g., "I can't do it.", "I don't know.")	
3. Expressions of negativity – vocalisations that indicate negativity towards a task but still pursuing work (e.g., "I don't like this.", negative tonality in expressions)	
3. Off-task behaviours	
1. Social strategies to divert attention - Asking questions (about the researcher, other topics), telling a story.	
2. Other non-task related behaviours – looking elsewhere, not listening (e.g., the author has to repeat instruction due to the student not listening), fidgeting.	

Appendix 7. Baseline assessment protocol

1. Estimation

Task (correct answer)	Questions and difficulties with understanding the task	Mistakes and assistance level	Analysis
Material test			
1. 50 or 90 (50)	The student started to count. After explaining what estimation means ("Don't count. Look at the dots. Do you think there are 50 or 90 dots?"), the student understood the task.	The student guessed 90 instead of 50. After an explanation and example ("This is a group of 10 dots. There are about five groups of dots, there are about 50 dots. How many are there then?"), the student answered 50 but did not circle the correct answer.	The student needed an example to estimate the number correctly. However, over here, the teacher told him the answer.
2. 20 or 70 (20)	The student started to count again. The teacher asked him to stop counting and choose one of the answers.	Solved independently.	The student estimated a group of 20 correctly given a choice between 20 and 70.
3. 40 or 80 (40)		The student estimated 80. After pointing to the previous example, the student continued to guess 80.	The student could not estimate a group of 40 correctly when given a choice between 40 and 80. This could mean that the student has difficulty estimating groups of at least 40 items.
4. 60 or 30 (30)	The student had difficulty understanding which answer could go for which test. The teacher pointed to the corresponding answer choices and dots.	Solved independently.	The student estimated a group of 30 correctly when given a choice between 60 and 30.
5. 40 or 80 (80)		The student first answered 40 but corrected himself and guessed 80 ("Actually, I think it's 80.")	The student analysed his answer and estimated a group of 80 correctly when given a choice between 40 and 80.

6. 70 or 30 (70)		The student first commented, “Wow, so many!” He guessed 30. The teacher showed the example in the first task. He continued to think 30.	Even though the student estimated a group of 30 correctly earlier, this time he thought the group had 30 dots instead of 70. This could be because he has poor estimation skills or, as both previous answers were on the right, he might have followed a pattern.
Digital test			
1. 30 or 80 (30)	The student started to count but stopped after the teacher mentioned it. The teacher read the task out loud.	The student looked at the example (“This is a group of 10 dots (circled on the test). There are about seven groups of dots, there are about 70 dots.”) After closing the example, the student answered 80. After he got it wrong, he looked at the example and listened to the instructions again.	The example of groups of tens did not help the student.
2. 40 or 70 (70)		Solved independently	The student could correctly estimate a group of 70 given a choice between 40 and 70.
3. 30 or 90 (90)		The student commented, “Oh, so many!” and answered “about 30” without waiting for assistance.	Even though the student correctly estimated a previous, smaller group as 70, on this task he estimated that it was 30 dots. This might mean he did not understand the value of 30 or 90 and did not compare his answer with the previous one.
4. 50 or 80 (80)	The student commented, “There’s too many.” The teacher read the choices to him.	Solved independently.	The student estimated a group of 80 correctly even though the difference between 30 and 90 is greater than between 50 and 80.
5. 50 or 90 (50)		The student answered “About 90” without waiting for help.	Again, the student did not estimate correctly even though the number of dots was smaller than before.
6. 20 or 90 (20)	The student started to count. The teacher told him not to count.	When the student seemed stuck, the teacher read the task out loud. After hearing the choices, the student answered 20.	The student estimated a group of 20 dots correctly.

2. Number bonds

Task (Answer choices)	Questions and difficulties with understanding the task	Mistakes and assistance level	Analysis
Material test			
1. How do you make 10? (3+8; 4+6; 2+5; 4+1)	The student first read the task and equations and said, "those equal 10", indicating that this was a task he did not understand. The teacher read the task and asked, "Which one of those is 10?" He answered, "Eight." The teacher explained: "One of these additions makes 10. Add them to see which one it is.	The teacher asked the student to add the equations one by one. Since he did not know how to, the teacher said, "One of the numbers is four, how much do you need to add to make 10?" He answered, "I don't know." After taking counting cubes, he had difficulty finding how many to add and counted all the cubes together.	The task was solved incorrectly. The student was unfamiliar with the task and could not understand how to represent the addition with counting cubes.
2. How do you make 8? (5+2; 3+6; 3+5; 9+2)		The student read all the equations and answered "Six". The teacher asked how much is 3+6. He answered "Eight". When taking counting cubes, the teacher first gave him three cubes and asked how many he needed to add to make eight. The student counted five more but answered with "8".	The student counted the correct number but either forgot the question ("How many do you need to add?") or did not understand the question and the task overall.
3. How do you make 7? (3+8; 4+6; 2+5; 4+1)		The student circled 3+8 and refused to continue that task.	The student answered incorrectly. The frustration from getting answers wrong seemed to decrease motivation for continuing.
4. How do you make 13? (11+4; 10+6; 3+1; 12+1)		Solved independently.	This was the only subtest that had early addition (+1) as the correct answer. He solved it correctly, which might indicate that this could be his current level.
5. How do you make 15?		The student answered 4+4. When asked, "How much is 4+4?" He answered 15. He	The student did not know how to make number bonds up to 20.

(2+10; 9+6; 13+5; 4+4)		refused to use number cubes.	
6. How do you make 12? (10+3; 8+6; 11+2; 8+4)		The student first answered 11+2. When the teacher asked him, “How much is 11+2?” He said the task was too hard and refused to look at the task any further.	The student was visibly frustrated and did not want to use any help.
Digital test			
1. How do you make 3? (1+3; 2+1; 1+1; 3+1)	After reading the task, the student counted on his fingers. The teacher pointed to the equations and asked, “Which one of these makes 3?”	The student first answered, “Two”, which would have been included in the correct equation but pressed the one that has the number 3 in it. After the program said he was incorrect, he looked at the example.	The student said one of the correct numbers in the equation but still chose the one with the number that was asked.
2. How do you make 10? (1+8; 3+7; 4+5; 3+6)	The student listened to the task while reading.	The student did not start to work, so the teacher asked how much each equation was. He answered all the equations as 10. The teacher said, “One of the numbers is 3. Which one makes 10: 3 +7 or 3+6?” The student answered correctly.	The student did not understand that numbers can be made of different numbers. He answered correctly after the answer choices were narrowed down.
3. How do you make 5? (1+3; 3+3; 4+1; 1+5)	The student read the task and answered with 1+5. The teacher told him to read the task again while listening.	When asked “How do you make 5?” The student counted to five. When asked which of the additions makes 5, the student pointed to 1+5. When asked “How much is 1+5” the student answered 1. The student refused to count on the cubes.	The student chose to count by ones instead of making the number out of two numbers with counting cubes.
4. How do you make 6? (4+1; 3+3; 2+3; 1+6)		The student did not start to work and said the task is too hard. The teacher said, “One of the numbers is 3. How much more do you need to add to make 6?” The student counted up to six. The teacher took counting cubes, counted out three, and asked, “How many do we need to add to make 6?” The student looked at the	The student needed persuasion to use the counting cubes. He answered correctly after guidance.

		cubes and counted three additional cubes. He counted that he needed to add three.	
5. How do you make 4? (1+3; 2+1; 1+1; 1+4)		The student took the counting cubes without trying to do the task independently. He counted the cubes into two piles but answered with 1+4.	The student chose the one that has the asked number in it, counting cubes did not help him, although he understood he needed to divide the cubes into two piles.
6. How do you make 2? (1+1; 1+3; 3+1; 2+1)		The student continued to work with the counting cubes, taking two cubes and counting them. He answered 2+1.	The student chose the one that has the asked number in it and the counting cubes did not help him.

3. Number sequencing

Task (student's answer)	Questions and difficulties with understanding the task	Mistakes and assistance level	Analysis
3.1. Position words			
Material test			
1. "After 18" (19)		Solved independently.	The student was quickly able to say the correct number.
2. "Before 78" (75)	The student read "after" instead of before. After asking him to read again, he repeated the mistake. After asking him if it was before or after, he read correctly.	Answered incorrectly, saying the number after instead of before. When the teacher asked which way is before, the student showed the wrong way (left instead of right). The teacher corrected him. The student still wanted to answer 79. The teacher asked if the number before was bigger or smaller to which the student answered smaller. The student continued to think it was 79. When asked to count up from 75, the student counted. When	Answered incorrectly. The student guessed instead of focusing on reading what the new task required and had trouble switching to a different task. He knew that the number before is smaller but failed to show it.

		asked what number was just before, the student got frustrated and said 75. Since the student was already annoyed, he continued to the next task.	
3. “Between 54 and 56” (56)	The student read the task correctly but named and marked 56 instead of 55. The teacher read the task again.	Since the student still guessed 56, the teacher made an example on a number line with 23 and 25: “Number 24 is between 23 and 25” while pointing to the numbers. After being asked to look again on his test, the student guessed 54 but did not circle it. When asked to touch and count the numbers, the student counted and touched the numbers. When asked what number was between 54 and , he decided the answer is 56.	Answered incorrectly. The student did not understand the meaning and action associated with the word “between.”
4. “After 99” (100)		Solved independently.	The student found the number “after” independently and with ease.
5. “Between 29 and 31” (31)		The student answered 31 instead of 30. The teacher asked the student to touch and count and say what was between 31 and 29. The student said 31.	Answered incorrectly. The student did not understand the meaning and action related to the word “between”.
6. “Before 40” (41)	The student read “after” instead of before”. When asked to read again, he made the same mistake. The teacher asked, “is it after or before?” The student read again and answered “before”.	The student answered 51 (the last number on the number line). The teacher asked him to read the task again. He corrected it to 41. When asked if before is bigger or smaller, he answered smaller. When asked “which number is smaller then?” he answered 41.	When reading, the student kept guessing that the sentence ends with “after” and did the action associated with it. He found it difficult to understand the action related to the word “before”.
<u>Digital test</u>			
1. “After 6” (7)	First started to read the number line. The teacher asked the student to read the task again.	Solved independently.	The student understood the action related to the position word “after” and knew which number comes after the said number.
2. “Before 3”	The student first read	The student answered with “4” although the	Answered incorrectly. When reading

(4)	"after" instead of "before". The teacher asked the student to reread. The student read "after" again. The teacher asked: "Is it after or before?". The student read again, this time saying correctly.	correct answer was 2. When asked if "before" was bigger or smaller, the student answered, "it's smaller, I think." He answered "4" again and submitted the answer. He looked at the example.	a task, the student guessed the last word. While he knew that the number before will be smaller, instead of saying the number that comes before – counting down – he counted up. This might mean the student has a poor understanding of the position word "before".
3. "Between 7 and 9" (10)	The student read the task correctly but kept answering the number after.	The teacher asked the student to find numbers 7 and 9 and asked what was between them. The student answered "ten". Since the student had difficulty understanding, the teacher made an example on a number line: "Can you see 23 and 25? 24 is between them." Even after the example, the student answered 10. When asked to touch and count and say what was in the middle, between 7 and 9, the student answered with 10.	Answered incorrectly. The student did not understand the meaning and action related to the word "between" even after assistance.
4. "After 21" (22)		Solved independently	Saying the number "after" was not difficult for the student.
5. "Before 28" (27)		He looked for the number line (ruler). When asked "which way is "before?" he showed the wrong way (right instead of left). When the teacher told "before" is the other way, he answered "27."	When telling the student which way numbers "before" are, he solved the task.
6. "Between 17 and 19" (18)		He looked for the ruler, found 17 and 19, and first answered 16. When the teacher pointed to 17 and 19 and asked, "what's between them?", he answered with 18.	The student understood what "between" means and the action related to it after several visual and verbal examples.

3.2 Sequencing on a number line

Material test			
1. 48, 49, …, 51, 52, 53		The student counted and said "44". The teacher asked him to count the number line out loud and	The error occurred when the student had to count up and cross tens

(44)		he said, “48, 49, 44…” The teacher asked him to look at the hundred chart. The student did not want to and said, “No, it’s okay. It’s 44.”	boundaries. The student refused assistance and was very certain of his answer.
2. 36, 37, 38, … , 40, 41 (39)		Solved independently.	The student needed some time to think but eventually managed to say the correct number by counting up.
3. 72, 71, 70, 69, 68, …. (67)		Solved independently.	The student could count down correctly.
4. 9, 10, …., 12, 13, 14 (11)		Solved independently.	The student could count up independently.
5. …., 20, 21, 22, 23, 24 (19)		The student first said “12”. The teacher asked him to count the row again. The student said hesitantly 19. He proceeded to count up from 14 and was certain it was 19.	The student could help himself by counting up from a smaller number instead of counting down.
6. 19, 18, 17, 16, …., 14, 13 (15)		Solved independently.	The student could count down independently.
7. 95, 96, 97, 98, 99, …. (100)		Solved independently.	The student could correctly cross tens boundaries up to 100.
8. …., 29, 28, 27, 26, 25 (19)		The student first said “21” and wrote it down. When the teacher asked him to look at the number line, he said, “one nine” and wrote 19. The teacher asked him to look at the hundred chart but he did not want to.	The error occurred on a tens boundary.
9. 69, …., 71, 72, 73, 74 (59)		The student looked at the whole number line and instead of saying 70, he said 59 and counted down. He did not want to look at the hundred chart.	At the tens boundary, the student, instead of counting up by ones, counted down by tens.

10. 44, 43, 42, 41, 40, …. (44)		The student first said the number is “15”. When asked to count down, he decided it’s 44.	The student probably counted up by tens instead of counting down by ones at the tens boundary. After being asked to count, he focused on the first number in the row.
11. …., 56, 55, 54, 53, 52 (54)		By this time the student was somewhat frustrated since the task was difficult. He read the number line out loud but said the answer is “fifteen four” and wrote it down. When asked to look at the whole number line, he was certain it was 54.	The student had trouble counting up from 56 since the number was at the beginning of the row. Instead, he counted down by twos. When pronouncing the number, he mixed up “-teen” and “-ty” endings but managed to write the number correctly.
12. 85, …., 83, 82, 81, 80 (95)		The student said confidently that “it’s 95”. When asked to count down from 85, he was already too frustrated.	The student counted up by tens instead of counting down by ones.
<u>Digital test</u>			
1. 2, 3, 4, 5, …. (6)		Solved independently	The student could count up.
2. …., 5, 6, 7, 8 (4)	First, read the number line. The teacher asked the student to read the task again.	Solved independently.	The student showed no difficulties in counting up.
3. 21, 22, 23, …., 25, 26 (24)		Counted up on the number line, solved independently.	The student showed no difficulties counting up.
4. …., 20, 21, 22, 23 (30)		Answered 30. The teacher told him to look at the number line again. This time he figured it was 20. The teacher asked, “What number comes before 20?” He answered 21. When asked to count down from 23, he said the answer is 40, but corrected himself and said, “No, it’s 30” and submitted the answer.	Since it was difficult to cross the tens boundary, instead of counting down by ones, he counted up by tens.

5. 13, …., 15, 16, 17, 18 (14)		The student said “30…40” and wrote 14.	The student mixed up “-ty” and “-teen” endings but wrote the correct answer.
6. 24, 25, 26, 27, …, 29 (28)		Counted up on the number line and solved independently.	Solved with no difficulties.

4. Number comparison

Task (student’s answer)	Questions and difficulties with understanding the task	Mistakes and assistance level	Analysis
4.1 Comparing numbers in a range of 17-50 using the comparison sign			
Material test			
1. Bigger 23 *vs* 45 (23)	The student started to read the numbers. The teacher asked him to read the task. He read the task but not the marks (<, >, =). When asked what they mean, the student did not know. When asked what comparing means, he did not know. The teacher explained, “Comparing means finding which one is bigger, which one is smaller, or are the numbers the same.” When explaining the marks, the student said, “I have never seen those before.” The teacher changed the task and asked the student to find the bigger one in the first column (marking it) and the smaller ones in the second one (marking it). When the student started to count the numbers from 23, the teacher stopped him and retold the task: “Make a circle around the bigger number. Which one is bigger – 23 or 45?”	The student answered 23. When looking at a hundred chart, the teacher asked the student if bigger numbers are before or after? The student answered “after”. When asked if 23 was before or after 45, the student answered “After.” The teacher told him that 23 is before 45 and showed on the hundred chart. When looking at the task again, he still chose 23 as the bigger number.	The student does not know the meaning of the comparison signs <; >; =. The student did not understand how to compare numbers on the hundred chart.

2. Bigger 38 *vs* 34 (38)		Solved independently.	The student chose the correct number but since he was already frustrated, it can also be hypothesized that he chose the number in the first row as he did the last time.
3. Bigger 50 *vs* 20 (50)		Solved independently.	The student chose the correct number but since he was already frustrated, it can also be hypothesized that he chose the number in the first row as he did the last time.
4. Smaller 47 *vs* 47 (47)	The teacher asked the student to look at the second column and circle if the number is smaller.	The student read the numbers. The teacher asked is one smaller or are they the same size. The student circled one of the 47's and said, "This one is bigger." The teacher said "Only mark if one is smaller. Is 47 smaller than 47 or are they the same size?" He was visibly frustrated and showed the one he marked and said, "This one is smaller!"	The student did not understand the conditional sentence and was unable to understand that 47 and 47 are the same size.
5. Smaller 17 *vs* 19 (19)	The student marked 19 as being smaller than 17. The teacher asked, "Is 19 bigger or smaller than 17? Circle the smaller one."	The student continued to answer 19. The teacher asked which to show on a hundred way is smaller? He showed correctly. The teacher showed 19 and 17 on the hundred chart and asked, "Which one is smaller? 17 or 19?" He answered 19.	It can be hypothesized that the student chose this answer because he was following a pattern from the previous subtest.
6. Smaller 31 *vs* 31 (31)	The student said 31 is smaller. The teacher asked and pointed "Is 31 smaller than 31 or are they the same?"	The student circled the second 31, saying "This one is smaller."	It can be hypothesized that the student chose this answer because he was following a pattern from the previous subtest.

4.2 Comparing numbers in a range of 1-85 by choosing the correct phrase.			
Material test			
1. 39 *vs* 46 (smaller)	The student first wanted to highlight the number. The teacher reread the task. The student kept saying "39". The teacher read all the choices and asked what they mean. When the student said he does not know, the teacher explained and pointed, "Greater than means bigger. Smaller than means smaller than the other number. Equal to means the numbers are same size. Is 39 bigger than 36 or smaller? Or are they the same size?"	After explanation, the student highlighted the correct word.	The student did not know what the comparison words meant but after an explanation could highlight the correct one.
2. 44 *vs* 44 (44)		Instead of highlighting a phrase, the student highlighted a number and seemed disinterested in the result. He was visibly tired by this time, so the teacher decided to take a short break and continue with a simpler task afterwards.	The student chose a random answer and was tired of the task.
Digital test			
1. 64 *vs* 63 (greater)		The student read the task and answered correctly.	The student chose the first answer without any comments.
2. 82 *vs* 85 (bigger)	The student wanted to answer, "is greater than". The teacher asked what "is greater than" means. The student answered "big". When asked what "smaller than means?" the student answered "small" and when asked what "equal to means, he said "Tiny baby." The teacher explained that "equal to" means they are the same size." The teacher explained that he needs to compare the first number to the second number to decide.	The student was distracted so the teacher asked "Is 82 bigger or smaller than 85? Or are they the same size?" The student answered "Bigger". The teacher showed the hundred chart and asked which way the numbers go bigger. The student pointed right. The teacher asked if 82 is before or after 85. The student answered, "Before." The teacher asked the student to choose the correct answer saying and	The student did not understand the task or how to compare the numbers.

		pointing to the options, “Is 82 bigger, smaller or the same size as 85?” The student answered, “Bigger.”	
3. 6 *vs* 6 (bigger)		The student answered before reading. When asked to slow down, he said “Whopsbee.”	The student chose a random answer impulsively.
4. 2 *vs* 3 (bigger)		The student answered again without waiting. Before looking at the mistake analysis, the teacher asked, “Which one is bigger, 2 or 3?”, the student answered, “3.”	The student compared numbers less than 5 correctly.
5. 1 *vs* 57 (smaller)		The student read the question and answered independently.	The student compared the numbers 1 and 57 correctly.
6. 8 *vs* 41 (equal to)		The student read the task and said, “I think it’s equal to.” When asked if 8 and 41 are the same size, he answered, “No”, but continued to press equal to. When asked which one is bigger, 8 or 41, the student answered, “41”.	By this time the student was visibly tired and kept answering impulsively instead of focusing. The teacher and student did a small movement break after this.

4.3 Comparing groups in a range of 20-80

Material test			
1. 60 *vs* 40 (60 is bigger)	Since the student had trouble understanding the previous task and wanted to circle, the teacher explained, “This is very similar to the last one. You need to compare groups. Highlight the correct word under the groups.” When he read the words, the teacher asked, “What does greater than mean?” The student answered, “I don’t know.” The teacher explained, “Greater than means bigger, smaller than means smaller, equal to means they are the same size.” When he did not start to work,	The student answered correctly after explanation.	After explaining the comparison words, the student chose the correct answer and could correctly compare groups in a range bigger than 40-60

	the teacher asked and pointed "Is this one bigger than this, smaller than this or are they the same?"		
2. 80 *vs* 80 (80 is bigger)		When asked "is this one bigger or smaller than this one or are they the same size?", the student answered, "This one is bigger."	The student does not see that the groups are the same size.
3. 30 *vs* 20 (30 is bigger)		Solved independently.	The student chose the correct answer but might have also followed the answer pattern from a previous subtest.
4. 40 *vs* 50 (40 is bigger)		The student said, "This one is bigger," while pointing to the smaller one. When asked to count how many rows each has, the student counted and continued to think the first one is bigger.	The student was unable to compare the groups correctly even after counting the groups.

4.4 Comparing groups in a range of 1-10.

Material test			
1. More 3 *vs* 5 (5)		The student counted the numbers in both groups and said "That has more and that has less."	The student commented his thinking and could correctly compare numbers in a range up to 10 and find the one that has more.
2. Less 6 *vs* 8 (6)		The student counted and commented which one has less. He solved it independently.	The student commented his thinking and could correctly compare numbers in a range up to 10 and find the one that has less.
3. More 5 *vs* 4 (5)		The student counted and commented which one has more. He solved it independently.	The student commented his thinking and could correctly compare numbers in a range up to 10 and find the one that has

			more.
4. Less 7 *vs* 10 (7)		The student counted and commented which one has less. He solved it independently.	The student commented his thinking and could correctly compare numbers in a range up to 10 and find the one that has less.
Digital test			
1. More 4 *vs* 2 (4)		The student read the task, commented which one has more and solved it independently.	The student commented his thinking and could correctly compare numbers in a range up to 10 and find the one that has more.
2. Fewer 1 *vs* 4 (4)	First read “more” instead of “less”. After asking him to read it again, he read it correctly, struggling with the word "fewer". When asked what fewer means, he answered “I don’t know.” The teacher explained that it means “less.” “Which one has less?”	The student pointed to the one that has more and when asked “is this one less or more?”, he pressed the answer. After looking at the mistake explanation after, he said “Oh, right.”	The student was fixed on the previous subtest where he had to choose the one that has more. The student needed an explanation of the meaning of “fewer.”
3. Fewer 3 *vs* 2 (2)	The teacher said again that fewer means less.	The student pointed to the one that has less and said, “This one has less”.	The student could compare the groups in a range of 5 and find the one that has less.
4. More 4 *vs* 5 (4)		The student counted both groups and said, “This one has more” and pressed. After receiving an incorrect answer, the student said “Whopsbee.”	Even though the student counted both rows, he found it difficult to compare groups that were similar in size.
5. Fewer 5 *vs* 4 (5)		Without counting, the student pressed the incorrect one. When asked to wait before pressing, he said, “Oops, sorry!”	Even though the comparable groups were the same as in the previous task, he found it difficult to compare them.
6. More 2 *vs* 5 (5)		Solved independently	The student compared the groups visually and chose the correct answer.

5. Counting

Task (student's answer)	Questions and difficulties understanding the task	Mistakes and assistance level	Analysis
5.1 Counting up and down by tens, fives, and twos.			
Material test			
1. Counting up by tens from 20 (40)		After reading the task, the student answered "21". The teacher reread the question and asked how does counting by tens go? The student counted up by twos (10, 12...) and when asked, "is it 12 or...", he answered, "10, 20, 40". When checking the hundred chart, he counted up correctly to 80, but kept saying "-teen" endings instead of "-ty". When asked again, what was after 20, the student answered 40.	The student can count forward by tens but forgets 30 in the number sequence.
2. Counting up by fives from 10 (20)		The student counted, "5, 10, 11…" He corrected his answer to "10, 20" After looking at the hundred chart, he still continued to think the answer is 20.	This indicates that he has some idea of counting by fives, but a weak understanding of the number sequence. Answering 20 could either be mixing up counting by fives and counting by tens or remembering the previous answer).
3. Counting up by twos from 16 (17)		The student answered 17. The teacher made an example of counting up by twos and showed the sequence on a number line. The student kept counting up by ones and said, "it's 17."	The student does not know how to count by twos on a task like this.
4. Counting down by fives from 25 (35)		When counting down by fives, he counted up by tens even after examples and using the hundred chart.	The student does not know how to count down by fives on a task like this.
5. Counting down by twos from 12 (10)		After rereading the task and giving an example (2, 4, 6), the student counted "2, 4, 6, 8, 7, 9, 10". So, he gave the correct answer, but did not get there the right way.	The student counted up by ones instead of twos.

6. Counting up by tens from 30 (91)		With counting up by tens from 30, the student first counted up by ones. After an example (10, 20, 30…), he changed from pronouncing "forty" to "fourteen" and ended up counting to nineteen. He proceeded to write 91 as the answer, indicating that he meant 19, but mixed up the numbers as well	The student was unable to count up by tens on a task like this. By mixing up "-teen" and "-ty" endings, he also mixed up the numbers.
7. Counting down by twos from 14 (8)		Even after an example on a hundred chart, he continued to count by ones but ended up writing number 8 as the answer because the teacher finished the example at 8.	The student was unable to count down by twos and was fixed on the example instead of the actual test.
8. Counting up by twos from 12 (2)		When counting up by twos, after the example (2, 4...) on a hundred chart, the student answered with number 2. When pointing out what he needed to count up from, he still said the answer is 2. Since the student was already tired and frustrated, the teacher took a short break and continued with a simpler task.	The student remembered the example and was persistent on the answer.
Digital test			
1. Counting up by twos from 34 (44)		The student read the task and answered 44. The teacher asked, "What do you need to count by?" The student answered, "it's 44." The teacher asked the student to listen to the task. The student answered, "it's 35." The teacher made an example of counting by twos, "Counting by twos goes 2, 4, 6, 8". The student answered, "It's 8." The teacher took out a hundred chart and showed how to count by twos on there while pointing and counting by 2s from 2. The student said, "It's 8." The teacher asked the student to find 34 and count by twos. The student said it was 44 and pressed the answer. He looked at the example given after being incorrect.	Instead of counting up by twos, the student counted up by tens.
2. Counting down by fives from 90 (0200)	The student first read "after" instead of "before" and instead of 90	The student answered, "it's 21". The teacher asked the student to pay attention to the number and asked, "is it 90 or 19?" The student looked and said, "ninety". The teacher made an example of how to count down by fives, "25, 20, 15, 10, 5." The student answered that the answer is 5. The	The student first mixed up 90 and 19 and proceeded to count forward by twos, indicating that he mixes up "-ty" and "-teen" endings which cause him to understand the number

	said 19. The teacher asked the student to read again.	teacher showed counting by fives on a hundred chart and by then, he had already answered “0200” and pressed “Submit.”	incorrectly. It also indicates that he has trouble switching between tasks.
3. Counting down by tens from 40 (50)	The student read the task first as “after” and when the teacher pointed to the word, he read correctly.	The student became very quiet. The teacher asked him to count by tens. The student counted, “10, 11, 12...”. The teacher made an example “10, 20, 30, 40”. The student counted with the teacher and instead of 30, said 40 and corrected himself. The teacher asked, “What was before 40?” The student answered “50” and wrote the answer. After this the student got frustrated and did not want to continue. The teacher switched to a simpler task.	The student understood how to count by tens but gets stuck on counting forward instead of backward.

5.2 Counting up and down by tens, fives, and twos on a number line

Material test			
1. Counting up by twos 48, 50, …., 54, 56 (49)	The student wanted to count by ones. The teacher explained the task and asked what he needs to count by – tens, fives, or twos. The student said, “I know, okay.”	Since the student was confused, the teacher told him that he must count up by twos. The student read the first number and immediately wrote 49. The teacher made an example of how counting by twos goes. After this the student thought it was 22, possibly because this was where the teacher stopped the example. When the teacher made an example on the hundred chart in the same range, the student insisted it was 49.	The student was unable to count by twos after examples on a hundred chart.
2. Counting up by fives 35, …, 45, 50, 55 (14)		After counting the row with the student, the teacher asked, “What should be here?” The student answered “40” but wrote 14.	The student could count up by fives but mixed up “-teen” and “-ty” endings and wrote 14 instead.
3. Counting down by tens		The student solved the subtest independently.	The student could count down by tens.

60, 50, 40, 30, …. (20)			
4. Count down by twos 56, 54, ..., 50, 48 (55)		The student thought the answer is 55. When making an example, he thought it was 36 (this was where the example ended). When showing on a hundred chart, the student still wrote 55.	The student was unable to count down by twos even after examples on a hundred chart.
5. Counting down by tens …., 30, 40, 50, 60 (20)		The student silently read the number line to himself and answered 90. The teacher asked him to read the number line again. The student answered 16. When the teacher asked what's before 30, the student answered 20.	The student could count down by tens after a guiding question.
6. Counting down by fives 65, 60, 55, 50, …. (51)		The student read the number line and first said it's 51. The teacher asked the student to look at the row again. He said, "17". The teacher asked if the numbers are going bigger or smaller. The student said, "Bigger." The teacher said, "No, smaller." By this time the student was visibly tired and yawning. The student looked at the hundred chart and said, "It's fifteen-one." When the teacher made an example, he was not paying attention and was writing the answer. The teacher took a short break after this.	The student was quite tired by this time. The student did not understand that he had to count down. Instead of counting down by fives, the student counted up by ones even after examples on a hundred chart. He mixed up "-teen" and "-ty" endings. The student was unable to count down by fives.
7. Counting up by fives 10, …., 20, 25, 30 (40)		The student first counted the row as "10, 20, 25, 30. It's 21." The teacher told the student to look at the row and asked what he needs to count by. The student said "40" and wrote it down. After being asked to look at the hundred chart, he was not paying attention.	The student was tired even after the break. Instead of counting up by fives, he counted up by tens from the last number in the number line.
8. Counting up by tens …., 40, 30, 20, 10 (50)		The student counted the number line and after a brief pause said "15" but wrote 50.	The student could count up by tens.
9. Counting up by twos 24, 26, 28, …..., 32 (29)		The student read the number line and said the answer is 29. The teacher asked what he is counting by – fives, tens, or twos. The student answered, "Ten." The teacher said he needs to count by twos. The student continued to think it's 29. The teacher counted with the student on the hundred	The student was unable to count up by twos even after an example on the hundred chart.

		chart but he still thought it's 29.	
10. Counting down by fives 35, …., 25, 20, 15 (60)		The student counted the row and after a pause thought it was 60 (but said 16). The teacher made an example of counting by fives on the hundred chart but he continued to think it's 60.	The student counted up by tens instead of fives and paid attention to the last number in the number line instead of the one in the middle. He mixed up "-teen" and "-ty" endings.
11. Counting up by tens 40, 50, …., 70, 80 (60)		The student read the number line and said "16" but wrote 60.	The student could count up by tens but mixed up the "-teen" and "-ty" endings verbally.
12. Counting down by twos 20, 18, …., 14, 12 (19)		The student said the answer was 19. When the teacher asked him to have a look on the hundred chart, he said he's too tired.	The student counted up by ones instead of counting down by twos.
Digital test			
1.Counting down by fives … 75, 80, 85, 90 (70)		The student read the number line and answered "17" but wrote "70".	The student mixed up "-teen" and "-ty" endings but wrote the correct answer indicating he could count down by fives.
2. Counting up by twos 50, 52, 54, …, 58 (55)		The student read the number line but instead of counting by twos, he counted by ones. After making an example (2, 4, 6, ...) the student counted the number line again to the end (52, 54, 55, 58). The teacher showed counting by twos on a number line (34, 36, 38), but the student was certain of his answer.	The student did not know how to count by twos.
3. Counting up by twos 2, 4, 6, 8, 10, 12, …. (13)		The student counted the number line and answered 13 instead of 14. When asked, "how do you count by twos" he counted up from 2 by ones. The teacher showed how to count on a hundred chart and asked the student to count his number line on the hundred chart also. He answered "13."	The student counted by ones instead of twos.
4. Counting up by tens		The student counted up and solved the task independently.	The student counted up by tens

40, 50, …., 70, 80 (60)			independently.
5. Counting up and down by fives …., 65, 60, 55, 50, … (66; 13)		The student read the number lines counting by ones. The teacher said: "You need to count by fives." The teacher showed the numbers on a hundred chart and counted the same sequence. He continued to count by ones.	The student was unable to count up and down by fives and instead counted by ones.
6. Counting down by tens 80, 70, …, 50, 40, …. (60; 30)		The student started to count up by tens. The teacher asked, "Do you need to count up or down?" The student answered, "Up?" The teacher said he needs to count down." When the student did not start to count, the teacher asked, "What comes before 70?" The student thought for a bit and answered 60. The student counted on and answered 20. The teacher asked the student to check the hundred chart. After this he answered 30.	The student could count down by tens with the help of a hundred chart.
7. Counting down by twos 66, …, 62, 60, …, 58 (50)		The student counted by ones instead of twos. When the teacher showed him the hundred chart, the student just said "No, no, I can do it."	The student was unable to count by twos and instead counted by ones.
8. Counting up by tens 40, 50, 60, 70, … (80)		Answered independently.	The student could count up by tens.

5.3 Counting by twos, fives, and tens with pictures

Material test			
1. Counting by fives, two sets (10)	The student started to count the trees by ones instead of counting by fives.	After examples on how to count by fives, the student continued to count by ones.	The student was fixed on counting by ones instead of fives.
2. Counting by tens, three sets (30)		The student wanted to start counting the pins, but after the teacher made an example, he could count by tens.	The student wanted to count by ones instead of groups of tens. After an example, the student could count by

			tens.
3. Counting by tens, four sets (40)		After the teacher explained that he has to count by tens like in the previous one, he answered correctly.	The student could count by tens after being reminded of the previous subtest.
4. Counting by twos, five sets (-)		The student started to count by ones. When the teacher asked the student to count by twos instead, he stopped. The teacher made an example on hundred chart but the student was not able to follow the example and kept counting by ones.	The student was not able to count by twos after examples on a hundred chart.
5. Counting by fives, five sets (50)		The student started to count by tens. The teacher asked the student to read the task again, the student counted, "5, 6, 7." The teacher made an example of how to count by fives on a hundred chart.	The student continued to count by tens instead of fives even after an example on a hundred chart.
6. Counting by twos, six sets (-)		The student wanted to count by tens but when asked to read the task again, he stopped working and said, "I can't do it."	The student does not know how to count by twos.
Digital tests			
1. Counting by fives, two sets (10)		The student started to count the radishes by ones. When the teacher made an example of how counting by fives goes on a hundred chart, he still counted each of the radishes by ones.	The student did not know how to count the pictures by fives and instead counted by ones.
2. Counting by fives, five sets (-)		The student started to count by fives using the hundred chart, but when he got to 10, he started to count by ones. When the teacher counted up with him on the hundred chart, he got to 20 and from there counted four more and wrote "24".	The student was unable to count by fives and instead counted by ones even after examples.
3. Counting by tens, five sets (16)		The student started to count each of the presents by ones. When asked to read the task again, the student counted "10, 12, 14, 15, 16." He submitted the answer before waiting for help.	The student mixed up "-ty" and "-teen" and skipped 30 on the number line.
4. Counting by twos, four sets (8)		The student counted the skates by ones instead of twos even after an example on a hundred chart. Since the student was visibly tired by now, the teacher stopped and took a break.	The student does not know how to count by twos.

6. Addition sentences

Task (student's answer)	Mistakes and help level	Analysis
	Material test	
1. 4 + 5 = (6)	The teacher switched to the easier task. Since the student had tried to use the number line before, the teacher asked if he would like to use it again. He said "No, I can do it," and wrote 6 as the answer. The teacher asked him to use the number line. He counted up to 10. The teacher again showed the example, "Find four. Now count five steps. What do you get?" The student answered, "Nine".	The student did not understand how to use the number line even after a previous example and started to count up to ten. The student could solve the addition after working together with the teacher and using a number line.
2. 2 + 6 = (8)	Solved using a number line.	The student used the number line to solve the addition.
3. 3 + 7 = (10)	The student miscounted on the number line and wrote the answer 11. When asked to count again, he counted 10 but did not correct the answer.	The student did not follow the one-to-one strategy when counting, therefore he counted two steps instead of one.
4. 4 + 3 = (7)	The student started to count from 3 twice. The teacher asked him to check again where he needs to start counting. He started from 4 and said, "It's seven."	The student did not know where to start counting and needed verbal assistance. He could add on a number line after this.
5. 5 + 5 = (10)	Solved using a number line.	The student used the number line to solve the addition.
6. 1 + 9 = (18)	The student found 1 and 9 on the number line and commented "I count to nine." He proceeded to count nine steps from 9, resulting in 18. When the teacher pointed out that he needed to start counting from number 1, he said "it's 18, okay. I don't want to." A short break was taken after this.	The student mixed up what to count on from. When corrected, the student got frustrated and did not want to continue. The student's mistakes might have come from being tired.
	Digital test	
1. 2 + 8 = (9)	The student read the equation and first answered "9". When using a number line, the student first needed an example of counting up. The teacher showed how to add 3+4 on the number line (Find number 3. Now add four, go four steps from here. What is the answer?) The student answered "7". The teacher asked him to use the number line for his task. The student followed the example	The student needed an example of how to count on a number line. The student failed to follow the one-to-one counting strategy. When getting the answer wrong, the student got frustrated.

	by starting to count from 2, counted two steps once instead of one and figured it was still 9. When asked to recount, he did and answered, “9” without waiting for help. When getting a wrong answer, the student said, “I can’t do it.” The teacher showed him the example again. The student agreed to continue.	
2. 2 + 7 = (9)	At first, the student thought the answer is number 8. When asked to look at the number line, he counted correctly.	The student used the number line after being asked to use it.
3. 4 + 3 = (7)	Solved using a number line.	The student can add using a number line.
4. 7 + 2 = (9)	Solved using a number line.	The student can add using a number line.
5. 3 + 3 = (6)	Solved using a number line.	The student can add using a number line.
6. 5 + 4 = (9)	Solved using a number line.	The student can add using a number line.

7. Addition word problems

Task, *Word problem text* *Answer choices (only digital test)* (Student’s answer)	**Mistakes and help level**	**Analysis**
Material test		
1. *Steve was counting his pencils. He has 6 red pencils and 3 blue pencils. How many pencils does he have?* (6)	The student read the text. The teacher asked, “What do they want to know?” The student reread the text and counted to six using his fingers. The teacher said “They want to know how many pencils Steve has. How do you find out?” The student said “I count six, that’s what it is. It's 6.”	The student had trouble understanding the task and how to solve word problems according to the algorithm.
2. *Mary went to a bakery. She bought 4 muffins and 3 cakes. How many sweets did Mary buy?*	The student read the text and counted to five on his fingers. When asked “How do you know?”, the student answered, “It just is, come on.”	The student counted up to five while looking at the text. The student does not know how to solve

(5)		word problems according to the algorithm.
3. *Dave asked for Pokémon cards for his birthday. He got 5 from Amy and 3 from Steve. How many cards did he get?* (6)	The student read the text and counted to six on his fingers. When asked "How do you know it's six?" the student answered "I don't know, okay. It's just..." and got frustrated.	The student does not know how the word problem algorithm.
<u>Digital test</u>		
1. *Last Saturday, Lena and her friends had a huge snowball fight. During the fight, 4 of the snowballs hit their targets, but 1 of them missed. How many snowballs were thrown?* *3 2 4 5* (3)	The student read the task and answered "3" without waiting for help. After the program said it was incorrect, the teacher asked the student to wait a bit before answering.	The student chose the first answer without focusing on solving the problem.
2. *Abby only feeds her dog two kinds of treats. Last year, Abby fed her dog 1 peanut butter treat and 4 carrot treats. How many treats did Abby feed her dog last year?* *4 2 5 3* (3)	After the student read the text, the teacher asked what they want to know. The student answered "3". The teacher asked the student to listen to the text. After listening, the teacher asked again "What was the question?" The student answered, "It's 3," and pressed the answer.	The student did not understand what was being asked and how to find out.
3. *Billy had 3 letters. Then 2 more came in the post. How many letters does Billy have now?* *4 3 2 5* (4)	The teacher asked the student to read calmly. The student read the task. The teacher asked, "What is the question?" The student read the question. The teacher asked how do you find out? The student answered, "It's 4." When the teacher asked, "How do you know?", he answered, "It's 4."	The student found the question but was unable to explain his thinking.

8. Subtraction sentences

Task (Student's answer)	Questions and difficulties with understanding the task	Mistakes and help level	Analysis
Material test			
1. 5 – 2 = (3)	The student read "plus" instead of minus". When the teacher said, it's not plus, its…?" The student answered "equals". The teacher read the task the correct way.	When asked "How much is 5-2?" the student answered "5". The teacher asked if subtracting makes numbers bigger or smaller, the student answered "Smaller." The student reread the equation and said "5-2 is 7". When suggesting using the number line, the student refused. The teacher made an example of counting down on a number line: "I'll show you. Let's do 7-3. Find number 7. Now count down 3. What's the answer?" The student answered "3". The teacher repeated the example while pointing to number 4, "7-3 is 4. Now you try 5 minus 2." The student counted down and answered with 3.	The student is more familiar with addition than subtraction. He added instead of subtracting, but after examples solved the task using a number line.
2. 6 – 3 = (3)		The student started to count on the number line but started counting from the second number so he answered with 2. The teacher redid the previous example, after which the student answered correctly.	The student needed an example on how to subtract on a number line but could solve it after that.
3. 8 – 2 = (6)		Solved independently using a number line.	He can subtract using a number line.
4. 9 – 7 = (2)		Solved independently using a number line.	He can subtract using a number line.
5. 8 – 5 = (3)		Solved independently using a number line.	He can subtract using a number line.
6. 6 – 6 = (0)		Solved independently using a number line.	He can subtract using a number line.
Digital test			
1. 8 – 3 = (4)	The student first read "8+3". The teacher asked "Is it plus? Read again."	When the student did not start to work, the teacher asked, "Are you making 8 bigger or smaller?" The student answered "Smaller." The teacher asked, "How do you do 8-3?". When	Even though the student had solved the subtractions using a number line on the previous week, he did not

	The student tried to listen to the program read it for him, but the program only read "Subtraction." When the student seemed confused, the teacher read "8-3".	the student wrote 83 as the answer, the teacher gave him a number line. The student said "No, thanks." When encouraged to try, the student found 8 and 3. The teacher asked the student to count down from 8, but the student counted up. The teacher said, "you need to count down." The teacher showed an example of counting down on a number line using an example of 9-5. The student said it's 4 and submitted.	remember how to use it this time.
2. 9 – 4 = (5)		The student read the equation correctly. The teacher asked him to find 9 and count down. He first started to count up. When reminded that he needs to count down, the student started to count from 10. The teacher reminded to check what he needs to count down from. He solved the task.	Even after seeing how to subtract previously on a number line, he needed help finding the number to count down from.
3. 9 – 5 = (4)		Solved independently using a number line.	He can subtract using a number line.
4. 8 – 4 = (4)		Solved independently using a number line.	He can subtract using a number line.
5. 7 – 5 = (2)		Solved independently using a number line.	He can subtract using a number line.
6. 7 – 2 = (5)		Solved independently using a number line.	He can subtract using a number line.

Appendix 8. Final assessment protocol

1. Addition and subtraction sentences.

Task (student's answer)	Questions and difficulties with understanding the task.	Mistakes and help level	Analysis
Material test – 1st day			
1. 2 + 3 = (5)		The student wrote "1" as the answer. The teacher asked him to read again. When he did not start to work, the teacher offered markers to visualise and said, "Draw the sentence." The student then counted the two markers instead. The teacher asked him to draw the sentence like he would draw counters. The student circled the numbers instead. The teacher repeated the instruction. The student drew four dots to represent "2". The teacher offered counters to the student. The student put two red counters and one yellow counter on the table and counted to three. When asked, "Read the sentence again," the student read and answered, "Three." When asked to show it with the counters, he put one more and counted to four. He then said, "I can't do it." The teacher gave him a number line (ruler). The student found nr. 2, counted three and said "Five."	The student had trouble understanding what visualising the sentence meant, even though he had learned to visualise number sentences with counters earlier. The teaching phase focused on using counters, and therefore those might be easier for him. He had no trouble solving the task with a number line, indicating that this skill, where he can count numerals, is more formed than visualising.
2. 6 + 3 = (9)	The student first read the wrong task (4+4) and then read the sentence wrong (6+2).	The student said, "I don't want the markers," and reached for the counters when starting to solve. He put six counters in the ten-frame setting and added three more counters while commenting on his work. He proceeded to count and said, "Nine."	The student solved the task with counters but with no additional help. Verbalising his actions show that he knows how to solve the task with counters. His confidence from solving the earlier task might have eased some of the stress, and therefore, he was able to solve it quicker and more independently.

3. 4 + 4 = (8)		After reading, the student did not start to work. The teacher asked, “What is 4 + 4?” The student said, “I don’t know.” The teacher asked, “Do you want to draw?” The student circled the numerals. When asked, “How much is it", he said, “It’s five.” When the teacher said it’s not, he thought it might be four. The teacher offered counters. The student put four counters and said, “add two more.” The teacher asked him to read again. The student read, added four (under the previous four) and counted. He skipped one counter and thought the answer was seven. The teacher asked him to count again. This time he counted correctly.	The student did not know what was meant by drawing the addition. By the time he took counters, he had already forgotten what he needed to add, but that might have been a mix-up. The student skipped one counter even though he touched all the counters when counting. This might be because of unnecessary hurrying.
4. 2 + 2 = (4)		The student read the sentence, took two and two counters, and counted each one. Although the teacher asked, “What does it look like?” before he started counting, he proceeded to count to four.	The student solved the task with counters and no additional help. Although he has shown earlier that he can subitise in a range of four, he relies on the counters and tries to rush through the task.
5. 2 – 1 = (1)		The student read the subtraction. When asked, “What do you need to do?” he said, “Subtract.” Instead of trying to solve it, he reached for the counters. He took two counters and added one. The teacher asked, “Do you make the number bigger or smaller?” The student said, “Smaller,” and counted the three counters. When the teacher said, “How do you make the number smaller?”, the student replied, “I’m trying.” The teacher asked the student to try again. He put two counters, left a gap, put one more, and then took the one away. The teacher asked if he’d like to try using the number line. On the number line, the student added one instead of subtracting. He then counted two and two. The teacher then asked which way he had to move. After this, the student found the number two and counted one back.	The student knew that the minus sign meant subtraction and remembered how the subtraction sentence was visualised but did not understand the operation of subtraction. Instead of subtracting one from two, he first added and then subtracted one. He was able to solve it using a number line with guiding questions.
6. 10 – 3 =		After reading the sentence, he asked for the counters, which he	The student eventually

(7)		set up in a ten-frame formation. Since only ten counters were on the table, he asked for more counters. He then added three counters, counted to 13, and wrote the answer. When hearing that it was incorrect, he said, “I can’t do this.” After some encouragement, he tried again. Before putting the counters in ten-frame formation, he said, “I have ten. I take three away.” He then counted and answered, “Seven.”	understood how to subtract using counters and verbalised his actions before. This shows that he planned his actions beforehand. Mixing up addition and subtraction might be from the similar way addition and subtraction sentences were introduced during the teaching phase – the difference between visualising the subtraction sentence and the subtraction operation might not be clear.
7. 5 + 4 = (9)		When asked if he’d like to visualise, he asked for the counters. He set five and four counters in the ten-frame setting. When asked what it looked like (before counting), he said, “Can I count, please?”	The student showed no trouble in adding with counters. Even though he has previously learned that one less from ten is nine, he relies on counting.
8. 6 – 3 = (3)		He read the task, put six counters, counted down three and said, “It’s three.”	The student understood the operation of subtracting using counters.
9. 2 + 5 = (7)		He read the task and said, “Watch this!” and put two and five counters on the table, counted them and answered, “Seven.”	The student has no trouble adding with counters.
10. 8 – 0 = (8)		He answered immediately after reading the task that the answer was 8.	The student understands that subtracting zero from something does not change the number.
Material test – 2nd day			
1. 8 – 2 = (6)		The student read the task and thought it might be nine. The teacher asked what he needed to do. And after a brief pause, the teacher asked if he needed to add or subtract. He said he needs to subtract. When he did not start to work, the teacher asked him if he needed to make a number bigger or smaller. At first,	The student did not know the bond of eight. He needed guiding questions and additional guidance to solve the task using pictures. He knew how to solve an

		he said bigger but then corrected. The teacher asked how he could do that. He said he could use dots. The teacher asked if he could try drawing it. He wrote eight. When he did not proceed, the teacher asked how he did it on the iPad earlier. The student drew 8 circles. The teacher asked what he could do next. He said he has to take away two. He wrote " -2 " and crossed off two circles. He then counted the remaining circles and answered that it's six.	addition sentence with pictures.
2. 3 – 2 = (1)		The student read the task and made the minus into a plus sign. The teacher said he cannot do that. He read the number sentence again. When the teacher asked what he could do, he said he needs to subtract. He wrote the subtraction sentence and drew circles accordingly, after which he counted all and said the answer is five. The teacher asked what he needed to do. He said he needed to subtract and take away. Initially, he thought he has to take away three but when the teacher asked him to look at the number sentence, he realised he needed to take away two. He proceeded to mark off two but when counting, he counted the two also, and said the answer is three. The teacher asked if 3-2 could be three. He thought it could be. When asked if he was making the number bigger or smaller, he said smaller and got frustrated. The teacher asked if he could try showing the subtraction with counters. He put three counters on the table. The teacher asked what he needed to do. He said he needed to take away three. He was asked to read the number sentence again. He read and said he needed to take away two. He said the answer is one.	The student visualised the subtraction sentence but when subtracting, counted the previously added ones also. He did not understand that three and three are the same size, therefore 3-2 cannot be 3. When using counters, he wanted to subtract the first number not the second. He solved the subtraction after several guiding questions and using counters.
3. 5 + 5 = (10)		The student read the task and wanted to take the markers to draw. The teacher asked him if he already knew the answer. After a brief pause, he said it's ten.	He knows that five plus five is ten. He solved the task independently after the teacher suggested he knew the answer.
4. 4 – 3 =		The student read the task and asked for the counters. Although	The student solved the

(1)		the teacher asked if he'd like to draw, he said he wants counters. He asked for four counters and put them on the table. When he asked for three more, the teacher asked what he needed to do. The student said he needs to take away three and realised he does not need more counters. He then took three counters from the group of four and said the answer is one.	subtraction with counters and a guiding question. He wanted to visualise the subtraction but understood that he has to take the three counters from four, not add three after a guiding question.
5. 1 + 2 = (3)		The student read the task and wanted to take the counters. The teacher asked if he knew the answer already. He said the answer is three.	The student is very reliant on the counters, but with some encouragement he answered correctly, indicating that he either knows it's a bond of three or solved early addition by applying the commutative properties of addition.
6. 6 – 5 = (1)		After reading the task, the student asked for the counters. The teacher asked if he would like to try using the markers. He said he'd try and drew 6 circles. After this, he said he has to take away five and crossed off five dots. He said the answer is one.	The student solved the task by drawing visuals. He verbalised his actions before doing them and solved the task correctly.
7. 2 + 8 = (10)		After reading the task he thought the answer might be nine. When the author said it was not nine, he thought it might be three. The teacher asked if he could try drawing it. After drawing two and eight circles, the student said, "Take away eight." The teacher asked what he needed to do. He then said he needed to add and counted all the circles and said the answer is ten.	Solved using visuals and guidance. Since he had subtracted earlier, he wanted to subtract again. When the teacher asked him to check what he needed to do, he realised and added the numbers. He does not know this bond of ten.
8. 9 – 7 = (2)		The student read the task and reached for the markers. He then drew nine and seven circles and crossed off seven circles from the nine blue ones while saying he is taking away seven. He said the answer is two.	The student solved the task by visualising. On earlier task, he has miscounted the circles he drew to visualise the subtraction sentence but this time he knew exactly what he was doing.

9. 1 + 1 = (2)		He read and answered without hesitation that the answer is two.	The student knows a bond of two or solved the task using early addition strategy.
10. 5 – 4 = (1)		The student read the task, took markers and drew four and five circles. He then said, “Take away four. It’s one.”	The student knows how to solve an addition when drawing visuals for assistance.
Digital test – 1st day			
1. 6 – 6 = (1)		The student read the subtraction and said the answer is six. The teacher said it’s not correct and asked what he needed to do. He said he needs to subtract (this was also written on top of the task). When asked if he needs to make the number bigger or smaller, he said smaller. He then said, “I don’t know, I can’t do it.” The teacher asked if he’d like to draw the subtraction and showed the option on IXL. The student just drew a number six and said, “It’s six.” The teacher then opened the virtual counters on another iPad and asked him if he’d like to use those. The student put 6 red and 6 yellow counters in a ten-frame setting and proceeded to count all of them. The teacher asked if he needed to add or subtract. He answered, “Add” but quickly corrected himself. When asked if he’s making the number bigger or smaller, he said he’s making it bigger and then corrected (after observing the teacher’s reaction). Instead of trying to use the counters correctly, the student tried to put number 12 as the answer. The program did not allow this. He then thought the answer might be one, wrote and submitted it.	The student did not solve the task with counters and answered before the teacher got to offer a number line. Even though the student knew that subtraction makes a number smaller, he proceeded to add, indicating that the concept of subtraction is not fully formed, and addition is the more favoured action. When asked guiding questions, he answered with addition facts instead of subtraction. Since he seemed to find the task overwhelmingly difficult and was already frustrated, he answered impulsively instead of working on the solution.
2. 6 – 1 = (5)		The student read the task and wanted to use counters. The teacher asked what he thought 6-1 equals. The student thought it is 7. The teacher asked what he needed to do. At first he said, “Add” but corrected himself after looking at the teacher. When asked if he needed to make the number bigger or smaller, he answered incorrect at first but corrected himself. The teacher repeated “You have to make the number smaller. How does that	The student solved the task after several guiding questions and using counters. Initially he added one instead of subtracting. After getting the answer wrong, the student grew more frustrated. But, after the guiding question

		go?" The student asked for the counters, put 6 red and one yellow counter, counted and answered, "Seven." The teacher asked if he made the number bigger or smaller. The student said he made it bigger and then said he made it smaller. The teacher then asked if he needed to put more or take away. The student answered, "Take away." The teacher refreshed the page, the student put six counters and took one away while commenting on his actions.	"Do you need to put more or take away?" his attitude changed and he was able to solve the task and verbalised his actions with the same words, indicating that this phrase might be a trigger for solving a subtraction.
3. 2 – 1 = (1)		Instead of trying to answer independently, the student reached for the iPad with counters. When asked what he must do, he answered, "Subtract, it's three." When asked, "Did you add or subtract?" he insisted that it's three and that he does not know. After this, the teacher asked if he'd like to draw the sentence, to which he said no and did not want to be persuaded. After this, the teacher asked him to try using the counters. At first, he put two red and one yellow counter. When asked "Do you need to make it smaller or bigger," he answered, "Smaller." He then took away the one yellow, and one red and answered, "It's one."	The student wanted to add instead of subtracting and got frustrated when it was incorrect. He was able to solve the task with counters and several guiding questions. However, the visualisation of the subtraction sentence seemed to distract him again.
4. 6 + 3 = (9)		The student read the task, used the counters in a fast and focused way and answered correctly. He did not want to solve the task either independently or by drawing.	The student solved the task using counters and needed no additional help.
5. 9 – 9 = (0)		When asked what he thought 9 – 9 equals, he thought it was ten. When asked what he has to do, he said he has to add. When asked to read the task, he understood he needs to subtract. When asked "How do you subtract," the student asked for counters. The teacher asked him again how much he thinks 9 – 9 might be, but he did not want to answer. The teacher asked if he could draw it. He did not want to. When offered counters, he first put 9 in a row and started to add more counters. The teacher asked if he needs to make the number bigger or smaller. He first said bigger, then said smaller and said "I take away." He counted the	The student wanted to first add one instead of subtracting. Even after several guiding questions, the student had trouble understanding what the answer might be. He did not want to solve the task independently or draw visuals but wants to use the counters instead. When using counters, he wanted to add again

		counters he has (9) and when the teacher asked, “How do you subtract?” he said, “Take away… It’s zero!” without counting.	and got frustrated when he did not get the answer correct. However, with guiding questions and the visual of nine counters, he realised that nine minus nine is zero.
6. 0 + 2 = (2)		The student read the task and answered immediately.	The student knows that adding zero does not change the number.
7. 1 + 4 = (5)		When asked what one and four makes, the student asked for the counters and did not want to figure it out by himself, even with guiding questions. He solved the task using counters.	The student is very reliant on the counters and does not want to try easier tasks by himself.
8. 4 + 5 = (9)		The student immediately asked for the counters and solved the task with little effort.	The student relies on the counters and does not want to try solving the tasks differently.
9. 9 – 2 = (2)		After the student read the task and asked for the counters, the teacher showed the student the drawing option again. Instead of using it correctly, the student started to draw circles and not focus on the task at hand. When using counters, the student put 9 in a row and added 2. When asked what he needed to do, he answered, “Subtract. Take away,” and took two counters off from the previous 11. The teacher pointed out that he took them from 11. The student commented how many he needed to remove but proceeded to take away 9. The teacher showed him the virtual number line and asked him to try solving it there. The student first said the answer is zero. When asked how you subtract on a number line, he counted to 8. When asked what way he needs to move, he pointed to the left. He then counted two from 10. When asked what he needs to start from, he said it’s two and pressed the answer.	The student was not able to solve the task even with a number line. The number line application was new for him, but since it did not have any added visuals, it was analogical to the one used to teach. He started counting from the wrong place and instead of subtracting, he added. Eventually, the student got so confused, the teacher decided to stop.
10. 4 – 4 = (0)		He read the task and wanted to use the counters. When asked what is 4-4, he asked for the counters again. At first he started	The student mixed up addition and subtraction again but solved

		to add. When asked what he needs to do, he said, “subtract”, took away the four counters and said the answer is zero.	the task using counters and guiding questions.
Digital test – 2nd day			
1. 4 – 1 = (3)		The student read the task and thought the answer is 10. The teacher asked if he was making a number bigger or smaller. He said he’s making it smaller. He counted three and two and his fingers and thought the answer is five. The teacher asked if he added or subtracted. The student said, “Subtract.” He then counted to four on his fingers and said “Take five away.” The teacher asked him to reread the task. The teacher then asked if he’d like to draw pictures. He wrote the subtraction (4-1). Since he did not know what it was, the teacher asked if he could draw this as dots. The student then drew and verbalised, “I draw four dots. I take one away. It’s three.”	Initially, the student mixed up addition and subtraction. He wanted to use some form of visualisation and therefore used fingers. Unlike yesterday, he drew the subtraction sentence after guidance.
2. 2 – 2 = (0)		The student read the task and wrote “2 – 2 =” and said the answer is three. When the teacher asked what he needed to do, he said he needs to subtract, erased the numeral 2 and said the answer is zero.	The student wrote the subtraction but not the dots. Erasing one of the “twos” made him realise the answer is zero, so this time he did not use sets but numerals.
3. 2 + 5 = (7)		The student wrote the addition sentence, verbalised as he drew dots and counted and answered seven.	The student was faster when adding but still needed visuals to add the numbers.
4. 3 + 0 = (3)		The student read the task and answered three without pausing.	The student can add with zero.
5. 8 + 2 = (10)		The student wrote the addition and said the answer is probably nine. The teacher asked if he’d like to try it or draw it. He chose to draw. While verbalising, he drew circles and counted to 10.	The student solved the task by drawing but did not need any additional guidance on this. At first, the student guessed the wrong answer, indicating he does not know this bond of ten.
6. 6 + 4 = (10)		The student read the task and drew only the dots to mark the sentence. He counted the dots correctly.	The student had no trouble solving the addition with

			pictures.
7. 3 – 2 = (1)		The student read the task and said he has to subtract (this is also written on top of the task). He wrote 3 – 2, erased the numeral two and said the answer is three. The teacher asked if he could show it like he showed the addition. He drew three and two dots, counted them and said the answer is five. The teacher asked what he had to do. He then erased three dots and said the answer is two. The teacher took the virtual manipulatives. The student put three counters. The teacher asked what he needed to do now. He said, "Take away three." The teacher asked him to look at the subtraction. The student said he has to take away two, removed the counters and said the answer is one.	The student tried to erase the numeral, similarly to when he erased the two earlier, indicating that he did not understand the subtraction of sets. With drawing the pictures, he added instead of subtracting and then erased the wrong amount (from the previous 5 dots). He solved with the help of counters and guiding questions.
8. 7 – 4 = (3)		The student read the task, wrote the subtraction sentence and drew seven and four dots. He then said, "Now take four away." He then took away seven dots from the earlier seven dots and said the answer is four. The teacher asked him to explain what he did. He said, "I subtracted from seven and made four." The teacher asked him to read the sentence again. He read and when the teacher asked if he'd like to try again or use counters, he asked if he could try again. He drew seven dots. The teacher asked what he needs to do now. He said he needs to take away. The teacher asked how many and he said four and erased four dots. He counted and said the answer is three.	The student visualised the subtraction sentence added and later subtracted from the sum. He also mixed up what he needed to subtract (4 instead of 7). Instead of asking for the counters that would have probably been easier for him, he wanted to try drawing, showing preference for challenge. He solved the task with visuals and guiding questions.
9. 7 – 0 = (7)		The student read and answered "Seven minus zero is still seven," without hesitation.	The student understands that subtracting zero from a number does not change the amount.
10. 6 + 1 = (7)		The student read the task and answered without hesitation, "Six plus one is seven."	The student has no trouble with early addition.

2. Addition and subtraction word problems.

Task, *Word problem text Answer choices (only digital test)* (Student's answer)	**Questions and difficulties with understanding the task.**	**Mistakes and help level**	**Analysis**
Material test – 1st day			
1. *There are nine kids in the class. Five of them are girls. How many boys are in the class?* (7)		The student read the word problem and answered, "Six." The teacher asked, "What do they want to know?" The student started to read from the start. The teacher asked, "What do they want to know? What is the question?" The student read the question. The teacher then asked, "How do you find out?" He answered, "Three." The teacher asked if he wanted to draw it. He did not. The teacher asked him to use the counters. The student said, "Nine," put ten counters in a ten-frame setting, counted them and said, "Ten boys." The teacher then read the word problem to the student and asked how he'd find out. He counted up to nine on his fingers and then said he could not do it. He then took five counters and said, "Five girls." He added seven counters and noted that seven boys were in the class. The teacher decided to move on to the next task.	The student did not solve the task, because he did not understand the word problem and what he needed to do. He had trouble deconstructing the group into two parts. He remembered that there were five girls in the class, so even after several mistakes, he did not forget one part of the information.
2. *Emma has 10 euros. She spends 4 euros on a toy. How many euros does Emma have left?* (6)		The student read the task and said, "So it's ten. Add four." The teacher asked the student to read again and then asked what the question was. After he read the question, the teacher asked, "How do you	The student needed guiding questions and counters to solve the subtraction but answered using a full sentence, indicating he understood the information that

		find out?". The student said, "Probably three." The teacher asked the student to draw, which he did not want to. When offered counters, he put ten counters and said, "add four." The teacher reread the question. The student said, "Take away four," and removed four counters. He then answered, "Emma has six euros left."	was provided, the question and the way he could use the information to answer the question. At first, he thought he had to add, but understood when the teacher read to him. Commenting on his actions indicates planning and understanding the task.
3. *Dave asked for Pokémon cards for his birthday. He got 5 from Amy and 3 from Steve. How many cards did Dave get?* (8)		The student read the task and reached for the counters. He then counted five and three while verbalising his actions. He lined the counters up in one row, counted and answered "Eight." The teacher asked if he had added or subtracted. At first, he said he had subtracted, but corrected it when he understood from the teacher's reaction that it was the wrong answer. Before writing the full answer, the student had to count again.	The student showed no trouble with the addition when using counters. Although previously he had lined up the counters in ten-frame setting, this time he lined them up in one row. Since he still counts the counters and the ten-frame setting does not seem to help him yet, it might just need more practice and perhaps, instead of a regular table, an empty ten-frame. The student answered the word problem using a full sentence.
4. *Mary went to a bakery. She bought three muffins and four cakes. How many things did Mary buy?* (7)		The student read the word problem, looked for the counters, counted three counters and answered in a conclusive tone, "Three." The teacher asked the student to read again. After rereading, he added four counters to the previous three, counted them and said the answer is seven. When the teacher asked what the full answer is, he had to read the question again.	Initially, he answered the question with only one part of the word problem. Although he had solved an analogical task previously, he had trouble understanding how to solve this one and needed to be asked to read again. This might have been an indication that the skill is not fully formed yet, but it could also be from the fact that he

			was tired. After rereading, he did not count the three counters he had set down previously but proceeded to add four counters, indicating that he remembered what he had done earlier.
5. *Steve was counting his pencils. He has 4 red pencils and 2 blue pencils. How many pencils does he have?* (6)		The student read the word problem, took the counters and lined up four and two counters. He then counted them and said the answer is six. The student wrote the answer in a full sentence.	The student understood what he needed to do and used counters to solve the task. He wrote the answer using a full sentence, indicating he had understood the word problem.
Material test – 2nd day			
1. *There are five cupcakes in the cafeteria. John eats three of them. How many cupcakes are left?* (2)		The student read the word problem and said, "Five." The teacher asked if he knows the answer. He asked for the markers. He wrote the numerals 3 and 5. When he did not do anything else, the teacher asked what they wanted to know. The student read the question. The teacher asked how he finds out. The student read the word problem and said he must add. The author asked him to read again. He then said he has to subtract three from five, coloured three circles and said the answer is two. He proceeded to write the full answer.	The student solved the task after guiding questions and visualising with drawing. The student chose the correct operation after reading the word problem several times. At first, he wanted to add, which shows he favours addition to subtraction. He coloured the circles in the right group, indicating he knows what he needed to subtract from.
2. *David has 2 dogs and 1 cat. How many pets does David have?* (3)		The student read the word problem. When he said he needs to subtract, the teacher asked him to read again and asked how he'll find out. The student said he needs to add. The author asked what he needs to	The student solved the task without visuals but using his fingers as counters. He used his fingers purposefully and made two groups instead of just

		add when he did not start to work. The student said he needs to add two and one. The student put up two fingers on one hand and one on the other, counted and said the answer is three. He wrote the full answer.	counting up. At first he wanted to subtract, possibly because the previous task was on subtraction.
3. *Julie is picking flowers. She picks one yellow flower and three red flowers. How many flowers did she pick?* (4)		The student read the word problem and said he has to subtract. The teacher asked him to read the word problem again, to which the student said he needs to add. Before he took the markers, the author asked what he needs to add. The student said, "One and three." The author asked what 1+3 is. The student thought the answer is three. The author asked if he'd like to draw. He wrote 1 and 3 and the matching groups. Then he said he needs to take away one. The teacher asked him to read the word problem again. The student then counted all the circles. The teacher asked how he found out. The student said he added one and three and that makes four. He then wrote the answer using a full sentence.	The student solved the task with the help of guiding questions and drawing visuals. At first, the student thought he needs to subtract again, possibly still remembering the operation in the first task. Choosing the wrong operation might mean that he did not understand the word problem fully. He did not apply the commutative properties of addition, which might have helped him, since he has solved early addition tasks before.
4. *James has 7 euros. He buys a movie ticket for 6 euros. How many euros does he have left?* (1)		He read the word problem and said he needs to write seven and 6. He drew seven circles and said, "I drew seven. Subtraction. I take away six." After colouring six of the circles, he counted and said the answer is one.	The student solved the task with visuals but with no additional help. He chose the correct operation, verbalised his actions and wrote the answer using a full sentence. This is indicative of understanding the algorithm and the word problem in full.
5. *There are eight sausages on*		The student read the word problem and	The student solved the task with

the counter. The dog comes and eats eight of them. How many sausages are left? (0)		commented, "Eight and eight. I can have the markers, thanks." The student said he needs to add at first but quickly corrected himself. He then said he needs to do eight minus eight. Before handing him the markers, the teacher asked how much that is. The student thought it was nine. The teacher asked him to draw it. He drew eight circles and said, "Take away eight," coloured and said it's still eight. The teacher asked him to cross off as many as he needs to take away so it would show better. The student crossed off eight and said eight were left. The teacher gave him counters and asked how many he needed. The student took eight counters and lined them in one row. The teacher asked what he has to do now. The student said he needs to take away eight and after counting concluded the answer is zero. He then wrote the full answer, "The dog eats zero sausages." The teacher asked him to look at the question. The student read the question, answered, "Zero sausages" and continued to write the sentence about the dog. When the teacher asked if the question was about the dog or the sausages, he knew it was about sausages but kept on writing the dog sentence.	counters and a guiding question. Subtracting the same number was too difficult for him to understand. He also struggled to understand the question, although he chose the correct operation.
Digital test – 1st day			
1. *Last Saturday, Nate and his friends had a huge snowball*	The student read the word problem and understood	After rephrasing, the teacher asked what they wanted to know. The student said,	The student solved the task with counters and guiding questions.

fight. During the fight, 3 of the snowballs hit their targets, but 1 of them missed. How many snowballs were thrown? (4)	that people threw snowballs, but since the wording and sentence structure were complicated, he needed additional rephrasing. The teacher rephrased: "Nate and his friends threw snowballs. Three snowballs hit the target. One snowball missed. How many snowballs did they throw altogether?	"The people" and then read the question. The teacher asked if he'd like to draw the problem and showed him the how to use it, but the student started to draw. The teacher asked what he needs to do. The student said "Three", took the iPad for counters and put three counters. Then he said, "it's zero." When the teacher asked what his answer would be, he read the question again and said, "Three and one. I have to add three and one." He then put three and one counters, counted and said the answer is four.	The student needed rephrasing, but that was due to the complicated sentence structure. After guiding questions, the student reread the question and figured out what he needed to do. Although he did not answer with a full answer, he found the necessary information and chose the correct operation. Since he only verbalised the operation and not the answer, it is not possible to say if he fully understood the text. It is also possible that the student might have seen the title of the subtest and chose the operation based on this.
2. *A school bus made a stop and 1 child got off the bus. However, 4 children stayed on. How many children were on the bus just before the stop?* (5)		The student read the task and said, "I got this." After which he took the tablet with counters and commented while putting counters, "One child… and four. Five. Five children."	The student solved the addition by using counters independently. He commented on what the counters represented ("1 child") indicating that he understood the word problem and followed the algorithm.
3. *The basketball team lost a game. They scored 1 point, but they needed 3 more points to win. In total, how many points did the team need to win?* (4)		The student read the word problem and asked for the counters. He then said and put counters, "One, add three." After counting he said it was four. The teacher asked him to say the full answer. He read the question again and said, "Four points."	The student solved the task with counters and answered with a phrase instead of a full sentence. The student understood the task and followed the algorithm.
4. *Mark has a total of 5 letters. He has opened 4 of them so far.*		The student read the word problem and said, "I got this," and proceeded to add 5	The student needed the word problem to be rephrased since

How many letters does Mark have left to open? (5)	Since the sentence structure was difficult for the student to understand, the teacher read and rephrased the task after the student had tried to add instead of subtracting: "Mark has five letters. He opened four of them. How many letters are still closed?"	and 4. The teacher read the word problem to the student and rephrased. The student said "Open," and asked for the counters. When the teacher asked what he needs to do, he said, "Subtracting. Six letters!" The teacher asked how he got to that answer and if he could show his thinking using the counters. The student added four and five. When the teacher asked what he needed to do, he said add, and then corrected. He then proceeded to take away four counters and said the answer is five and answered.	structure was difficult to understand. After rephrasing, the student knew he has to subtract (although this was in the title also) and, instead of subtracting four from five, he added one to five. When using counters, initially he added the counters but after a guiding question subtracted. Since the tablet screen already had nine counters, he solved the operation correctly but reached the wrong answer.
5. *The music school in Jefferson County held a children's concert and an adult's concert at the same time. A total of 5 students performed at the two concerts. If 2 students performed at the children's concert, how many students performed at the*	The word problem needed rephrasing since it had a complicated structure and the sentences were too long. The teacher rephrased: "There were two concerts. Five students performed. Two students were at one concert. How	The teacher asked how the student could solve it. He said, "I think it's two." When offered counters, he said he was tired of this and refused to work with the counters. The teacher opened the number line app, which the student wanted to try. The teacher repeated the word problem: "Five students performed. Two students were at one concert. How many were at the other?"	The student solved the task while looking at the number line but did not calculate correctly on it. Since he could not show his thinking, it is uncertain, if he knew the bond of five or if he guessed (he has offered three as an answer on several occasions before).

adult's concert? *2 4 1 3* (3)	many were at the other concert?"	The student looked at the number line but did not use it and said, "It's three." The teacher asked how he knows. When asked if he could show it on the number line, he said he does not know but it's three and two.	
Digital test – 2nd day			
1. *Seth needs to stand on 5 pillows to reach the biscuit jar. He takes 2 pillows from the bed. How many more pillows does he need to reach the biscuit jar?* (7)		The student read the word problem. The teacher asked if he understood. He said that he needs five pillows to reach the biscuit jar. He then said, "One." The teacher asked what he needs to do. He said, "Actually, it's six." The teacher asked what they want to know. The student did not answer but wrote the subtraction sentence. He said he needs to subtract but proceeded to add 5 and 2, concluded it was 7 and pressed the answer without waiting. The teacher asked if he added or subtracted. The student said he added.	The student did not solve the task. At first the student added one to five instead of subtracting. After a guiding question, the student did not seem to understand the word problem fully but wrote the correct subtraction sentence. The student visualised the sentence but mixed addition and subtraction and added instead, although he had said he needs to subtract earlier. The student did not solve the task with pictures and did not wait for the help with counters. This shows that although he wrote the subtraction sentence correctly, he still prefers addition.
2.*Last week, Tina practised a song 5 times. If she practised the song 3 times on her own, how many times did she practise the song in front of others?* *4 1 2 3* (2)	The word problem had a difficult sentence structure and conditional words in it, so the teacher rephrased	The student read the word problem and said "Three, three." When the teacher asked what they wanted to know, he said, "five songs."	The student solved the task with counters and guiding questions. At first, the student wanted to add. After rereading his work and the word problem, he understood that he needs to erase some of the visuals but erased too many. The fact that he realised his mistake in

	it: “Tina practised a song five times. She sang by herself three times. How many times did she sing in front of others?	After the teacher rephrased, the student answered, “Four.” The teacher asked how he knows. He said he just does. The teacher asked if he could draw it. He wrote 5-3 and drew 5 and three dots. At first, he added and answered eight. He then looked at the word problem and the subtraction sentence he wrote and said, “No wait, I have to subtract. Take away five,” and erased five dots from the previous eight. When using counters, he added again and thought the answer is eight. The teacher asked if 8 was one of the options in the answer section. He then thought it might be five. Since this was not an option, he thought he could take away three. He subtracted and answered two.	the beginning shows that to some extent, he analysed his work and tried to fix it. When using counters, he added again instead of subtracting. After guiding questions he understood what he needed to do. In this task he mixed up addition and subtraction because of the visualisation of the subtraction sentence. Again, this might be from visualising the subtraction sentence the same way as an addition sentence in the teaching phase. Although he realised 5-3 does not mean adding, he forgot and made the same mistake again with counters. He finally solved the task with the help of guiding questions and counters.
3. *Mrs. Grey's class raised a total of 5 silkworms, and 3 of them turned into moths. How many silkworms did not turn into moths?* (-)	The student read the task but did not understand. The teacher rephrased it: “Ms Grey’s class raised five bugs. Three of them turned into butterflies. How many did not turn into butterflies?”	The student said “I could write it down,” and wrote 5 + 3 and the same amount of dots. The teacher asked what he needs to do. The student said he does not want to do those anymore and wanted to stop even after asking if he'd like to try with the counters.	The student misunderstood the word problem even after rephrasing and answered incorrectly. That might have been because of the unfamiliar context. The student stopped after initially failing, probably because he had failed too many times and found it too stressful. He might have also been somewhat tired. The teacher asked if he’d like to take a break

			or try some other word problems. He wanted to continue with other word problems.
4. *Mandy and Sue collected shells on the beach. Mandy found 5 shells and Sue found 3 shells. How many shells did they collect in all?* (8)		He read the task and wrote 5 and 3 (no plus sign). He then drew the dots and counted. Initially, he miscounted (skipped one) but recounted correctly after the teacher asked him to count again. He solved the task correctly and answered, "8 shells."	The student solved the addition word problem correctly using drawing visuals as assistance. He wrote the information but not the addition sentence.. He miscounted by skipping a dot, but recounted correctly after being asked by the teacher.
5. *A husband and wife are on the Oregon Trail. Bugs get into their food and ruin 2 cups of wheat and 2 cups of cornmeal. How many cups of grain does the couple lose?* (4)		The student read the word problem and said, "Two and two." He wrote 2+2 and said it makes three. The teacher said that's not correct. The student then thought it might be ten. The author asked how he could find out what it is. He said he could draw dots. After drawing and counting, he said it's four.	The student solved the task with guidance and visuals. He understood what he needed to do and wrote the addition sentence. He offered choices for the answer which were incorrect. This shows that he does not know the bonds of four and also ten or three, since he was just guessing. He probably added 2+1 instead of 2+2. To solve the task, he needed to draw dots.

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