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ORIGINAL ARTICLE

Promoting basic arithmetic competence in early school years–using a response to intervention model

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Abstract

This study investigated whether mathematics education based on a multi-tiered response to intervention (RTI) model can support students' arithmetic competence in primary schools in Sweden. The intent was to identify and support students at risk of failure. In this study, 113 students participated in the intervention, and 30 students participated in the control group. Both groups were followed from Grade 1 to the end of Grade 2 and compared. During the first semester in Grade 1, all students were taught basic addition and subtraction with explicit instructions in Tier 1. Those who did not respond to Tier 1 after one semester were provided support within Tier 2 during the second semester. The same was repeated in grade 2 and the students that did not respond to Tier 2 were supported within Tier 3. At the end of Grade 2, students in the intervention group performed significantly higher on the basic arithmetic competence in the number range 1–9 than the control group. No significant difference was found in a test measuring basic arithmetic competence in the number range 10–19. This study shows that using multi-tiered RTI might be sufficient to identify and support students at risk in early arithmetic competence.

KEYWORDS

basic arithmetic competence, early school years, mathematics, number sense, RTI

Key Points

- The current pilot study showed that mathematics education based on multi-tiered RTI could support students with weak basic arithmetic competence in Grades 1 and 2 in primary schools in Sweden.
- The Tier 2 intervention was effective as it allowed the students to have more individual explicit instructions and support in discussing mathematics and to do mathematics with multiple representations of numbers and basic arithmetic in an intense form with a special teacher with great expertise in the area.
- The students' developed within the 1-9 in basic arithmetic, but not as significant within the range of 10-19 implying the need of helping students make generalization connections from their knowledge in the range of 1-9.

INTRODUCTION

A primary intention of mathematics education is to make the mathematical content accessible to every student in the classroom. The intention is also realized in the Swedish school Act, which states that education in the school system must ensure that students acquire and develop knowledge and values and promote all students' development and learning (SFS, 2010:800, 1 chap., 4§). One way to accomplish this for every student is to identify students at risk of failing in mathematics early to support them and make the mathematical content accessible in interventions (Dowker & Sigley, 2010).

International research show that about 5–10% of students display low achievement in mathematics and need early support (Geary, 2011). Similarly, over 9% of primary school students in Sweden are perceived as low achievers (Karlsson, 2019). Thus, the early identification and support of students at risk of falling behind in basic arithmetic competence during primary school is a critical challenge facing educators. In light of this, it is imperative to ask how such students can be identified and, more importantly, how they can be effectively supported in early primary school. To address these questions, the present study investigates a model for early mathematics interventions that can identify and provide timely support to students at risk of failure in mathematics. By evaluating the potential of this model, this study seeks to contribute to evidence-based strategies for promoting academic success and preventing math-related learning difficulties in early primary school.

Early interventions in mathematics are not that seldom deprioritized in practice with the motivation to 'await mathematical maturity'. However, from a Swedish perspective, since 1, July 2019, there is a governing act in the Swedish school Act regarding a guarantee for early support (SFS, 2010:800). The purpose of the guarantee for early support is to draw attention to the students in primary school who need support in their learning regarding Swedish, Swedish as a second language, and mathematics. Here there is a requirement to implement early interventions according to the need of each student. The guarantee of early support has led to a debate on how such support should be implemented, and a recent report from the Swedish School Inspectorate (2022) showed that primary students are not provided support, and special educational support is missing.

There needs to be more research on early support in mathematics in Sweden. However, there are some studies conducted in Sweden; for instance, Sterner et al. (2020) show that number sense growth with a sustained effect in a randomized intervention with 6-year-old students. Also, Elofsson et al. (2016) show a positive effect on early mathematical development in an intervention playing number games with 5 years old in Sweden.

The current study aims to add to this previous research by focusing on early interventions in mathematics to identify and support students at risk of failure in mathematics in grades 1 and 2 (6–8 years old). The mathematical focus is number sense, which is referred to as whole number arithmetic competence (Sayers & Andrews, 2015). The whole number arithmetic competence, a basic number understanding, strongly predicts future arithmetic competence (Aunola et al., 2004). Also, it has been shown that children entering school with a weak arithmetic competence, achieving low when dealing with numbers, tend to remain as low achievers all through the school system, which has consequences for prospects in adulthood (Geary, 2013). Accordingly, how identifying and supporting students at risk of failing regarding number sense in the first years of schooling is essential, not only for the individual child but also on a societal level.

One way of early identification and support of students at risk of failure in mathematics is Response to Intervention (RTI). RTI has been used substantially in an American context to focus on early interventions preventing children from being left behind in their learning (e.g., Bryant et al., 2011; Jitendra et al., 2021). However, a limited amount of research on RTI has been conducted in the Nordic context, but for example, some Nordic studies indicate the usefulness of RTI, focusing on mathematics education (e.g., Björn et al., 2018). Consequently, this study aims to investigate RTI in a Swedish context as a model for systematical identification and support for students with weak, basic arithmetic competence in Grades 1 and 2 to implement specific interventions to enhance number sense within the particular area of basic arithmetic competence.

Number sense and basic arithmetic competence

Number sense is a concept commonly used within mathematics education, even though it is definitively elusive (Gersten et al., 2005). Griffin (2004) pointed out that we all know number sense when we see it, but it is hard to describe. Reys et al. (1999, p. 61) refer to number sense as a 'general understanding of numbers and operations, along with the ability and inclination to use this understanding in flexible ways to make mathematical judgement and to develop useful and efficient strategies of managing numerical situations'. Based on this definition, Reys et al. (1999) suggested six components of number sense: understanding the meaning and size of numbers, understanding and use of equivalent representations of numbers, understanding the meaning and effect of operations, flexible counting strategies for mental computation, written computation and calculator use. Though, this definition is elusive and not always easy to apply in mathematics education.

Instead, often when referring to and using number sense in mathematics education research, Gelman and Gallistel's (1978) research from the 1970s is referred to where number sense is described as consisting of a set of five guiding principles. These principles are: (1) Understanding the verbal sequence of counting, being able to say the number names in sequential order; (2) One-to-One correspondence, understanding that when saying the names of the numbers in sequence, each object receives one count; (3) Cardinality, to understand that the last number spoken in a counting sequence names the quantity for that set; (4) Abstraction, to understand that it does not matter what or how you count, the quantity is still the same. For example, any set of objects can be counted, regardless of whether they are the same shape, colour, size, etc. (5) Order irrelevance, to understand that the order in which the objects in a set are counted is irrelevant, if every object in the set is given one count and only one count (Gelman & Gallistel, 1978).

More recent research on number sense (Sayers & Andrews, 2015) highlights preverbal number sense, applied number sense and foundational number sense. Preverbal number sense is referred to as 'number insights that are innate to all humans and comprises an understanding of small quantities in ways that allow for comparison' (Sayers & Andrews, 2015, p. 124). Applied number sense refers to how students can use their knowledge of handling numbers in everyday life, and foundational number sense refers to a non-innate number-related competence typically taught during the first years of schooling. Foundational number sense can be summarized by eight key components; number recognition, systematic counting, awareness of the relationship between number and quantity, quantity discrimination (an understanding of magnitude and comparisons of magnitudes), knowledge of different representations of numbers, estimation, basic arithmetic competence and an awareness of number patterns (Sayers et al., 2016).

The current study will focus on the parts of foundational number sense covering *basic arithmetic competence*. The reason for this focus is the importance of students' development of a solid understanding of numbers during early primary school (Woods et al., 2018) to know or rapidly retrieve basic facts and addition and subtraction (Geary, 2011). In other words, the students need to develop basic arithmetic competence. Such competence and understanding of the system of positioning and operations are the basics for being able to handle addition, subtraction, multiplication and division with multi-digit numbers. Nevertheless, many students need to be more sufficient in the basic addition and subtraction combinations and need to be exposed to core instructions that are explicit and systematic (Gersten et al., 2009). Also, not understanding the base-10 system and not having a basic arithmetic competence has been an early indicator of the need for interventions in the first grade (Bryant et al., 2008). Accordingly, the underlying motive for the current study is to use a model for specific interventions to enhance students' basic arithmetic competence.

The RTI model

The RTI model intends to identify and address students' learning needs early through appropriate interventions and support (Gersten et al., 2009). It is a multi-tiered system of support focusing on prevention, identification and intervention (Bouck et al., 2019). The multi-tiered system in the RTI model consists of a monitoring model of how students respond to interventions that increase in intensity across multiple Tiers (Fuchs & Fuchs, 2006; Mellard et al., 2010). The 'increasing intensity is achieved by (a) using more teacher-centered, systematic, and explicit (e.g., scripted) instruction; (b) conducting it more frequently; (c) adding to its duration; (d) creating smaller and more homogenous student groupings; or (e) relying on instructors with greater expertise' (Fuchs & Fuchs, 2006, p. 94).

A RTI model often has two–four Tiers delivering instructions to meet every student's needs. Tier 1 comprises class-wide core instructions for all students in the classroom based on research and proven experience (Mellard et al., 2010). The students that are at risk of failing due to not responding to the teaching in Tier 1 need Tier 2 support. Prior studies have shown that 15–20% of students need Tier 2 (e.g., Fuchs & Fuchs, 2006; Mellard et al., 2010). The support in Tier 2 is generally given in a small group. Here additional specialized instructions are given by a general or special educator. If students do not respond to the instructions in a Tier 2 intervention, they can continue to have repeated Tier 2 interventions or move into Tier 3. An average of 5% of the students usually need Tier 3 support (Fuchs & Fuchs, 2006). In Tier 3, more intense individualized instructions are provided (Bouck et al., 2019).

The RTI approach is a contrasting approach to the traditional way of handling special education where students' academic failures are addressed after a few years of schooling, resulting in an assessment of learning difficulties, diagnosis(es) and provision of special education (Fletcher et al., 2004). Subsequently, RTI can be regarded as a proactive approach where special education is included. Later research in RTI (Berkeley et al., 2020) shows an evolution of the RTI model, building on Fuchs et al. (2012), who used the notion of Smart RTI. According to Fuchs et al., multistage screening is one key to identifying risks and determining appropriate levels of instruction as well as a special educational approach for preventing academic failure. Hence, RTI has evolved and been adapted. Though, the focus is still on a multi-tiered system of support (MTSS; Berkeley et al., 2020).

Using RTI has been shown to reduce the number of students in segregated placements and time in special education (Grosche & Volpe, 2013). Besides being proactive, preventive and successful in reducing students with special educational needs, RTI also focuses on the individuals, assessment and expected development in an American setting (Nilholm, 2022). This needs to be considered when moving the RTI model into a Swedish setting and adapting the model according to the educational system and cultural context.

RTI in mathematics education

In mathematics education, RTI studies often focus on mathematical difficulties (MD) and effective interventions for developing mathematical understanding (Jitendra et al., 2021). In general, research on RTI in mathematics education focuses on Tier 2 interventions (Bouck et al., 2019).

Concerning MD, the research stresses the importance of considering different factors, such as screening criteria and cut-off scores, in relation to different deficits when analysing the observed effects of mathematics interventions (e.g., Fuchs et al., 2014; Jitendra et al., 2021). In relation to the complexity of different factors to consider in mathematics interventions, the effectiveness of RTI interventions in mathematics education has been questioned (Bouck et al., 2019). A recent meta-analysis demonstrated that Tier 2 RTI interventions had a treatment effect of 0.41 (Jitendra et al., 2021). In addition, Jiménez et al. (2021) showed that the earlier the intervention, the larger percentage of students decreased risk of mathematical difficulties.

When looking into the content of mathematical RTI interventions in early school years, the content mainly covers basic number sense competencies, such as place value and basic arithmetic competence (Dennis et al., 2015). An example of this type of content is Fuchs et al. (2006) who covered arithmetic combination fluency. In another study with Tier 2 interventions, Fuchs et al. (2007) covered number concepts, arithmetic combinations and double-digit addition and subtraction. Bryant et al. (2008, 2011) used Tier 2 interventions covering number concepts and basic operation fluency, which also is in focus in two intervention studies by Dowker and Sigley (2010). Most RTI studies in early school years focus on basic competencies essential to mathematics understanding, including counting, whole number relationships, addition and subtraction strategies and fluency and place value (Van de Walle et al., 2012). Hence, prior found mathematics RTI studies in early school years focues on arithmetic competence. This current study intends to add to this prior RTI research on basic arithmetic competence, specifically focusing on addition and subtraction understanding and fluency within 1–20 in young primary school students in Sweden.

Aim and research question

The current study is a pilot study investigating whether mathematics education based on multi-Tiered RTI can support students with weak, basic arithmetic competence in Grades 1 and 2 in inclusive primary schools in Sweden.

- How do students perform in tests measuring basic arithmetic competence after 2 years of mathematics education based on multi-tiered RTI compared to a control group?

METHODS

The Swedish context

The study is conducted in Sweden, one of the Nordic countries. In Sweden, compulsory school starts the year students turn 6, starting with preschool class and then primary school for 9 years. Education is free, and parents can choose a school. Students with various needs and backgrounds are educated together. The teachers must meet all students' needs and differentiate their teaching.

Mathematics education starts in the preschool class. Mostly, mathematics is taught by a general teacher in the early primary school years. Many schools have a special education teacher who, in addition to a teaching degree, has a year and a half of training in a special teacher program. According to the Swedish school Act, students at risk of not reaching education goals should be supported. The teachers should differentiate and adjust the education, and special support can be offered in small groups or individually. In general, special support is provided by the special education teacher. Sometimes the general and special teachers educate the students together in the classroom.

Participants

In the current study, two groups of students participated. One group of students had mathematics education based on multi-tiered RTI, whereas the other group had ordinary teaching in mathematics. The students were followed from the beginning of Grade 1 to the end of Grade 2. All students and their caregivers signed an informed consent form.

As data on students' diagnoses is not registered in Swedish schools, such information was not collected. Students with intellectual disabilities follow a specific curriculum, and such students were not included in the study. The study has received ethical approval (Dnr 2019–04814).

Intervention group

A total of 113 students (60 boys and 53 girls) participated in the intervention. The students attended three different schools, one urban school with four classes ($n=68$), one rural school with two classes ($n=38$) and a school in a small village with one class ($n=10$). Their mean age at the beginning of the study was 7.2 years ($SD=0.3$). There were 30 (27%) of the students who had Swedish as their second language.

The Swedish National Agency calculates the socioeconomic index for education, which reflects the probability of students passing and failing related to background variables such as parents' level of education, income, degree of welfare and migration background. The approximate average for Swedish schools is 100. A low socioeconomic index for a school means that the school generally has a favourable condition for a good result and a high index signals that the school has an unfavourable condition. The participating schools had an average socioeconomic index for education, namely 102.

Control group

The control group consisted of 30 students (18 girls and 12 boys) from two schools in Sweden. They were selected due to the demographics and socioeconomic index for education to be similar to the intervention group. A regular teacher taught mathematics, and a mathematics book guided the education. None of the students were provided special educational support in mathematics during the first grade. In Grade 2, a special education teacher supported two of the students in the control group. They were provided special education in mathematics twice a week.

Measures

Two tests measuring basic arithmetic competence were applied. One of the tests (Ag1) measures the competence of basic addition and subtraction from 1 to 9 (Löwing, 2016). It includes tasks such as 6+2=__ and 7-3=__. The test has 24 tasks of this type and 12 tasks of 5+_=8. The total test score is between 0 and 36. The other test (Ag2) measures the competence of basic addition and subtraction from 10 to 19 (Löwing, 2016), and there are tasks such as 10+7=__ and 17-12=__. The test has 24 tasks of this type and 24 tasks of the type 14-_=10, one point per task. The total test score is between 0 and 48. Both tests were limited to 3 min per test to be able to measure fluency. The tests were carried out one after the other in the classroom. The tests were handed out and presented orally, and the students were allowed to ask questions to ensure the instructions. The students then took the tests. The tests are not standardized, though they are frequently used in Swedish schools to assess primary school students' arithmetic competence.

Data collection

The administration of the tests followed the standard procedures described in the test manual (Löwing, 2016). Two authors (HR and LK) conducted all the testing with the students and corrected them together afterward to increase validity. The first test occasion was at the beginning of Grade 1. The test procedure was repeated five times during the project to monitor all students' mathematical development (middle and end of Grade 1, beginning, middle, and end of Grade 2). At the beginning of Grade 1, only the test measuring basic addition and subtraction from 1 to 9 was used. On all other test occasions, both tests were used

Procedure

Intervention group

Before the participating students' attendance in Grade 1, the researchers prepared all the teachers teaching in the RTI group with a lecture and workshop on number sense and arithmetic competence. The emphasis was on successful teaching strategies for number sense and arithmetic competence, for instance, working with number recognition, how numbers relate to one another and relations within numbers, so-called part-whole relations. For example, the number 4 can be split into 1 and 3, 2 and 2 and 3 and 1. Besides, number 4 is one more than 3 and 1 less than 5. The teachers were informed on the importance of working with basic addition and subtraction combinations with explicit and systematic core instructions (Gersten et al., 2009). Also, the importance of working with the base-10 system was highlighted. The teachers were offered examples of how to work in mathematics education with different representations, and manipulatives were discussed and tried out.

In the first semester in Grade 1, Tier 1 was carried out for all students by the general classroom teachers for each class (n=6). The students who scored 15 or less at Ag1 after one semester in Grade 1, or 25 or less at the beginning of Grade 2, were admitted to Tier 2 interventions. If the students did not respond to Tier 2 interventions and scored 25 or less after one semester in Grade 2, they got into Tier 3 interventions. Tier 2 was carried out by special education teachers in mathematics with great expertise in the area with students in groups of 3–5. There were 15 sessions, 30 min each time, over 5–6 weeks. The intervention focused on understanding and fluency of arithmetic competence. As Doabler et al. (2018) described, special education teachers worked with explicit instructions, using pictures and manipulatives and a systematic instructional approach of pedagogical instructions to promote students' conceptual understanding and procedural fluency of the numbers 1–19. They also worked with arithmetic math games for students' fluency. To increase fidelity, the special education teachers met with the researchers and discussed the interventions in relation to the specific students attending Tier 2.

Tier 3 was initiated if the students did not respond to Tier 2 interventions. In two cases, it was initiated when small group Tier 2 interventions were unsuitable due to the students' attention difficulties, and these students needed individualized instruction with a teacher. Tier 3 consisted of 15 sessions, 30 min each time, over a 5- to 6-week period. In Tier 3, the special education teachers worked with the students' understanding and fluency of arithmetic competence. In Tier 2 and 3, if a student were sick, the teachers made sure to make up for lost time so that every student in each Tier intervention received 15 sessions. Teachers documented in a logbook throughout the two school years with notes to one of the authors (HR). In addition, the special education teachers also used logbooks to document the special instructions provided in small groups and individually.

Statistical analysis

Data were analysed with SPPS version 29. We used independent samples t-tests to investigate whether the students in the RTI group performed differently from those in the control group. When data were not normally distributed, non-parametric tests such as the Kruskal–Wallis *H* and Mann–Whitney U tests were applied. Wilcoxon signed ranks test was used as a repeated measure to investigate the students' increase in test scores over time.

RESULTS

Students' performance and support in Grade 1

At the beginning and end of Grade 1, the RTI and control groups students were assessed with a test measuring basic arithmetic competence on numbers between 1 and 9 (see Figure 1). Initially, the RTI group performed significantly weaker than the control group on the basic arithmetic competence 1–9 test, $t\ (131) = -2.90$, $p < 0.05$.

During the first semester, all students in the RTI group were educated within Tier 1. At the beginning of the second semester of Grade 1, the students were again assessed with the basic arithmetic competence test on numbers between 1 and 9. They were also assessed with another test on basic arithmetic competence in numbers 10–19. According to the test results, 22 (21.4%) of the 103 students in the RTI group were provided support in small groups for 5–6 weeks, including 15 lessons. During Grade 1, these students performed significantly weaker on basic arithmetic competence tests than those educated in Tier 1 for the whole year (see Table 1).

However, when comparing the RTI and control group students at the end of Grade 1, no significant difference in the basic arithmetic competence 1–9 test was found, $t\ (131) = 1.52$, $p = ns$. At a group level, both the students in the RTI and control groups had increased their performance on the basic arithmetic competence 1–9 test during Grade 1 (cf., Figure 1). The mean score increase was 17.8 ($SD = 6.5$, $Mdn = 18.0$) among the students in the RTI group and 12.3 ($SD = 7.5$, $Mdn = 12.0$) among the students in the control group. According to Wilcoxon signed rank test, the scores in the basic arithmetic competence 1–9 test significantly increased for the students in the RTI group, $z = -8.24$, $p < 0.001$, but not for the students in the control group, $z = -1.62$, $p = ns$. Hence, mathematics education seemed to be more beneficial regarding basic arithmetic competence in numbers 1–9 among the students in the RTI group compared to those in the control group during the first grade in primary school.

We performed additional analysis to investigate the improvement among students in the RTI group. A comparison of the students in the RTI group who received support in Tier 2 with their peers in ordinary teaching in Tier 1 revealed no significant difference in the basic arithmetic competence 1–9 test, $t\ (101) = -0.70$, $p = ns$. Students who were provided small group instructions within Tier 2 had a mean increase of 16.9 scores ($SD = 5.2$, $Mdn = 17.0$) on the basic arithmetic competence 1–9 test. The other students in Tier 1 had a mean increase of 18.0 scores ($SD = 6.8$, $Mdn = 19.0$).

Students' performance and support in Grade 2

At the beginning of Grade 2, the RTI and the control groups were again assessed with the two tests measuring basic arithmetic competence. No significant differences in test scores were obtained among the students in the two groups at the beginning of Grade 2 (see Table 2). Thus, among the students in the RTI group, 29 (28.2%) were considered at risk of mathematical difficulties. They performed significantly weaker on the 1–9 test than their peers in the RTI group, Mann–Whitney $U = 138.5$, $p < 0.001$. Their performance on the 10–19

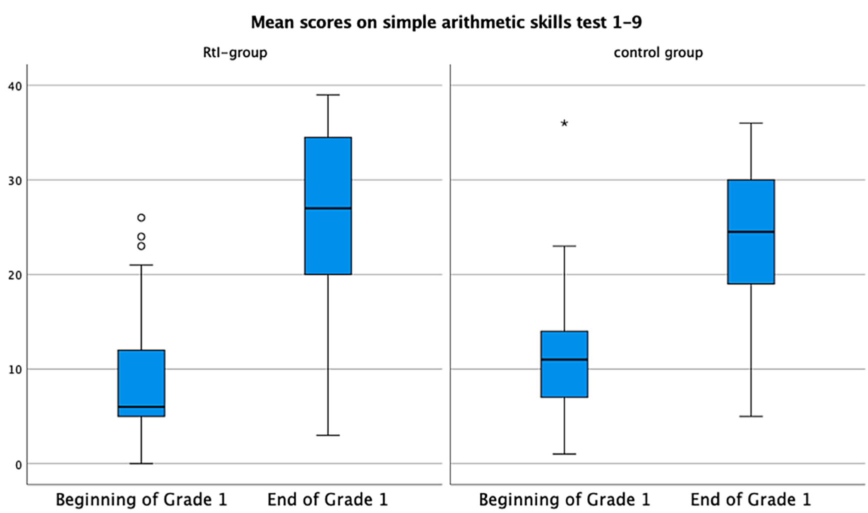

FIGURE 1 Mean scores on basic arithmetic competence test 1–9 among students in an RTI group ($n = 103$) and a control group ($n = 30$) at the beginning and end of Grade 1.

TABLE 1 Comparison of tests measuring basic arithmetic competence among students provided with and without small group instructions in the RTI group in Grade 1.

	Tier 1 (n=81) *Mdn*	Tier 2 (n=22) *Mdn*	*U*	*p*
Beginning of Grade 1				
Arithmetic competence in 1–9	8.0	4.5	399.0	>0.001
Middle of Grade 1				
Arithmetic competence in 1–9	19.0	9.5	243.0	>0.001
Arithmetic competence in 10–19	9.0	2.5	290.0	>0.001
End of Grade 1				
Arithmetic competence in 1–9	30.0	21.0	491.0	>0.001
Arithmetic competence in 10–19	19.0	13.0	469.5	>0.001

Note. Students in Tier 1 were educated in ordinary mathematics education, whereas those in Tier 2 were provided support in small groups during the second semester in Grade 1.

TABLE 2 Comparison of tests measuring basic arithmetic competence among students in an RTI group and a control group in Grade 2.

	RTI-group (n=103) *M* (*SD*)	Control group (n=30) *M* (*SD*)	*t* (131)	*p*
Beginning of Grade 2				
Arithmetic competence in 1–9	25.7 (8.4)	24.3 (9.0)	0.78	ns
Arithmetic competence in 10–19	19.0 (10.2)	17.4 (10.1)	0.75	ns
End of Grade 2				
Arithmetic competence in 1–9	32.6 (5.5)	27.4 (8.7)	3.06	<0.01
Arithmetic competence in 10–19	29.8 (11.4)	27.3 (12.5)	0.98	ns

test was also weaker than the other students in the RTI group, Mann–Whitney U=372.5, p<0.001. Nine of these 29 students, which is 8.7% of the whole RTI group, had previously been provided support within Tier 2 during the first grade. All these 29 students were provided small group instruction within Tier 2 (n=28) or individualized support within Tier 3 (n=1). Small group instruction was provided in 5–6 weeks during 15 lessons, and individualized support during 15 lessons, each lesson 30 min.

The RTI students' progress in basic arithmetic competence was continuously monitored during Grade 2, and in the second semester of Grade 2, there were still 15 students considered at risk of mathematical difficulties. Of these, 12 were previously offered support in Tier 2 or 3, corresponding to 11.7% of the RTI group. Of these 15 students, 7 (5.3%) were provided eight lessons within Tier 2. After that, two of them were offered individualized support in Tier 3 during 8 lessons. Besides, 8 (7.8%) students were provided 15 lessons with individualized support within Tier 3. These 15 students, who were provided support in Tier 2 and 3, had a mean increase of 12.6 scores (SD=4.5, Mdn=11.0) on the basic arithmetic competence 1–9 test and 12.2 scores (SD=7.0, Mdn=10.0) on the basic arithmetic competence 10–19 test during the second semester in Grade 2. Their peers within Tier 1 had a mean increase of 5.9 scores (SD=6.2, Mdn=5) on the 1–9 test and 10.6 scores (SD=8.4, Mdn=11.0) on the 10–19 test. The increase was significantly higher on the 1–9 test among the 15 students who had been provided support within Tier 2 and 3 compared to the peers in Tier 1, t (101)=−3.97, p<0.001. No significant difference was found in the 10–19 test, t (191)=−0.69, p=*ns*. However, the total scores on the basic arithmetic competence 1–9 test were higher among the students educated in Tier 1 (M=33.2, SD=4.9, Mdn=36.0) compared to those in Tier2 and Tier3 (M=29.1, SD=7.2, Mdn=30.0), U=451.5, p<0.05. The same pattern was also demonstrated on the basic arithmetic competence 10–19 test. Compared to the students in Tier 1 (M=31.1, SD=11.2, Mdn=32.0), students provided support within Tier 2 and Tier 3 (M=22.1, SD=8.5, Mdn=23.0) scored significantly lower on the basic arithmetic competence 10–19 test, U=347.0, p<0.01.

At last, we compared the test scores at the end of Grade 2 among the students in the RTI group with those in the control group. The students in the RTI group performed significantly higher on basic arithmetic competence focusing on numbers between 1 and 9, compared to the students in the control group (see Table 2). No significant difference was revealed in the basic arithmetic competence 10–19 test between students in the RTI and control groups. When investigating the students' scores on the basic arithmetic competence 1–9 from the beginning of Grade 1 to the end of Grade 2, both students in the RTI group, z=−8.93, p<0.001, and in the control group, z=−4.93, p<0.001, had a significant increase. Similarly, the scores on the basic arithmetic competence 10–19 increased from Grade 1 to Grade 2 for the students in the RTI group, $z = 8.94$, $p < 0.001$, and the control group, $z = -3.52$, $p < 0.001$.

DISCUSSION

The current pilot study investigated whether mathematics education based on multi-tiered RTI could support students with weak basic arithmetic competence in Grades 1 and 2 in primary schools in Sweden. According to the results, the students in the RTI group had greater performance gains than the control group in basic arithmetic 1–9 (see Figure 1 and Table 2). The additional interventions provided within Tier 2 (and 3) for the students in the RTI group seemed beneficial for the students' development of basic arithmetic competence on numbers 1–9. Hence, the present study shows the potential of RTI interventions in primary schools in Sweden.

Results from our pilot study in Sweden align with previous Tier 2 mathematics interventions conducted in the USA (e.g., Bryant et al., 2021; Clarke et al., 2016) and Spain (de León et al., 2021). In the current study the instructions of the special teachers in mathematics with great expertise in the area seemed to be important in Tier 2 and 3. Similarly, Fuchs and Fuchs et al. (2006) stressed the importance of instructors with greater expertise in Tier 2 for students' development. The Tier 2 intervention allows the students to have more individual explicit instructions and support in discussing mathematics and to do mathematics with multiple representations of numbers and basic arithmetic in an intense form with a teacher with great expertise in the area. This has been shown effective in prior studies (e.g., Bryant et al., 2021), and we can see the same tendency in this study.

The difference between the two groups in the current study was not significant at the end of Grade 1 but at the end of Grade 2. In the RTI group, the students in need of support in basic arithmetic competence and who were educated within Tier 2 and 3 during Grade 2 improved their test scores on the basic arithmetic competence 1–9 significantly compared to their peers in Tier 1. However, the median score on the basic arithmetic competence 1–9 test was still higher among students educated within Tier 1 than those in Tier 2–3 at the end of Grade 2. Even though the RTI instruction had importance for the student's development of basic arithmetic competence, we can conclude that the Tier 2 and the Tier 3 students did not catch up with their peers in Tier 1 at the end of grade 2. Possibly, students provided support within Tiers 2 and 3 might have weak executive functions, especially visual short-term memory, affecting mathematical attainment (cf., Bull et al., 2008). Difficulties in retrieving arithmetic facts from long-term memory are also associated with math-related learning difficulties among young students (Krajewski & Schneider, 2009), as well as delays in language acquisition (Van Luit & Toll, 2015), intelligence and socioeconomic status (Krajewski & Schneider, 2009). They might have needed more explicit instructions (Doabler et al., 2018) to consolidate arithmetic competence within 1–9. According to Doabler et al., explicit instruction needs to scaffold, allocate time for the student to engage and work with the content, as well as work with discussions and visual representations, and have time to go back and review the concepts and procedures consciously and frequently.

Furthermore, another finding in the current study was the students' development within the 1–9 in basic arithmetic but not as significant within the range of 10–19. This result could be related to the content of the teaching in the RTI group. Among students with weak basic arithmetic competence, the teachers spent more time on the 1–9 range and did not explicitly focus on the higher number range (10–19). The teachers might implicitly have taken for granted that the students could make the generalization connections from their knowledge in the range of 1–9 by themselves. However, not every student has generalization skills, and therefore some need to be explicitly instructed on translating between representations (Kong & Orosco, 2016).

Pedagogical implications

The present study indicates the importance of monitoring and using explicit instruction in addition and subtraction, not just in the range of 1–9 but also in the range of 10–19, and explicitly working with connections (Roos, 2017) and translations between representations. For instance, if a student understands 8–5, the student should be able to generalize the knowledge to 18–5. Hence, this study indicates the importance of early interventions in mathematics and not to 'await mathematical maturity', which sometimes can be heard from primary teachers in practice. Early interventions can be an important cornerstone in preventive work, preventing students from struggling with mathematics. Regarding the intensity of interventions, it seems important not to quit but to hold on and preserve the interventions with students who continue to demonstrate difficulties in basic arithmetic competence. As Bryant et al. (2021) pointed out, some students might respond positively to the second period of early intervention.

In addition, this study shows that using multi-tiered RTI to meet the Swedish school Act requirements for a guarantee for early support in mathematics (SFS, 2010:800) might be a sufficient and cost-efficient way to identify and support students at risk in mathematics early. Here the support can be in a small group in an intense period, and only a few students need to continue with Tier 3 interventions in one-to-one support. Though, as the Swedish School Inspectorate (2022) pointed out, a critical aspect is the quality of the special educational support—that the interventions are planned and carried out with a skilled special teacher in mathematics.

Limitations and future research

This pilot study has potential limitations. The limitation is partially due to the Coronavirus pandemic that restricted the data collection in public schools in Sweden. For example, the control group was planned to have the same size as the RTI group, but due to the restrictions and teachers' heavy workload, we were not allowed to conduct the study and collect data in some of the chosen control classes. The limited number of students in the control group is related to the power of the study and the risk of not reaching significant results. Besides, there is also a risk of bias in sampling. More information about the students' backgrounds could have revealed group differences and potential confounders, which would be essential to include in a future study. For example, it would be valuable to match the students on gender, socioeconomic status, second language, reading acquisition and number sense.

Another limitation is the applied tests measuring basic arithmetic competence. These tests are frequently used in primary schools in Sweden, but they need to be standardized. These tests have apparent ceiling effects, and it would be valuable to know when students are expected to reach maximum test scores. However, we chose these tests as there are no standardized tests in early mathematics education in Sweden. Consequently, further studies should be conducted after a larger sample of students' performance on these basic arithmetic competence tests is evaluated and validated among students in Grades 1 and 2. Valid cut-off scores for weak arithmetic competence among students in Grades 1 and 2 should be included.

However, the promising results from the current pilot study speak for additional research with larger samples of students in the intervention and the control groups with matching procedures. The content of the tiers should also be paid attention to, for example, the number range of 10–19 concerning addition and subtraction should be emphasized in the instruction to investigate whether such a focus will increase students' results in this number range. It could also be vital to include other parts of foundational number sense in the interventions, such as understanding different representations of numbers, estimation and awareness of number patterns (cf., Sayers et al., 2016) to develop a more comprehensive number sense awareness of students. Using technology to support students at different stages in the RTI model could also be a new direction for future studies.

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CONFLICT OF INTEREST STATEMENT

There are no conflicts of interest in this research.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

This study has received ethical approval from the Swedish Ethical Review Authority (Dnr 2019-04814). The data in its original form is stored in a safe place and available.

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