

Linköping Studies in Behavioural Science No. 257

Early Elementary School Interventions in Reading and Mathematics

Hanna Lindström-Sandahl

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Abstract

Supplemental special education support in reading and mathematics is essential for some children who struggle to learn basic reading or mathematics skills in their first years of schooling. Previous research shows that supplemental phonics and early numeracy and arithmetic instruction help students at risk for reading or mathematics difficulties. Few intervention studies have been conducted in the Swedish elementary school context evaluating the effectiveness of early reading and mathematics instruction, limiting evidence-based practices guiding special education in Sweden. This thesis aimed to develop and test the impact of two intensive instructional programs on word reading and reading comprehension skills and number knowledge, arithmetic and problem solving. Transfer-effects of training across the reading and mathematics domains and the long-term impact of the programs were also investigated. The study enrolled 753 first grade students who were screened for low performance ($\leq 25^{\text{th}}$ percentile) in decoding, spelling, number knowledge and arithmetic. To evaluate how the impact of the interventions differ from regular school instruction, students were randomized to intervention and control groups and pre-tested with extended assessment of reading and mathematics skills ($n=32$ vs. 30 in mathematics, $n=34$ vs. 34 in reading). Both interventions were implemented at the start of second grade. The intervention programs spanned 36 lessons of supplemental explicit, one-to-one instruction with a special education teacher. Control group students received support planned by their schools. The results were evaluated at post-test and followed-up after 1 year. Both programs indicated significant intervention effects at post-test compared with controls with the reading intervention showing medium impact on decoding and reading comprehension and a strong effect on word recognition. The mathematics intervention program displayed significant moderate impact on number knowledge, arithmetic and basic problem solving. For both interventions, these effects declined at follow-up one year later. In addition, no transfer across reading and mathematics interventions were found. A main conclusion drawn from these randomized controlled studies is that students' performance in basic reading and mathematics can be substantially accelerated by a time-limited and intense effort, adding to the evidence-base of explicit phonics and early numeracy and arithmetic intervention as recommended practices also in a Swedish school context. As many previous studies have shown, intervention gains tend to fade over time. The longevity of intensive intervention impacts should be considered in post-intervention efforts to support learning. Alignment between supplemental programs and general classroom instruction is suggested.

Keywords: intervention, special education, instruction, reading, mathematics, randomized controlled study, follow-up, elementary school

Sammanfattning

Att lära sig läsa och räkna hör till grundläggande färdigheter i början av lågstadiet. För en del elever som kämpar med att tillägna sig dessa färdigheter behövs specialpedagogiskt stöd i form av extra läs- eller matematikundervisning. Studier har visat att undervisning med ljud-bokstavsmetoden, *phonics*, och undervisning i taluppfattning och grundläggande aritmetik hjälper elever som riskerar läs- eller matematiksvårigheter. I en svensk skolkontext finns få läs- och matematikinterventioner som utvärderat effekter på elevers läs- och matematikfärdigheter med en randomiserad kontrollerad studiedesign. Syftet med denna avhandling var att utveckla, implementera och utvärdera effekterna av två intensiva undervisningsprogram i läsning respektive matematik. Fokus för läsprogrammet var att utveckla ordläsning och läsflyt och i matematikprogrammet fokuserades taluppfattning och grundläggande aritmetik. Ett ytterligare syfte var att undersöka eventuella överföringseffekter mellan läsning och matematik för de elevgrupper som deltog i projektets interventionsgrupper. Dessutom studerades långtidseffekter av interventionerna. Totalt deltog 753 elever i åk 1 i urvalet till interventions- och kontrollgrupper. Elevernas läs- och matematikfärdigheter (ordavkodning, stavning, taluppfattning och aritmetiskt flyt) screenades vid två tillfällen på våren i åk 1 och elever med låga resultat (\leq percentil 25) randomiserades individuellt till interventions- och kontrollgrupper för läsprogrammet eller matematikprogrammet ($n=32$ vs. 30 i matematik, $n=34$ vs. 34 i läsning) för att undersöka effekten av dessa undervisningsprogram på elevernas läs- och matematikprestationer jämfört med skolans ordinarie undervisning. I början av åk 2 genomförde eleverna en för-testning och deltog därefter utöver den ordinarie undervisningen i en explicit, intensiv, individuell träning med en speciallärare om 36 lektioner i läs- eller matematikprogrammet, medan eleverna i respektive kontrollgrupp fick undervisning planerad av skolan. Efter interventionsperioden genomföres ett efter-test som upprepades ett år senare. Läs- och matematikinterventionen resulterade i signifikanta effekter jämfört med kontrollgrupperna direkt efter träningen. I läsprogrammet var effekten medelstor för ordavkodning och läsförståelse och träningen visade stor effekt på ordigenkänning. Resultaten för matematikprogrammet visade medelstor effekt på taluppfattning, aritmetik och grundläggande problemlösning. Dessa effekter hade reducerats vid långtidsuppföljningen. Inga överföringseffekter mellan läs- och matematikinterventionerna uppmättes. Slutsatser från dessa studier är att elevers läs- och matematikfärdigheter kan öka avsevärt med hjälp av ett tidsmässigt begränsat, intensivt *phonics*-program respektive taluppfattnings- och aritmetikprogram även i en svensk skolkontext. Resultaten kan på så vis bidra till evidensbaserade undervisningsmetoder. I likhet med ett flertal tidigare undersökningar visade uppföljningsstudien att effekterna av interventionerna avtog över tid. Det tyder på vikten av att överväga stöd även efter en intensiv läs- och matematikintervention. Vidare föreslås att skapa överensstämmelse mellan klassrumsundervisningen och interventionsprogram som ges utöver ordinarie undervisning.

Nyckelord: intervention, specialpedagogik, undervisning, läsning, matematik, randomiserad kontrollerad studie, uppföljning, grundskola

List of Papers

- I. Lindström-Sandahl, H., Elwér, Å., Samuelsson, S., & Danielsson, H. (2023). Effects of a phonics intervention in a randomized controlled study in Swedish second-grade students at risk of reading difficulties. *Dyslexia*, 29(4), 290-311. Published under CC-BY-NC license.
- II. Lindström-Sandahl, H., Samuelsson, J., Danielsson, H., Samuelsson, S., & Elwér, Å. (Submitted). A randomized controlled study of a second grade numeracy intervention with Swedish students at-risk of mathematics difficulties.
- III. Lindström-Sandahl, H., Danielsson, H., Elwér, Å., Samuelsson, S., & Samuelsson, J. (Submitted). A 1-year follow-up of two intensive supplemental reading and mathematics programs in Swedish elementary school.

Table of Contents

Abstract	i
Sammanfattning	ii
List of Papers.....	iii
Table of Contents	v
Introduction	9
Strategy and Overall Aim	10
Outline	13
Background	15
Word Reading and Spelling Skills.....	15
<i>The Simple View of Reading</i>	15
<i>Word Decoding</i>	15
<i>Word Recognition</i>	16
<i>Reading Comprehension</i>	16
<i>Orthography</i>	17
<i>Fluency</i>	17
<i>Spelling</i>	18
Early Numeracy and Arithmetic Skills	18
<i>Number Systems</i>	18
<i>Numeracy Skills</i>	19
<i>Arithmetic</i>	20
<i>Conceptual Knowledge</i>	21
<i>Procedural Knowledge</i>	21
<i>Mathematics Facts</i>	21
<i>Arithmetic Word-Problems</i>	22
Mathematics and Reading Development.....	22
<i>Bi- and Unidirectional Relations</i>	22
<i>Transfer of Skills</i>	24
<i>Reading Difficulties</i>	24
<i>Mathematics Difficulties</i>	25
<i>Reading and Mathematics Difficulties and At-Risk Populations</i>	26
Early Elementary Grades Reading and Mathematics Instruction.....	27
<i>Early Reading Instruction</i>	27
<i>Phonemic Awareness</i>	28
<i>Phonics</i>	28
<i>Morphology Training</i>	29
<i>Fluency Training</i>	30
<i>Spelling Instruction</i>	30
<i>Early Mathematics Instruction</i>	31
Instructional Features of Special Education Interventions.....	32

<i>Effective Instruction</i>	32
<i>Intensity</i>	33
<i>Group Size</i>	34
<i>Content Principles in Phonics Interventions</i>	34
<i>Content Principles in Early Mathematics Interventions</i>	35
Impact of Early Reading and Mathematics Interventions	35
<i>Effect Studies in Foundational Reading</i>	35
<i>Effect Studies in Foundational Mathematics</i>	37
Context of the Study.....	40
<i>The Swedish Context – Reading Instruction</i>	40
<i>The Swedish Context - Mathematics Instruction</i>	41
<i>Organization of Special Education Instruction in Reading and Mathematics</i>	42
<i>Response to Intervention</i>	44
Methodology and Evaluation.....	45
<i>Evidence-Based Practices</i>	45
<i>RCT Methodology in Educational Research</i>	46
<i>Fidelity</i>	47
<i>Follow-Up of Intervention Studies</i>	48
Method.....	51
Procedures	51
<i>Participants</i>	53
<i>Ethical Considerations</i>	53
Screening Measures	54
<i>Reading Tests</i>	54
<i>Mathematics Tests</i>	55
Extended Testing	55
<i>Reading Tests</i>	55
<i>Mathematics Tests</i>	56
Program Descriptions, Monitoring and Fidelity	57
<i>Intervention Programs</i>	57
<i>Implementation</i>	58
<i>Progress Monitoring Measures</i>	59
<i>Intervention Protocol</i>	59
<i>Interventionist Questionnaire</i>	59
Data Analyses.....	60
Summary of Studies.....	61
Study I.....	61
<i>Aim</i> 61	
<i>Method</i>	61
<i>Results</i>	61
Study II.....	62
<i>Aim</i> 62	

<i>Method</i>	62
<i>Results</i>	62
Study III	63
<i>Aim</i> 63	
<i>Method</i>	63
<i>Results</i>	63
General Discussion	65
Main Results	65
<i>Improved Reading Skills</i>	65
<i>Word Decoding and Recognition</i>	66
<i>Orthography and Phonics</i>	67
<i>Transfer to Reading Comprehension</i>	68
<i>Improved Mathematics Skills</i>	69
<i>Number Knowledge and Calculation</i>	69
<i>Simple Arithmetic Word Problems</i>	70
<i>Sustainability</i>	71
<i>Transfer</i>	73
Methodological Considerations with the RCT Design	73
Intervention Features	75
<i>Moderating Variables</i>	75
<i>Multicomponent Programs</i>	75
<i>Intensity</i>	76
<i>Alignment</i>	77
<i>Implementation</i>	77
Conclusions	81
Summary of Contributions	81
<i>Theoretical Implications</i>	82
<i>Practical Implications</i>	83
<i>Future Directions</i>	84
Acknowledgements	87
References	88

Introduction

With this thesis, the intention was to develop, implement and evaluate the effects of two interventions for second-grade students at risk for early reading and mathematics difficulties with randomized controlled studies (RCT) to be implemented as supplemental training in Swedish special education. I will describe details on research aims, its importance and procedural as well as methodological considerations and address implications for special education.

Special education in schools is aimed at improving student learning and preventing academic failures in the broadest sense and utilizing effective teaching methods and materials to meet the specific needs of students in the early grades (Nelson et al., 2021). Students who display learning difficulties constitute a large proportion of students receiving special education support (e.g., National Center for Education Statistics, 2023; Swedish National Agency for Education, 2022a), yet what the support consist of and for whom it is implemented is not well identified in Sweden (Westling Allodi, 2016). In the Swedish school context, these children attract teachers' attention early on and they are entitled to supplemental, and if needed, individually directed support from the earliest grades to master basic literacy and arithmetic skills (SFS, 2010:800; Swedish National Agency for Education, 2021). Reading and mathematics difficulties are common, but there is neither a nationally organized, nor structured support system for these young students in need of special education. In the Swedish school practice, instructional content and the implementation of various support is decided at the local school level (Nilvius 2022; Nordström, 2018). Well-designed research addressing teaching methods, essential language and cognitive skills underlying early literacy acquisition, and its implementation are few if any in a Swedish school context. In Sweden, Wolff (2011, 2016) has designed and published an intervention study with a high scientific standard addressing children in early reading difficulties. Her study shows that phoneme-based teaching together with speed components enhance early word reading development and more importantly, had prolonged effects five years after intervention. Research addressing early mathematics difficulties and interventions guiding teaching is increasing (Sterner et al., 2020; Östergren et al., 2023) but still needs to assess numeracy and basic arithmetic skills training in early school age with high standard research evaluating its causal impact on mathematics learning.

Strategy and Overall Aim

This thesis encompasses four main purposes. First to replicate and not least generalize phonics as a core target in Swedish special education to support children at-risk for early reading difficulties. Second, to replicate early numeracy and basic arithmetic training as effective targets for enhancing early mathematics skills. Third, to develop two well-structured teaching materials for special education teachers meeting children at risk for reading and mathematics difficulties early in school. The fourth aim was to evaluate sustainability of training effects over time and potentially transfer effects between interventions.

A broader objective is to contribute to the diverse field of Swedish school-based research intended to bring empirical special educational research and practitioners closer and develop aspects of practice (Magnusson & Malmström, 2023). Hence, I make an argument for interventions that are implemented by teachers as a mean to connect the instruction to the school context despite tightly researcher-controlled conditions. While school-based research typically does not include effect studies, educational studies with an RCT design are increasing in Scandinavia (Magnusson & Malmström, 2023; Pontoppidan et al., 2018) and the present thesis could be seen as an addition to that field as well as to the growing body of Swedish general and special education early intervention studies (Sterner et al., 2020; Wolff, 2011; Östergren et al., 2023). Hopefully, this research has implications for policy and practice demands of implementing evidence-based teaching practices (Levinsson, 2013). After all, special educational research findings are seldomly implemented in school practices (Hirsch et al., 2022; Odom, 2009) and standardized interventions evaluated by researchers to support students struggling with early mathematics and reading in the Swedish educational context are limited.

In this thesis, I have evaluated two supplemental intervention programs each with a randomized controlled design addressing early reading and mathematics skills. Central to the intervention strategy were (a) highly structured lessons, (b) high intensity, (c) one-to-one, (d) explicit administration aimed at optimizing the response to early reading and mathematics interventions. The intervention projects were collectively labelled early interventions in mathematics and reading “*Tidiga Interventioner i Matematik och Avkodning*”, TIMA, and the research team members of five were together experienced in special education research, educational psychology, reading and mathematics education and quantitative methodology. My role as a PhD student was to develop, construct and produce a new reading intervention and to adapt and extend a mathematics program to the target group and to

produce training materials. I have had the main responsibility for recruiting schools, organizing, and managing contacts with participating teachers and supporting the implementation of the programs. Administration of the screening, the extended testing and scoring were part of my responsibilities. In both waves of the school implementation, I had the opportunity to conduct the interventions with some students in the reading and mathematics program. Some specific decisions on study design, instructional content and procedures were jointly made by the project team. An overall description and motives for those decisions present the rationale for the thesis, which is outlined below.

The RCT study design was applied to support strong causal claims (Shadish et al., 2002) of the observed impact of the interventions on students' reading and mathematics performance since the focus was to evaluate the effectiveness of the programs compared to regular instruction. Moreover, the design allows comparison with outcomes from similar interventions (Kraft, 2020) in the international intervention literature, which enables considerations of the present study's validity in a Swedish school context.

The rationale for targeting supplemental phonics and early numeracy with arithmetic was the extensive knowledge base advocating these skills as central to foster reading and arithmetic in early grade children with or at-risk for reading and mathematics difficulties (e.g., Aunio & Räsänen, 2016; Castles et al., 2018; McArthur et al., 2018; Nelson & McMaster, 2019), again sparsely evaluated in Swedish educational intervention research.

The decision to parallelly evaluate two interventions stems from an interest in investigating if extensive training in one content area affects outcomes in the other as mathematics and reading development and learning seem related (Erbeli et al., 2021; Hübner et al., 2022; Peng et al., 2020). The overall project design offered a unique opportunity to study transfer of effects of intervention in addition to the expected impact on reading and mathematics skills respectively.

Early interventions seem critical to prevent long-term consequences of reading and mathematics difficulties (Jordan et al., 2010; Lovett et al., 2017; Nelson & Powell, 2018). However, the present study considered the timing of the intensive training in relation to opportunities for students to learn basic reading and mathematics skills from general classroom instruction. Hence, identification of difficulties began in the second semester of first grade and was completed after 4 months, when the students had received a full year of early curriculum guided beginning reading and mathematics instruction.

Special education in the earliest grades may imply being supported by the classroom teacher or receiving additional support from the special education teacher in class or in a small group setting. Since one-to-one instruction in reading and mathematics interventions is an effective practice offering more opportunities for the teacher to give full attention to the student, to monitor student response, give immediate feedback, and provide intensive interaction opportunities (Chodura et al., 2015; Gersten et al., 2020; West et al., 2022), individual instruction was implemented for both interventions in this thesis.

Of major importance was to make conditions as similar as possible between intervention teachers and students across the different sites of the study. Therefore, scripted instructions were opted for. The preplanned instructions detailed how lessons were to be implemented and hence the packaged programs sharply contrasted with the syllabi which are non-specific in guiding instructional approaches (Swedish National Agency for Education, 2022b). While the fixed lesson outlines are considered divergent from common Swedish special education practice, where the teacher is responsible and independent in tailoring instructions based on curricular guidelines, curricular content was mirrored and thus overall aligned with the interventions (Lutz, 2013; Swedish National Agency for Education, 2022b; Werler & Tahirsylaj, 2022).

The explicit instructional approach that is a recommended practice with students who struggle with reading or mathematics (Gersten et al., 2009; Rupley et al., 2009) was incorporated in the readymade lesson plans and designated materials. We also decided to design non-computerized instructional programs that should have the benefit of requiring no extra equipment or technical maintenance and promoting high teacher-student interaction with concrete materials.

A one-year follow-up of the two programs was conducted because longitudinal results can be informative to research and practice in judging the impact of supplemental reading and mathematics support, and still considerably fewer empirical studies adopt a longitudinal perspective relative to the number of school interventions studies that investigate impact immediately post intervention (Watts et al., 2019).

Overall, close collaboration with stakeholders has been considered pivotal in conducting RCT studies in educational settings (e.g., Frankenberg et al., 2019), particularly to give rich opportunities for participating teachers to interact with the research team before, during and after the interventions and clearly explain the aims of the project and for ethical reasons to consider what the outcomes could mean to the population of children the project was targeting and to the individuals

enrolled in the intervention and control groups (Alderson & Morrow, 2011).

Four specific research questions were addressed:

1. What are the effects on word decoding, word recognition and reading comprehension following an RCT designed reading intervention addressing phonics in second grade students at risk for reading difficulties?
2. What are the effects on arithmetic calculation, conceptual knowledge, and problem solving following an RCT mathematics intervention in second grade students at risk for mathematics difficulties?
3. What are the long-term effects of the reading and mathematics interventions, specifically: Is there an impact on reading related outcomes 1 year post-intervention in children who participated in the RCT reading intervention study? Is there an impact on mathematics related outcomes 1 year post-intervention in children who participated in the RCT mathematics intervention study?
4. Are there transfer effects to reading skills from participation in the math intervention? Are there transfer effects to mathematics skills from participation in the reading intervention?

Outline

The thesis is divided in five chapters. The first chapter provides a background to reading and mathematics skills as conceptualized in this thesis, and its development and difficulties. The following sections, in turn, present an introduction to general early mathematics and reading instruction, instructional features of reading and mathematics special education interventions, the impact of early grades reading- and mathematics interventions and a brief description of mathematics and reading beginning instruction in Sweden to situate the study in its educational context. It also describes the organization of special education support in reading and mathematics from aspects of teachers' instruction to organizational arrangements and describes RCT methodology and considerations about evidence-based practice relevant to the present study. The Methods chapter gives a description of participants, testing, the intervention programs, implementation and fidelity aspects and data analyses. Chapter three, Summary of the

Studies, presents Study I-III. The final two chapters are General discussion followed by Conclusions.

Background

Word Reading and Spelling Skills

In this thesis, basic and fundamental skills are used interchangeably and refer to early reading skills including phonological awareness, decoding, word recognition and basic reading comprehension, for example word- and sentence level comprehension. The concept of reading is primarily used here limited to proficiency with decoding, word recognition and fluency and will not further elaborate on the broader term literacy (Aukerman & Chambers Schuldt, 2021).

The Simple View of Reading

As pointed out by Perfetti and Stafura (2014), reading theory is not a unitary construct, entailing developmental as well as cognitive processing theories. Gough and Tunmer (1986) proposed the most cited theoretical model for conceptualizing reading ability, the Simple View of Reading (SVR) to explain the essentials of reading ability. The SVR model in this thesis identifies and describes important factors to be addressed in a reading intervention and it has guided the development of the reading instruction program. The SVR model represents two mutually exclusive factors, decoding, and linguistic comprehension. These components interact to produce reading with comprehension. Even though the model is not developmental and its applicability to different populations have been contested, it has proved reliable as an explanatory model of what constitutes reading (Foorman et al., 2018; Hoover & Tunmer, 2018; Lervåg et al., 2018). According to the model when decoding is low, full reading comprehension will not be obtained, and in the early elementary grades decoding accounts for most of the variance in children's reading comprehension (Adlof, et al., 2006; Lervåg et al., 2018). Reading comprehension is initially constrained by the child using cognitive resources to execute word decoding, which is the technical aspect of word reading (Perfetti, 1985).

Word Decoding

The acquisition of word decoding skills is fundamental as it represents the ability to decipher printed words in beginning readers (Hoover & Tunmer, 2018). Ehri (2014) described the development of word reading

acquisition in a sequential fashion, which initially means the child recognizes printed words as visual entities without analyzing its orthography or phonology. Gradually, characteristics of words are identified by some orthographic feature such as a first letter. As the child then connects letters with corresponding sounds and starts blending, decoding reaches the alphabetic-phonologic level. This is a critical phase in learning to read as children learn to master reading unfamiliar words by sounding out and blending individual letters. The most accomplished level is orthographic, which characterizes the skilled reader who accurately and efficiently reads orthographic units, such as morphemes, in a quick and automatized manner. Following repeated exposure, the child develops orthographic representations of words in the mental lexicon and word recognition becomes more efficient (LaBerge & Samuels, 1974; Perfetti, 2007) and functions in a self-teaching procedure (Share, 1995).

Word Recognition

Word recognition means that orthographic patterns, such as morphemes, and whole words can be retrieved from the mental lexicon by “sight”, which facilitates reading and spelling (Ehri, 2005, 2014). Perfetti (2007) presented the Lexical Quality Hypothesis, suggesting that high quality representations of a word’s phonology, orthography, morphology and meaning result from multiple exposure to a word. According to the lexical quality hypothesis, exposure is an important factor that can facilitate decoding and reading comprehension processes (Perfetti, 2007). As decoding and word recognition skills gradually become more automatized, the influence of general language skills in explaining individual differences in reading comprehension increases (Foorman et al., 2018; Hoover & Tunmer, 2018; Tilstra et al., 2009).

Reading Comprehension

Reading comprehension requires adequate interaction of decoding and comprehension of oral language (Hoover, 2023). Strong oral language skills influence both reading comprehension and listening comprehension (Lervåg et al., 2018). Specifically, linguistic knowledge of vocabulary, morphology and syntax are required to understand written text structure and meaning and to successfully execute the meaning making process which also demands attention, text monitoring, inference-making, and world knowledge (Elleman et al., 2019; Tannenbaum et al., 2006). Next paragraph briefly describes the impact of orthography in learning basic reading and spelling skills.

Orthography

When learning to read and spell, the properties of the orthography matter (Seymour et al., 2003). Transparency, or depth, is the estimation of the consistency of the one-to-one correspondence of grapheme-phoneme connections in alphabetic orthographies (Riad, 2014). The orthographic transparency of a written language is related to learning to read in at least two important ways relevant to the present study.

First, cross-language comparisons have found variation in the rate of reading acquisition depending on the level of transparency where decoding in transparent or semi-transparent orthographies as Swedish, is more rapidly acquired than in opaque orthographies (Seymour et al., 2003). It is considered less time consuming to establish an orthographic reading level when the written language contains few monosyllabic words and simple consonant structures and more effortful when there are inconsistencies in phoneme-grapheme mappings (Seymour, 2005). Swedish may be semi-transparent, but still has a rich inflectional structure, a complex consonant clustering, a large share of compounds, vowels with long and short realizations and inconsistencies in phoneme-graphemes and irregularly spelt function words (Hagtvét et al., 2005; Seymour et al., 2003).

Second, most instructional reading interventions in phonics referred to in the thesis were developed in English, an opaque orthography, which means that training generally targets a wider and more complex array of letter-sound connections in early literacy instruction (Share, 2021). This is because of the English writing system's many inconsistencies and irregularities in grapheme-phoneme connections and spelling patterns (Seymour et al., 2003).

Fluency

Efficient reading implies fluency, which comprises effortless and accurate reading with speed (Hudson et al., 2008). In transparent orthographies word reading fluency seems to predict reading comprehension in young readers, because when accuracy is mastered the speed of reading is influential in reading comprehension (Florit & Cain, 2011). Studies of fluency development in transparent orthographies shows that it is a stable skill over the elementary grades, once decoding is mastered (Landerl & Wimmer, 2008). According to LaBerge and Samuels' (1974) theory of automatic information processing, quick and correct decoding through repeated exposures for written words enables allocation of cognitive resources to text comprehension. Hence, learning to automatically read words is related to reading comprehension. Fluent reading is practice dependent, often by repeated reading (Ardoin et al.,

2018; Torgesen et al., 2001), with mixed results regarding the optimal grain size level of printed training material. Some researchers consider repeated text or passage reading to be superior to word-list reading, while others advocate robust word accuracy as a first instructional objective (Chard et al., 2002; Metsala & David, 2022; Rasinski, 2014). The former studies typically operationalize fluency as a wider concept including comprehension and prosody and not restricted to speed and accuracy of word decoding. Hudson et al. (2008) suggested adapting the repeated reading material to fit the level of the student's difficulties, which embraces different levels of written materials.

Spelling

Turning to writing, in the Simple View of Writing framework, spelling is assumed to require two main factors: ideation and encoding. Encoding is the process whereby speech sounds are translated to printed letters and composed to words, whereas generating and structuring content is the focus of ideation (Juel et al., 1986). Reading supports spelling and spelling is beneficial for the development of word reading (Graham & Santangelo, 2014; Kim, 2020). Theoretical models of reading and spelling development state that reading and spelling rest on similar, cognitive processes and that skills develop in tandem (Fitzgerald & Shanahan, 2000). For this thesis, decoding and spelling were the two main components addressed in the reading intervention conceptualizing phonics.

Early Numeracy and Arithmetic Skills

In the following paragraphs early numeracy and arithmetic will be outlined. References to foundational skills in early mathematics in this thesis are used interchangeably with basic skills and entail skills related to early numeracy, simple addition and subtraction, and arithmetic word problem solving.

Number Systems

Mathematics development depend on an interplay between cognitive abilities, described as domain general and a set of domain-specific abilities that form a foundation for mathematics acquisition (Fuchs, Geary et al., 2010; Träff et al., 2020; von Aster & Shaley, 2007). Before being subjected to formal mathematics instruction, children develop informal knowledge of number based on an innate cognitive capacity to apprehend and discriminate magnitude which means to represent numbers before they are associated with symbols or verbal labels. This

representational ability is hypothesized to reside in two systems, an approximate number system responsible for inexact estimation of larger sets of objects and a system for exact representation of small numbers that allows discrimination between small sets and apprehension of small quantities without counting, denoted subitizing (Feigenson et al., 2004; von Aster & Shalev, 2007). The preverbal number sense is fundamental to the development of symbolic number sense and represents domain-specific capacities for mathematics (Feigenson et al., 2004; Kroesbergen et al., 2021). Also, domain general abilities such as executive functions seem important in mathematics processing (Geary, 2004).

Childrens' drive to use their knowledge of number spontaneously and their environment's ability to boost this awareness are supportive in bridging informal and formal mathematics (Hannula-Sormunen et al., 2021). Informal as well as formal instruction in basic counting and sense of quantity before school entry enhance numeracy development (Friso-van den Bos, 2018; Gersten, et al., 2005). Building on the initial, preverbal number sense, verbal number competencies then include counting verbally, understanding of the count list that is ordinality, and that the last number counted in a set corresponds to the total number of items which is cardinality (Jordan et al., 2010). In von Aster and Shalev's (2007), developmental model of numerical cognition, early learning of whole number is outlined as a hierarchical sequence where the child initially utilizes the innate system of magnitude to subitize small quantities, then learns to map verbal numbers onto objects, followed by the ability to represent number as written Arabic numerals and finally, to develop a mental number line, representative of arithmetic thinking. In the model (von Aster & Shalev, 2007) general cognitive abilities such as language, executive functions and working memory are included as necessary components to integrate the two systems and for further symbolic development.

Numeracy Skills

Early numeracy, also denominated number sense, has been conceptualized in different ways within mathematics cognitive and educational research with some scholars interested in the cognitive underpinnings and others focusing on student behavior or educational implications (Berch, 2005; Hirsch, et al., 2018; Howell & Kemp, 2006; Whitacre et al., 2020). Whereas Berch (2005) described number sense covering inherent and acquired abilities, Whitacre et al. (2020) found in their review of conceptualizations of number sense, three broad constructs used within social and behavioral sciences. These were, in turn, approximate number sense related to innate neurobiological abilities, early number sense involving learned basic skills in school

mathematics, and a mature number sense connected to the learned and refined understandings of mathematics components in upper elementary to adult education.

Andrews and Sayers (2015) attempted to specify the components of early number sense (Whitacre et al., 2020), which students develop in their first years of formal schooling. The researchers described number recognition, systematic counting, number and quantity awareness, quantity discrimination, estimation, simple arithmetic competence, and number pattern awareness to be foundational numeracy skills. Number recognition denotes the ability to associate verbal and written representations of numbers (Aubrey et al., 2006). Systematic counting involves the understanding of the count sequence related to ordinality and cardinality (Andrews & Sayers, 2015). To have number and quantity awareness implies understanding that numbers represent quantities which is important in understanding the linear representation of numbers (Booth & Siegler, 2008). Number pattern awareness describes knowledge of number relations and simple arithmetic skills is defined as knowledge of operations with addition and subtraction.

In the present thesis, early numeracy skills are referred to as knowledge of numbers, number relations and number procedures subject to instruction in early elementary grades (National Research Council, 2009), hence pertaining to the early number sense construct (cf. Andrews & Sayers, 2015; Whitacre et al., 2020).

Arithmetic

Theory of arithmetic development emphasizes its multi-componential nature and a hierarchical and stepwise development (Dowker, 2008; von Aster & Shalev, 2007). In arithmetic, calculation is central and requires conceptual, procedural and mathematics fact knowledge to be learned and efficiently executed.

Arithmetic includes addition, subtraction, multiplication, and division (Kilpatrick et al., 2001). Generally, young children progress from using counting strategies to answer basic number combinations to more sophisticated reasoning strategies, and finally, they can retrieve answers to number combinations from memory. Research suggests that at different times over the course of development and when engaging with different operations, children's mathematics skills depend on domain general and domain specific skills to varying degrees. For example, during the first year of instruction, basic number abilities seem most influential in procedural counting while working memory and other domain general cognitive abilities plays a more important role in word problem-solving (Fuchs, Geary et al., 2010). Longitudinal research

on predictors of arithmetic development suggests that non-symbolic number sense and number knowledge in kindergarten are associated with arithmetic performance in first grade and symbolic number sense at first grade predicts arithmetic achievement in third grade (Jordan et al., 2010; Malone et al., 2020).

Conceptual Knowledge

Conceptual knowledge denotes understanding of numbers, their relations and principles related to or underlying number processes (Kilpatrick et al., 2001). For example, knowing that counting does not have to start from 1 enables a child to add sums by the procedure of counting on from one addend instead of counting both addends separately from 1 (Geary, 2004). Empirical studies have found conceptual knowledge underlying arithmetic counting skills to be supported by and influencing procedural skills (Canobi, 2009).

Procedural Knowledge

Procedural knowledge represents learned knowledge of calculation sequences. For example, a child might use a decomposition strategy to solve an arithmetic problem, for example if $5+5=10$ then $5+6=5+5+1=11$ or the child might use the basic procedure of counting to reach an answer (Geary et al., 2012). Typically, children use their fingers when adding in the early stage, counting both addends. Some basic strategies include counting all to reach a sum and later the more advanced counting on strategy that implies to start adding from the larger addend. Decomposition strategies are based on the child's ability to retrieve simple mathematics facts (Geary, 2004). These applications of strategies for computation co-develop with conceptual understanding (Rittle-Johnson, 2017).

Mathematics Facts

Mastery of mathematics facts refer to the knowledge, storage, and automatized retrieval of learned mathematics facts. Knowing the answers to simple, single-digit arithmetic addition and subtraction tasks seems to facilitate multi-digit calculation and problem solving and fluency with simple arithmetic tasks, that is number combinations, is associated with word problem performance. (Geary, 2004; Kilpatrick et al., 2001; Träff et al., 2018).

Arithmetic Word-Problems

The main difference between number combinations and arithmetic word problems is the latter being embedded in a linguistic context, hence more challenging to identify and requiring language skills, problem identification and a strategy to derive an answer (Fuchs et al., 2009).

Mathematics and Reading Development

Mathematics and reading skills typically develop rapidly because of instruction in early grades (Hübner et al., 2022). It is recognized that skills in both areas rely on domain-general and domain-specific abilities. Their interrelationships are outlined in cognitive models which will not be further elaborated, because the research interest here is at the behavior level, that is the manifestations of reading and mathematics, reflected in children's mathematics and reading performances. However, research is rich in investigations of the relations between early mathematics and reading abilities with most studies presenting correlational relationships and some based on longitudinal data (Lin & Powell, 2022) showing varying directions of the relationship.

Bi- and Unidirectional Relations

Peng et al. (2020) conducted a meta-analysis of correlational studies of the developmental relationship between mathematics and reading and found bidirectional correlations in a large sample covering infancy to adulthood. That the relative importance of mathematics development for reading outcomes and vice versa may also change over time was shown in the meta-analysis of longitudinal studies by Lin and Powell (2022) tracking the development in reading and mathematics with the purpose to investigate the impact of early performance on school mathematics outcomes and the moderation of age. Participants included both typically developed and children with reading and mathematics difficulties. The results showed that reading and mathematics fluency was predictive of later mathematics performance. However, reading seemed to assert less impact on mathematics performance over time, instead working memory was a more predictive factor (Lin & Powell, 2022).

Hübner et al. (2022) investigated developmental paths in reading and mathematics in a large sample of elementary grade students. They were specifically interested in information that could inform education and intervention. Results showed that the relationship between development in each domain on average differed between children at different performance levels such that early strong reading performance seemed to predict mathematics growth positively, while early high

mathematics achievement was negatively associated with later reading achievement growth. Hence children may benefit differently from early instruction and efforts to strengthen early reading skills seem relevant. Also, in a longitudinal study Erbeli et al. (2021) investigated reading and mathematics correlations in elementary students deemed academically at risk. The researchers found that good reading performance predicts changes in mathematics performance, affecting students with weak mathematics performance positively. These studies concluded that reading skills seem to be predictive of mathematics development (Erbeli et al., 2021; Hübner et al., 2022).

A meta-analysis of the relationship between phonological processing skills and mathematics found a moderate correlation for phonological awareness, PA, and mathematics and hypothesized training young students in PA skills could have a positive impact on their mathematics learning (Yang et al., 2022). Contrary to the findings above, Duncan et al. (2007) showed that mathematics performance at school entry was as predictive of reading achievement in later school years as reading, while early reading was not as predictive of later math achievement, suggesting benefits of promoting early mathematics skills. This study was based on large datasets of achievement, behavioral and cognitive measures from selected and representative samples. As reading and mathematics difficulties are associated and co-occur, Cirino et al. (2018) followed the development of reading and mathematics in children from kindergarten to first grade by examining associations between reading and mathematics predictors and outcomes in both domains measured at the end of first grade. Results indicated that the language-based skills PA, rapid automatized naming, RAN, and symbolic naming identified both subsequent reading and mathematics difficulties and the authors suggested to monitor children with low performance in one domain for difficulties in the other. This study indicates that there might be transfer effects between reading and mathematics development. Researchers have tried to find explanations of the estimated relationships in theories of reading and mathematics predictors, theories of cognitive domain specific- and domain general abilities such as phonological processing, working memory and general cognitive processing abilities (Balhinez & Shaul, 2019; Fuchs et al., 2005; Singer & Strasser, 2017, Spencer et al., 2022). Still, research addressing if and how (in what direction) reading and mathematics development is related is not conclusive. Even more so whether directed intervention in reading impact on mathematics or the other way around.

Transfer of Skills

Given the dual exposure to mathematics and reading instructions in elementary grades and correlations in skills performance presented above, studying transfer across domains resulting from supplemental instruction in one domain was an objective of the present study. Transfer of skills between reading and mathematics training has gained less attention in intervention research (Dowker, 2005). In a recent preschool class number sense intervention study by Sterner et al. (2020), targeting numeracy skills the researchers specifically discussed transfer of skills after intervention. Children were randomized to a training or a control group receiving structured intervention in numeracy and PA, respectively. Their study reported a significant effect between post-test mathematics and follow-up reading comprehension suggesting that preschool mathematics improvement was associated with first grade reading comprehension. However, the control group outperformed the intervention group in reading comprehension at follow up which led Sterner et al. (2020) to conclude that the mathematics intervention seemed to improve mathematics outcomes. Next paragraphs describe difficulties in reading and mathematics.

Reading Difficulties

An overview of broad descriptions of reading difficulties can be derived from the Simple View of Reading framework, which have been used in numerous classification studies of reading difficulty (Hoover, 2023). For example, problems with one of the components of the formula can manifest as poor decoding skills, but sufficient linguistic comprehension resulting in a dyslexic reading profile (Adlof et al., 2006). Another example of a reading profile derived from the model is to have sufficient decoding skills with poor linguistic comprehension resulting in a profile of poor reading comprehension (Elwér, 2013). Research suggests with relative consensus that the dominant deficit in decoding related reading difficulties is phonological with poor word reading and fluency as cardinal symptoms (Castles & Coltheart, 2004; Melby-Lervåg et al., 2012; Snowling et al., 2020; Torgesen et al., 2001). Problems with word decoding in beginning readers serves as an obstacle to the development of reading comprehension leaving children with early reading difficulties in need of training that provides exposure to connections between phonemes, graphemes and larger orthographic units combined with decoding rules and fluency training, to move beyond the level of decoding (Compton et al., 2014; Melby-Lervåg et al., 2014; Torgesen et al., 2001). In alphabetic languages with a regular orthography, learning to read words accurately typically happens during the first year of formal

reading instruction, therefore word reading speed can be interpreted as a measure of fluency (Landerl & Wimmer, 2008). For students with ineffective decoding, reading difficulties can become more apparent over time because of compromised reading comprehension (Byrne et al., 1992) leading to less engagement with text due to a lack of skills and practice (Stanovich, 1986).

As mentioned, in consistent orthographies phonological decoding accuracy can be mastered by learners despite underlying reading difficulties because the relationship between letters and sounds are rather predictable (Landerl & Wimmer, 2008; Seymour et al., 2003). Hence, in Swedish orthography, a student with reading difficulties may present decoding skills and ability to sound out words when reading, and still struggle with spelling as correspondence between phonemes and graphemes are less clear-cut than the other way around, which could impose increased demands on phonological abilities (Furnes & Samuelsson, 2011).

Mathematics Difficulties

Mathematics learning difficulties, MD, have been related to underlying cognitive deficits, more specifically problems with forming connections between the preverbal number sense system and the symbolic system (Wong et al., 2017). Main theories have suggested that young students with mathematics difficulties show deficiencies in accessing the magnitude of number symbols or to process magnitude (Mazzocco et al., 2011; Rousselle & Noël, 2007; Wong et al., 2017). More recent explanations integrate domain general and domain-specific deficits in comprehensive and complex frameworks that account for multiple related factors in mathematics difficulties (Kaufmann et al., 2013; Kroesbergen et al., 2021).

Early mathematics knowledge and skills are known to predict subsequent mathematics acquisition in several areas such as counting, and number knowledge (Aubrey et al., 2006; Aunio & Niemivirta, 2010; Jordan et al., 2010). Moreover, research indicates that mathematics performance skills are hierarchically connected (e.g., Träff et al., 2018), with early mathematics problems possibly comprising later stages of mathematics development and that students with weak early numeracy skills are at risk for continuing mathematics failure (Geary, 2011; Gersten, Fuchs et al., 2005). From a developmental perspective, low mathematics achievement in kindergarten seems to be persistent throughout elementary school (Träff et al., 2020) and later arithmetic skills can be predicted from conceptual and procedural number knowledge in early elementary grades (Desoete et al., 2009; Jordan et al., 2010).

For children with mathematics difficulties, conceptual and procedural aspects of arithmetic present challenges (Kilpatrick et al., 2001). These children seem to commit more errors when using strategies to solve number combinations and retrieving mathematics facts (Geary et al., 2000). Examples of immature strategies include prolonged use of finger counting and a limited repertoire of ways to solve number combinations (Geary et al., 2000; Jordan et al., 2003). The lack of skills in fluently solving number combination is a hallmark of mathematics difficulties and a basic requirement to engage in procedural computation and word-problems (Fuchs et al., 2009). Word problem-solving connects mathematical thinking with real word problems and requires processes of understanding and integrating numerical information, linguistic information, problem identification, and selecting an appropriate solution strategy – all processes associated with early mathematics difficulties (Lein et al., 2020).

Reading and Mathematics Difficulties and At-Risk Populations

Reading and mathematics difficulties are heterogenous and multifactorial, even within the group of diagnosed learning difficulties, LD, with a neurobiological aetiology manifested as limitations in reading or number and arithmetic skills (Kaufmann et al., 2013; Peterson & Pennington, 2015; Snowling et al., 2020). Furthermore, LD in mathematics and reading are frequently comorbid (Snowling et al., 2020; Willcutt et al., 2013). Both reading and mathematics LD are associated with weaknesses in domain general cognitive abilities such as processing speed, working memory and phonological processing (Peng et al., 2018; Willcutt et al., 2013).

Intervention studies define students struggling with mathematics or reading differently, with the main contrast between criteria for disability and difficulty. For mathematics studies typically, disability is used when there is a diagnosed mathematics LD or a low-set cutoff score on a mathematics screening test. Some studies include students with a LD in the broader term mathematics difficulty, MD (Stevens et al., 2018). MD is commonly referred to as performance at or below the 25th percentile on standardized mathematics tests but other cut-off limits are applied and teacher judgement has also been used for MD identification in intervention studies (Dennis et al., 2016; Gersten, Fuchs et al., 2005; Mazzocco et al., 2011; Mononen et al., 2014). Students who display difficulties in mathematics, not labelled MD but deemed at-risk for mathematics difficulties, represent a heterogenous group (Kroesbergen & Van Luit, 2003). The same diverse use of terminology and criteria for

defining reading problems and risk-status has been acknowledged in studies of reading difficulties (Hall et al., 2023; Peterson & Pennington, 2015). In a recent large cross-sectional study, approximately 20% of Swedish first to third grade students with Swedish as their first language, scored below the 22nd percentile on a measure of decoding which was interpreted as students in need of extra support, adding to the terminology of descriptions of reading difficulties (Fälth et al., 2023). In addition to LD and difficulties is the at-risk status, which can be considered a diverse term. For example, Dietrichson et al. (2021) used it to classify students with low socio-economic status or other environmental risk factors, in their meta-analysis of mathematics and reading intervention. Other studies have used at risk for low achieving students and students with additional difficulties such as language disorders (Wanzek et al., 2016). Clearly at risk can denote poor, insufficient, or socially disadvantaging environmental circumstances, specified disorders, or low performance.

The Swedish school policy is indicative of who needs or is entitled to instructional support based on performance, instead of specifying categories of learning disability (SFS, 2010:800). In this thesis details of specific LD profiles in participating students (dyslexia and dyscalculia) were omitted from inquiry, as the participants were identified based on a conceptualization of at-risk status that did not include diagnoses but low performance on selected screening measures. Also, the students were generally too young to have had assessment for a LD diagnosis. For this thesis children with an intellectual disability were excluded, since they were not a target group of the present research study. Instead, we operationalized children with low performance on reading or mathematics tests as being at risk for reading and mathematics difficulties.

Early Elementary Grades Reading and Mathematics Instruction

In the following two paragraphs I outline some general classroom instructional insights as well as special education teaching approaches founded in research addressing teaching for students acquiring early skills in reading and mathematics.

Early Reading Instruction

In the reading science literature controversy about best practice in beginning reading has been played out between scholars advocating for a bottom-up approach vs. proponents for a top-down approach to

reading instruction (Rayner et al., 2001). Strong scientific evidence supports the bottom-up procedure as a starting point, which means explicitly teaching phonological-alphabetical connections first, starting from the sound-symbol level, and then gradually moving to the word and text level. This instructional sequence highlights the deciphering of print, which facilitates access to the orthography, not least when the correspondence between print and pronunciation is low, as in English (Castles et al., 2018; National Institute of Child Health and Human Development, 2000). The core of phonics teaching and intervention is the speech sound-orthography relation and additional content may embrace teaching about word structure, morphology, and semantics (Ehri & Flugman, 2017; Meeks et al., 2016).

Phonics is the overarching term for reading instruction that teaches students about the alphabet as a code, with phonemic awareness and sound-symbol correspondences training. In phonics the instruction is based on at least two strong predictors of reading, phonemic awareness, and letter knowledge (Melby-Lervåg et al., 2012). Rapid automatized naming, a third strong reading predictor, is seldomly applied as an element of instruction, but research indicate a predictive relationship between RAN and reading fluency (Furnes & Samuelsson, 2011).

Phonemic Awareness

Phonological awareness comprises the meta-analytical skills needed to analyze the sound structure of oral language and at its most advanced levels it includes phonemic awareness, PA, which refers to the ability to segment the individual sounds of a word and vice versa to blend sounds into words which is the core of spelling and reading (Schuele & Boudreau, 2008). PA, accompanied with letters, should be taught explicitly in reading instruction, as it forms the basis of understanding the alphabetic principle that spoken words consist of sound segments corresponding to orthographic symbols (Bradly & Bryant, 1983; Ehri et al., 2001a; Schuele & Boudreau, 2008). Rich empirical evidence shows that phonological awareness training (Bradley & Bryant, 1983; Lundberg, 2009), more precisely phonemic training combined with letter-sound knowledge, facilitate learning to read words and the relationship between PA and reading is reciprocal (e.g., Bus & van IJzendoorn, 1999; Hulme et al., 2012; Melby-Lervåg et al., 2012).

Phonics

The varying applications of phonics programs and what format is most effective have been investigated with no clear consensus. However, there seems to be more of a consensus about the core principles of instruction,

including phoneme-grapheme correspondence training and PA (Castles et al., 2018; Hall et al., 2023; McArthur et al., 2018). That phonics instruction is structured seems more important for outcomes, than whether training focuses on synthetic or analytic phonics processes (Ehri et al., 2001b). An example of reading with synthetic phonics is reading a word by segmenting each phoneme by its corresponding grapheme and then blending the sounds together to make up the whole word. The analytic phonics approach instead starts investigating the sound structure of words from a whole written word or segment, and thus, is less explicit about individual sound-symbol correspondences. Furthermore, control of which sound-symbol correspondences should be targeted in training is less controlled with an analytic approach (Castles et al., 2018).

Research indicates that phonics is beneficial also in less opaque orthographies (Saine et al., 2011; Solheim et al., 2018; Wolff, 2011). In Sweden, a few quasi-randomized and randomized controlled studies conducted in schools were built on explicitly teaching phonics to students with reading difficulties. In a second grade, one-on-one intervention (Levlin & Nakeva von Mentzer, 2020) and in a third grade program (Wolff, 2011), the interventions yielded strong to small effects favoring the intervention groups compared to controls. The Levlin and Nakeva von Meltzer study showed, compared to Wolff, strong effects on decoding, which they attributed to the focused intervention on decoding skills. Wolff conducted a multi-component study, also targeting reading comprehension. Both studies were non computerized, used teachers as implementers and spanned 30-48 lessons respectively. de Graaff et al. (2009) is another example of successful phonics training in a more transparent orthography. They trained Dutch kindergarteners in a brief phonics program, comparing a structured intervention to an unstructured one and teaching as usual. Both training groups improved on literacy measures compared to controls post intervention, but the systematized phonic approach outperformed both comparison groups.

Morphology Training

Teaching morphology as part of reading instruction has gained recognition as a linguistic and orthographic aspect of words that facilitates decoding (Goodwin & Ahn, 2013) and the relation seems to be reciprocal (Law & Ghesquière, 2017). Instruction in morphological patterns and identifying and manipulating morphemes seem to have a moderate to minor impact on word reading in early elementary students (Goodwin & Ahn, 2013; Hall et al., 2023). However, teaching about morphological aspects of words may not be done on a regular basis in

beginning reading instruction. Alatalo (2016) found in a survey of 269 Swedish K-3 teachers' content knowledge related to reading, spelling, and PA instruction that about 30% were unable to answer questions about the benefits for students to know compounds and root words. Alatalo (2016) concluded that teachers do not seem to teach this morphological knowledge.

Fluency Training

Repeated oral reading of connected text seems to be an effective instructional component for elementary students with reading disabilities, associated with improvements in accuracy, rate and comprehension (Chard et al., 2002). Some researchers suggest that repeated reading is as effective as non-repeated wide text reading in increasing fluency for elementary students at different reading levels (Ardoin et al., et al., 2016). For students who struggle at the word level, fluency intervention should be accompanied by systematic and explicit instruction in the alphabetic decoding principle, such as phonics to support the development of decoding accuracy, and not speed only (Hudson et al, 2008).

Spelling Instruction

Studies have found that integrating spelling in early literacy instruction is beneficial for students at risk of reading difficulties. It can be used to foster PA and understanding the alphabetic principle resulting in improved word reading and spelling (Møller et al., 2021; Santoro et al., 2006; Weiser & Mathes, 2011). The relationship seems reciprocal as phonics and phonological awareness interventions without spelling or writing instruction have only small to medium effect on students' spelling (Graham et al., 2018). Integrating spelling as a feature of phonics instruction comprises phoneme segmentation which directs attention to the grapho-phonemic patterns of the orthography, and phonics with spelling instruction in a transparent orthography seems to influence both word reading, pseudo word reading and spelling positively in children with reading difficulties (Treiman, 2018; van Rijthoven et al., 2021). Teaching transcription, which includes handwriting skills and spelling, shows a positive effect on writing quality in struggling writers at early elementary grades (Graham et al., 2012). An underlying logic is that fluency in spelling leaves room for the student to focus on text generation and compositional aspects of writing.

Early Mathematics Instruction

Early mathematics instruction focuses on whole number knowledge and operations, comprising elements of conceptual and procedural knowledge (Kilpatrick et al., 2001). Recommended practice encourages integration of these elements (Rittle-Johnson et al., 2015), and displaying different representations of number rather than separating, for example, number relations as practiced with concrete objects from symbolic representations in number combinations (Powell, Hughes et al., 2022). To build students' fluency with number combinations, researchers have found support for teaching conceptual understanding and to engage students in mathematics fact retrieval by memorization (Baroody et al., 2009; Östergren et al. 2023). Specifically, early numeracy skills have a long-time impact on subsequent mathematics development and therefore should include instruction of mathematical relations, counting and basic arithmetic (Aunio & Räsänen, 2016; Jordan et al., 2009; Jordan et al., 2010). Moreover, it seems beneficial to students' learning to organize arithmetic instruction according to a developmental progression grounded in the strategies children often employ and making them explicit (Clements et al., 2020).

Similar to the situation of early reading instruction, mathematics education research report of conflicting views of what should be the focus in teaching young student in mathematics (Lee & Anderson, 2013). In short, almost miming the reading war debate, there are strong proponents for focusing traditional mathematics instruction emphasizing content and procedures, while others emphasizing discovery, reflection and meaning (Schoenfeld, 2004).

Some 20 years ago, Baker et al. (2002) compiled the first meta-analysis of instruction for children with mathematics difficulties. Their review pointed to the fact that there were only 15 studies examining the extent and cause of difficulties and development for children struggling with learning early mathematics skills. Baker et al. (2002) concluded that there are “extremely small number of research studies on the broad topic of effective mathematics instruction for low-achieving students” (p. 63). Over the last 15 years, several syntheses and reviews have been released that aggregated the effects of instructional efforts for general ability students and students who struggle with foundational mathematics (Chodura et al., 2015; Dennis et al., 2016; Gersten et al., 2009; Mononen et al., 2014; Nelson & McMaster, 2019; Reynvoet et al., 2021), all confirming the positive impact of explicit and conceptual based instruction. This research also suggests that intervention programs in yearly grades should target number knowledge, operations and word problem solving with intensity and span up to a whole school year

(Bryant et al., 2008). Next, I will address crucial aspects of contents and approaches for early school-based interventions for young students at-risk for early reading and mathematics difficulties.

Instructional Features of Special Education Interventions

Effective Instruction

An explicit instructional approach has been applied in many intervention studies in reading and mathematics because of its perceived benefit for student learning (e.g., Gersten et al., 2009). Defined by Huges et al. (2017) as comprising of five key instructional elements, explicit instruction represents an overarching theme for a set of effective instructional practices in special education. These practices are in turn segmenting complex tasks, giving clear teacher demonstrations or presentations of skills, guiding and scaffolding student's practice, providing practice opportunities with teacher feedback and offering rich opportunities for the student to respond and receive teacher feedback (Hughes et al., 2017). Teaching with clear presentations of content and procedures is a valuable practice for teaching mathematics to young children in general, often realized by use of manipulatives and different visuals to concretize number representations and strengthen conceptual knowledge (Doabler et al., 2015). Specifically, an explicit instructional approach benefits students with mathematics disability and is a recommended practice for students with or at-risk for mathematics difficulties (Bryant et al., 2008; Gersten, Fuchs et al., 2005; Gersten et al., 2009). Correspondingly, a clear presentation of content and procedures is known to benefit reading and spelling instruction in poor readers and writers (e.g., Fletcher et al., 2021; Graham et al., 2002; Moates, 2009; Rupley, 2009). When teaching word decoding and recognition, explicit and systematized teaching has been recommended the best instructional model for students at risk of reading difficulties (e.g., National Institute of Child Health and Human Development , 2000). Systematic, referring to a clear and sequential instructional sequence, is also part of an explicit instructional approach (Hughes et al., 2017).

Today, explicit instruction and direct instructions are terms used partly interchangeably (Hughes et al., 2017; McMullen & Madeleine, 2014). However originally, direct instruction referred to instructional principles of U.S. academic curriculum programs developed in the 1960s, which emphasized the importance of teaching to mastery by addressing subskills in a predetermined sequence and monitoring

students' progress (Gersten, 1985; McMullen & Madelaine, 2014). These methods have been found effective for teaching varying student populations and skills in mathematics, reading and spelling and to a substantial degree, the principles of direct instruction and explicit instruction overlap, even though explicit instruction does not per se imply the scripted lesson plans used in direct instruction curricula (Hughes et al., 2017; Stockard et al., 2018). Roos and Bagger (2022) studied how explicit instruction described in the mathematics special education literature relates to the Swedish mathematics curriculum and found features of explicit instruction such as providing systematic instruction and scaffolding by modelling and using different representation compatible with realizing the goals of the curriculum.

Intensity

To better understand how early reading and mathematics intervention programs work to improve learning the aspect of intensity has gained some focus. The assumption being that intensity may alter the impact of instruction. High intensity is assumed to promote change in students' learning and should be based on previous response to instruction. It is argued that intensive instruction should be provided when children do not respond to regular instruction in mathematics or reading (Harn et al. 2008). Still, evidence of how to best define and use intensity dimensions in interventions is lacking (Coddling & Lane, 2015; DeFouw et al., 2019; Vaughn et al., 2010).

Intensity, however, is far from a unitary construct in the intervention literature. Definitions of intensity aspects are extended length of intervention, increased or deepened practicing opportunities within sessions or added components, reduced group size, individually adjusted learning content, the phasing of training and the frequency of delivery (Vaughn et al., 2010; Yoder & Woynaroski, 2015). Duhon et al. (2009) showed that quantification of intensity in an intervention is a delicate matter because intervention components are often added to intensify the program and altering or adding one component may imply different interactions among program components making it difficult to evaluate effects on students' outcomes. Increasing the frequency rather than altering components should provide a more methodologically stringent approach to evaluate and generalize benefits of intensification (Duhon et al., 2009). Politics, educational policy, and practice seem to drive the use of, or indeed, the lack of intensive educational efforts, meaning intensity levels of instruction in school interventions may be chosen based on other purposes than what has been evidenced as effective early reading and mathematics special education practices

(Fuchs & Fuchs, 2015). In short, the severity of difficulties should be decisive in determining program intensity (Vaughn et al., 2010).

Group Size

The mathematics and reading intervention literature is also ambiguous of the optimal group size, when providing extra support to young students. Jitendra et al. (2021) in a meta-analysis found that the effect of small group tutoring was superior to one-to-one instruction in supplemental mathematics interventions, while a mathematics intervention meta-analysis for preschool to first grade students at risk for mathematics difficulties found equal effects for small-group and one-to-one instruction (Nelson & McMaster, 2019). Dietrichson et al. (2021) similarly found no significant difference in effectiveness between small-group and one-to-one format in their meta-analysis of reading and mathematics interventions. However, their review was unable to correlate student characteristics with group size and hypothesized that the severity of difficulties may be related to the effect of instructional group size. Chodura et al. (2015) found individual mathematics intervention effective and superior to group settings in at-risk students. Vaughn et al. (2003) attempted to investigate the impact of group size in a reading intervention and found one-to-one reading instruction comparable to small groups of three students when keeping type and length of intervention equal. Some meta-analyses of reading intervention studies support both one-teacher-one student format and small group settings (Gersten et al., 2020; Wanzek et al, 2018). Tutoring one student at a time, provides a chance to closely monitor how the student understands and adopt concepts and procedures and a closer relationship between student and tutor is suggested to be an additional benefit of the format (Chodura et al., 2015).

Content Principles in Phonics Interventions

The purpose of using decodable texts in beginning reading phonics instruction is to support students' practicing of trained grapheme-phoneme correspondences, because it offers a chance to read phoneme-grapheme regular words by application of phonics skills (Mesmer, 2000). Research has, however, not confirmed the superiority of decodable text over less decodable. Instead, findings suggest that phonics instruction and ample opportunities to read texts may be more important than the level of decodability in supplemental programs for young children at risk for reading difficulties (Jenkins et al., 2004). Still, many phonics programs in English orthography include reading decodable text as it provides opportunities to practice learned phoneme-

grapheme correspondences at the students' ability level (National Institute of Child Health and Human Development, 2000). In relation to reading comprehension, texts containing a high degree of words that the reader can decode with automaticity may facilitate comprehension (LaBerge & Samuels, 1974).

Content Principles in Early Mathematics Interventions

Teaching students about varying representations of number is part of early mathematics instruction and a required knowledge for the child that enables the transition from informal number sense to formal knowledge and operations (von Aster & Shalev, 2007). Instruction can facilitate the process by using artifacts representing number with varying degrees of abstraction. Specifically, the sequence of using concrete manipulatives such as cubes, moving to a representational level by using visuals, dots etc. and reaching an abstract level represented by numbers supports the conceptual understanding of number and can be utilized to demonstrate procedural competency for young students (Carbonneau et al., 2013; Doabler & Fein, 2013; Witzel & Allsopp, 2007).

Impact of Early Reading and Mathematics Interventions

Effect Studies in Foundational Reading

Meta-analytical research syntheses provide a platform for information about the impact of instructional programs for specified groups, types of instruction, instructional domains, and not least aggregated effects of different intervention approaches. For this thesis, syntheses and reviews of intervention studies including children with or at risk for reading difficulties have been consulted. The intervention syntheses below are representative of interventions conducted in English as there are no compilations of intervention study effects made in the Scandinavian orthographies (Swedish, Norwegian). Several reviews have been released in the last decade (Gersten et al., 2020 Hall et al., 2023; Neitzel et al., 2022; Wanzek, 2016, 2018) addressing children with varying levels of reading difficulties with some including other language than English and some including participants with early difficulties. Most of the reviews define at-risk status as students scoring below a cut-off limit on mathematics or reading measures. However, some included studies refer to at-risk for academic difficulties in terms of low socio-economic status, as displayed below.

Hall et al. (2023) conducted a meta-analysis with the aim to clarify the effects of reading intervention for children in grades K-5, with or at risk of dyslexia, including studies with a stringent sample criteria and study designs restricted to treatment-comparison designs or quasi-experiments. A mean overall effect of .33 (*g*) was reported. The intervention content in this analysis was foundational skills targeting word reading, spelling, text reading, phonics, and PA. Students at or below the 25th percentile on a norm-referenced test measuring word reading, spelling or abilities considered foundational to reading and spelling were included. In all, the analysis included 52 studies. The authors specifically investigated if and to what extent the impact of intervention was moderated by student characteristics or intervention features. They found that dosage and spelling as a component of instruction, significantly and positively moderated intervention effects. Interventions including word reading and spelling presented a larger effect .37 (*g*) compared to interventions without spelling .23 (*g*). The studies varied widely in range, (9-160 hours, mean 55.19 h) and the moderator analysis indicated an increase in effect of intervention of .002 (β) by each additional hour of instruction. Also, interventions that used reading and/or spelling outcome measures yielded higher effects than those measuring reading comprehension. Grade was not a significant moderator. Notably, this meta-analysis only included studies that reported outcomes from standardized outcome measures.

Wanzek et al. (2018) extended and updated a meta-analysis of intensive literacy interventions targeting young students with or at risk for reading difficulties (see Wanzek et al., 2016). The study included 25 original studies with participants in grades K-3 and presented an overall mean effect size of .39 (*g*). Included study designs were treatment-comparison or multiple treatment studies. At-risk status included students with language disorders and weak phonemic awareness. The interventions focused on PA, phonics, fluency, reading comprehension, writing, and spelling. As the authors attempted to evaluate the moderating effects of dosage and group size on intervention effectiveness, some moderator analyses were conducted. They showed no significant difference between small group size .33 (*g*) and one-to-one instruction, however effect sizes favored the one-to-one format .59 (*g*). The authors highlighted the need for more studies of intensive interventions in second and third grade as most studies included were conducted in K-1.

Denton et al. (2022) conducted a meta-analysis targeting the effects of early grade reading interventions on reading comprehension in grade K-3 (of which 8 were kindergarten studies). The study included 47 quasi-experimental and experimental studies. Student with identified

reading disabilities, difficulties or considered low achieving were included with no specified cut-off limit for scores on reading measures applied. The main overall effect size on reading comprehension was .37 (*g*) and included studies represented interventions of foundational literacy skills with or without a reading comprehension component. Moreover, the meta-analysis aimed at investigating variables that had a moderating effect on intervention outcomes. Here, no difference was found in the effect on reading comprehension between multicomponent interventions and those interventions targeting single foundational reading skills. This result indicated that interventions focusing on basic reading skills, even without specifically targeting reading comprehension aid the development of comprehension in young students.

In a meta-analysis, Gersten et al. (2020) targeted reading interventions for at risk students in grades 1-3 and found evidence of effectiveness for beginning reading interventions of foundational skills rather than pre-reading or later reading competency that can arise with a wider inclusion of grades. Thirty-three studies, with RCTs (30) and quasi-experimental designs were included. Students identified as at risk or scoring below the 40th percentile on a standardized test were included. The outcomes evaluated comprised word- and pseudo word reading, reading comprehension, and reading fluency. The overall estimated effect was .39 (*g*). This meta-analysis also investigated study and intervention characteristics as moderators (such as instructional content, the duration, or the study design) of the mean intervention effect. They found the inclusion of encoding and writing instruction significantly and positively moderated intervention effects. Also, effects were larger for one-on-one instruction than small group but only in first grade students.

To summarize, meta-analyses of reading interventions incorporate studies of varying study- and participant characteristics, different and overlapping content areas, as well as different outcome measures. A common factor is evidence of medium impact on reading, reading comprehension and spelling from early grades' interventions targeting foundational skills in children with or at risk for reading difficulties. Moreover, the analyses point out the impact on overall effects of intervention features that relates to organization and implementation of interventions.

Effect Studies in Foundational Mathematics

Meta-analyses of effective mathematics interventions have included students with mathematics difficulties based on different criteria and the foci have been broad or narrow regarding operationalization of

difficulties and the outcome measures used (Chodura et al., 2015; Dennis et al., 2016; Gersten et al., 2009; Lein et al., 2020; Nelson & McMaster, 2019). Consulting relevant meta-analyses about instructional features and moderating effects on intervention outcomes was part of the preparation for the present study's mathematics intervention.

Nelson and McMaster (2019) reviewed interventions in numeracy in typically developing, at-risk students and students with identified mathematics disability from preschool to first grade. At-risk for MD was defined in the included studies based on low-achievement or low socio-economic status, (SES). Most studies applied a random assignment to conditions. The interventions targeted early numeracy content and skills in the domains number, relations and operations and outcome were measured with comprehensive or narrow mathematics measures assessing aspects of early numeracy. The analysis included 34 studies and generated an average effect of .64. (*g*). Authors evaluated variations in the overall mean intervention effect in relation to study and intervention characteristics. Results showed that grade significantly moderated outcome effect, presenting larger effects for kindergarten students .74 than for first grade students .31. Also, studies providing one-to-one instruction yielded a slightly lower effect of 0.65 compared to small group settings of .76. A negative treatment effect was found for interventions lasting longer than 8 weeks which was interpreted as a sign of catch-up from controls, who may be learning the same content as taught in the intervention group. In terms of target for the intervention the study found moderate effects for the domains number, relations, and operations (.61-.68). Number included for example practicing counting, subitizing and cardinality while relations included ordinal number skills and number line estimation and the domain operations entailed composing and decomposing skills.

Lein et al. (2020) presented a meta-analysis of interventions in word problem solving that included students in grades K-12 with identified learning disabilities and mathematics difficulties (one third were 3rd grade students). Their main purpose was to inform school practitioners of effective practices. In all, the analysis included 31 studies with quasi-experimental or randomized controlled designs. The criteria for coding study participants as having an MD were scoring at or below the 35th percentile on a standardized mathematics test. The mean overall effect reported was .56 (*g*). Most of the included studies targeted word problems with whole number addition, subtraction, multiplication, and division and outcome measures included a word problem measure. Moderator analyses were conducted to assess how study characteristics affected overall intervention outcome. Among other variables, grade level and who implemented the intervention were significant moderators

with a medium effect for interventions in elementary grades .63 compared to secondary grades .33, and medium effect .76, for school staff and researchers together compared to implementation by school personnel only of .28 (*g*). Interventions framed as schema-based instruction with teaching for transfer of skills had a strong moderating effect 1.06 (*g*), in relation to overall word-problem outcome. MD type, dosage and one-to-one or small group did not moderate effect on outcomes, suggesting the interventions reviewed were equally effective exclusive of students' mathematics status, number of hours and group size.

In their meta-analysis of effective mathematics interventions Chodura et al. (2015) included 35 studies of elementary grade students with a pre-test, post-test, and control group design. They applied a percentile 25 cut-off on a standardized mathematics test as inclusion criterium. The analysis included students with or at risk for MD or a diagnosed LD. The interventions targeted basic numerical competencies, basic arithmetic, problem solving, and outcomes were general measures of mathematics achievement. They found an overall strong effect of .83 (*g*). A subgroup analysis found significant effects for students labelled at-risk who received direct instruction and were taught in one-to-one setting. Also, medium to strong effects were found for the different competencies addressed by the interventions. The authors commented on the lack of explicit description of the intervention duration, the overall variability among the approaches and targets of included studies, warranting cautious interpretation of effects. They also highlighted the lack of longitudinal studies, making it impossible to perform meta-analysis on the long-term effects of mathematics interventions.

Dennis et al. (2016) performed a meta-analysis targeting interventions directed to students with or at risk for mathematics difficulties and showed an overall mean effect of .53 (*g*) across intervention studies evaluating different mathematics outcome such as problem solving and computation. Their purpose was to extend previous syntheses by including more moderator variables to better understand what modified intervention impact. The analysis included 25 quasi-experimental and randomized controlled trials with participants in kindergarten and elementary grades. MD status varied in the included studies, but an inclusion criterion was that MD status was explicitly described. Specifically, for students identified by a cut-off on mathematics tests at or below percentile 10-25, the intervention studies included showed a medium effect. Also, grade moderated intervention impact with elementary school interventions yielding a medium effect of .57 compared with a small effect of .30 in kindergarten. The overall intervention outcome was further moderated by who implemented

training with small effects of .27 for teachers. When the interventionist was a researcher, the effect was strong .81. In terms of group size, small groups and one-to-one instruction were in the range of medium effects with .70 and .47, respectively. The study evaluated the effect of teaching domain and instructional approach and found many studies (18) using an explicit, teacher led approach and most studies targeting basic mathematics facts, computation or early numeracy with effects spanning .47-75. When assessing isolated instructional components, a strong effect was found for one-on-one format, reinforcing, practice and task elaboration.

In sum, the meta-analyses above cover a range of mathematics interventions with the purpose of preventing or remediating mathematics difficulties. While the findings are not fully consistent on features such as grouping, interventionists or timing of the intervention across reviews, there is consensus in reports of medium overall effects for early interventions in foundational skills and word problem solving for students with or at risk for mathematics difficulties. Interventions implemented by researchers seem to yield larger effects than with other interventionists and early grades intervention appears more effective than intervening in later grades.

Context of the Study

The following paragraphs give some insight into reading and mathematics general instruction in Swedish elementary grades, and organization of special education.

The Swedish Context – Reading Instruction

Since 2018 preschool class is compulsory for Swedish 6-year-olds with a curriculum emphasizing that students should learn pre-reading literacy skills including getting familiar with the alphabet, developing phonological awareness, listening to, and engaging with text (National Agency for Education, 2022b). Thus, students are expected to enter first grade equipped with some degree of literacy knowledge and prepared for further reading and writing instruction. A recent Swedish classroom observational study indicated however, that first grade literacy instruction seems to contain more of the same content taught in preschool class, which might provide students with less than adequate challenges and opportunities for progression (Aminoff, 2021). While children differ in their pre-reading abilities and reading skills at school entry, the Swedish orthography offers a relatively transparent link between letters and sounds, which facilitates quick adoption of the

alphabetic principle and benefits learning to read simple words already during the first semester (Seymour et al., 2003).

First grade reading instruction in Sweden typically includes a strong focus on learning the alphabetic symbols and their corresponding speech sounds, as common in transparent orthographies (Aro, 2005). There are no mandatory curriculum guidelines advocating phonics as the primary strategy in beginning reading instruction (Swedish National Agency for Education, 2022b). Instead, balanced reading is recommended practice based on a Swedish systematic review of reading and writing instruction, comprising both PA, decoding, linguistic comprehension, spelling, vocabulary and reading comprehension (Taube et al., 2015), echoing the recommended areas of reading instruction from the U.S. National Reading Panel systematic review (National Institute of Child Health and Human Development, 2000). A balanced approach to reading instruction, meaning time is divided between decoding, language, and meaning-making literacy activities, is widely applied in Swedish classrooms (Alatalo, 2011). Students are generally placed in self-contained classrooms served by the same primary school teacher teaching most subjects throughout early elementary (grades 1 to 3 in Sweden). Hence, teachers follow the progression of their students' learning over the first three school years.

The Swedish Context - Mathematics Instruction

Mathematics instruction, like reading, is governed by the national curriculum and the syllabus with a central content area focusing number and procedures. In pre-school class, instruction is aimed at bridging informal and formal mathematics by focusing on students' curiosity for mathematics and providing encounters with mathematics concepts and problem solving. In first to third grades number knowledge, relations, operations, the base 10 system, decomposition of numbers, and arithmetic represent parts of the teaching content (Swedish National Agency for Education, 2022b).

Researchers have demonstrated a high reliance on mathematics textbooks in Swedish elementary instruction and the role of teaching seems to emphasize facilitating student's engagement with the book. Analysis of some of first grade mathematics books used in Swedish schools revealed salient differences in what early numeracy content was displayed and different proportions of procedural vs. conceptual focus as well as integration of procedural and conceptual knowledge in tasks (Sayers et al., 2021). It also appears from teacher interviews that teachers are more engaged in taking on a student-responsive approach to be able to understand students' perceptions and mathematics thinking than of a

teacher-led approach with specific instructional methods (Hemmi & Ryve, 2015; Van Steenbrugge & Ryve, 2018).

Organization of Special Education Instruction in Reading and Mathematics

Some factors related to student characteristics, instructional approaches and the organization of support are relevant in intervention studies as they may be decisive of what support works for whom, under certain circumstances or in different environments. This paragraph highlights how students' performance is analyzed to identify reading and mathematics difficulties, and what instruction can be in special education

The foundational view on students' cognitive development and learning has implications for the construction of educational support and didactic approaches (Odom, 2016). Special education services in Sweden operate under standards set by national agencies and policy documents. However, the autonomy of the teaching professional concerning teaching methods is extensive. Teachers and communities operate in different educational traditions, which may affect how the curriculum is implemented in practice. On an overall level, a tradition of didactics seems strong in Northern Europe while a curriculum tradition dominates in the Anglo-American school context. The main differences, simplified, lies in the teacher's autonomy and authority to create meaningful learning activities guided by the knowledge of didactic theories in the former tradition, and in the latter that teachers are more engaged in setting and evaluation goals for student's achievement based on policy standards (Werler & Tahirsylaj, 2022).

According to the Swedish education act and the current national curriculum for compulsory school (SFS, 2010:800; Swedish National Agency for Education, 2022b), students who show difficulties reaching learning goals should be offered timely support. From 2022, a newly updated curriculum the Lgr 2022 (Swedish National Agency for Education, 2022b) governs compulsory education. Swedish school agencies neither apply prespecified targets that certain groups of students with academic difficulties should strive for, nor use national academic tests to single out the achievements of these groups (cf., Schulte & Stevens, 2015 for a US perspective), but students' achievements are monitored from the start of schooling. National assessments of early mathematics and reading are mandatory in first grade since 2016 and in preschool class since 2019 (SFS, 2010:800) as a governmental effort to prevent early academic failure. A recent teacher evaluation of the implementation, however, stated that a slim majority

found these assessments helpful in identifying students who need extra or special support to develop their skills (Swedish National Agency for Education, 2021), and the reading assessment has been criticized for not investigating decoding sufficiently (Rådström-Drougge, 2019).

In Sweden, teachers who provide special education instruction have different professional background and expertise (e.g., special education teachers with various specializations, special education needs coordinators, speech and language therapists, teaching assistants, classroom teachers) owing to legislation that states the obligatoriness of schools to provide non-specified special education competency (SFS, 2010:800). In practice the special education teacher has great autonomy in designing the teaching of students on their caseload (Lutz, 2013). While research informed teaching is prescribed in the curriculum (Swedish National Agency for Education, 2022b), it does not guarantee that educators fully adopt the procedures and curricular material evaluated in educational research studies of instructional effectiveness, but instead make instructional decisions based on experience and personal beliefs (Cook & Cook, 2011). Special education teachers find support for specific instructional methods and practices through a wide collection of sources ranging from authority, teacher education, professional development to social professional forums (Guckert et al., 2016; Mesmer & Kambach, 2022; Travers, 2017), and thus encounter claims of evidence-based practices supported by varying, and incidentally with no information of research quality. Also, instructional strategies in special education are eclectic by nature, with influences from different sets of learning theories that are not always overt to the individual teacher (Odom, 2016).

Obstacles to efficient special education can be identified at different organizational levels of the school organization. At the classroom level, resources and teacher competency are decisive in the quality of special education (Alatalo, 2011). Swedish general and special education instruction in mathematics and reading are delivered with a high degree of freedom for teachers to realize the curriculum (Roos & Bagger, 2022) and little research has been carried out that expands upon special education practices (Eriksson Gustavsson & Samuelsson, 2007). Investigations of how content and procedures of Swedish mathematics special education is enacted through dialogues with students, indicate that special education teachers alter between an inventory approach to students' knowledge and an orientating approach pointing out specific knowledge and procedures to be learned (Eriksson Gustavsson & Samuelsson, 2007). Next paragraph describes an organization for providing student support, the Response to Intervention framework.

Response to Intervention

Since the past two decades reading and mathematics intervention studies conducted in elementary schools are commonly organized within the response to intervention (RTI) framework, most frequently reported in North American research studies (e.g., Gersten et al., 2008; Jimerson et al., 2007). The overall aim of the framework is to organize school support to meet students' educational needs and ultimately to prevent school failure. Moreover, RTI is used to identify learning difficulties. Goals within RTI are linked to curricular standards and national policy documents. An important feature of the framework relates to data-based decision making using universal screenings of all students' performance (Lembke et al., 2012). In practice, RTI represents three or more tiers meaning levels of support created to identify, prevent, and remediate academic difficulties (Jimerson et al., 2007).

At Tier 1, the universal level, the school provides evidence-based teaching to all students, as the primary mean to avoid academic difficulties is qualitative, general classroom instruction. Continuous progress monitoring is implemented to keep track of students' performance. The second Tier supports students who risk falling behind despite Tier 1 instruction. Intervention effectiveness is typically evaluated through Curriculum-Based Measures (CBM), brief standardized checks of word reading, computation or conceptual understanding that are used to decide whether students respond as expected based on set benchmarks or criteria (Lembke et al., 2012).

The main difference between intervention in the second and third Tiers lies in the degree of intensity and differentiation (Stentiford et al., 2018). Intensified, individualized, small-group or individual tutoring delivered by qualified teachers are common features of support at Tier 3. However, the contributions of specific features at this tier are less well researched than for Tier 2 interventions (Al Otaiba et al., 2016; Gersten et al., 2009; Stentiford et al., 2018). In contrast, Tier 2 mostly adopts standardized protocols of evidence-based interventions in small-group settings (Nilvius et al., 2021). Some studies suggest increased intensity to be the driving force of success of Tier 2 interventions compared to Tier 1 (Coyne et al., 2018). Al Otaiba, et al. (2014) suggested directing first graders at risk of reading difficulties to intensified intervention within RTI is contrary to the wait-to-fail approach. Moving straight from Tier 1 to intensive Tier 3 seems to accelerate student learning and is supported from the perspective of offering students opportunities to catch up with grade-level peers (Al Otaiba et al., 2014; Vaughn et al., 2010). Research confirms that Tier 2 mathematics interventions delivered to elementary students span on average 10 weeks with 3 to 5 sessions per week

(DeFouw et al., 2019) and the majority has a duration of up to 20 hours (Jitendra et al., 2021). In contrast Tier 2 reading interventions typically last between 8 to 24 weeks (Vaughn et al., 2010).

Swedish elementary school is not required to monitor progress according to RTI, nor deliver special education support in a tiered fashion. However, supplemental special education support arrangements usually follow a two staged sequence of intensified efforts. The main difference between levels is the extent and durability of the support, where students who require more support get their needs documented and followed-up in an individual education plan (Swedish National Agency for Education, 2022c). At present there are some reading and mathematics educational research initiatives utilizing and presenting benefits of the RTI model also in Scandinavia and more specifically, in Sweden (Andersson et al., 2019; Björn et al., 2018; Nilvius, 2022). This thesis presents findings from two interventions that were organized similar to Tier 2 with scripted lesson plans and designated materials, but with an intensive and one-on-one delivery common in Tier 3 settings.

Methodology and Evaluation

Evidence-Based Practices

An educational intervention or strategy earns the label evidence-based practice (EBP) when it is supported by empirical research studies conducted with a rigorous design that points to meaningful effects on educational outcomes and is evaluated against some framework of quality indicators (e.g., Gersten, Jordan et al., 2005). Different from EBPs, the wider term research-based practices include those supported by noncausality claiming designs, without criteria for certain effects and based on a single study's results (Cook & Cook, 2011). Furthermore, the evidence-based practices in special education can be identified as macro EBPs that comprise of curricula and certain implementation restrictions that users should adhere to. Alternatively, they can be identified as micro EBPs which are specified practices or strategies that teachers can implement more liberally (Cook & Cook, 2011; Nelson et al., 2021).

Critiques against the concept of evidence-based practice argue that one size does not fit all, suggesting an oversimplified belief in streamlined interventions. A primary concern is that using an EBP may not lead to success for everyone, and they may be complicated to implement in the school context (Cook & Cook, 2011). Self-reported data from teachers on what factors sustain the use of educational EBPs suggested that teachers are most prone to use interventions which they

judged had a positive impact on academic outcomes and that are easy to implement (Daniel & Lemons, 2018). The prior professional experiences of the individual teacher might also impact the inclination to adopt an EBP and intervention up-take in school settings seems to be supported by close collaboration between researchers and school staff (Daniel & Lemons, 2018; Gersten et al., 2000).

Gersten et al. (2000) pointed to two concepts that can be seen as a lens through which sustainability of new innovations, that is EBPs, in schools should be viewed and understood. On the one hand, a new practice can be defined as structural which concerns environmental or material aspects of teaching. On the other hand, a practice can be defined as a core-of-teaching practice changing what goes on in the classroom. The core of teaching innovations may conflict with teacher autonomy, and therefore, it is important to focus on teachers' knowledge, beliefs, and inclination to change as well as providing professional development about the new practice (Gersten et al., 2000).

As mentioned above, EBPs are the result of high-quality research evaluations of effectiveness (Cook & Cook, 2011). The next section describes a related subject, randomized controlled trials, which was applied to design the intervention studies in this thesis.

RCT Methodology in Educational Research

Using a randomized controlled research design is a comparatively new practice in educational research, spanning some 60 years, with an increase in published studies during the past couple of decades (Odom, 2021; Pontoppidan et al., 2018; Styles & Torgerson, 2018). Often denominated the 'gold standard' of experimental designs (Shadish et al., 2002), RCTs are fundamental to the field of evidence-based practices in education and have gained influence in educational research and practice by governmental and policy incitements and reforms such as the establishment of national educational clearinghouses that evaluate and disseminate evidence-based labelled research (Odom, 2021). Here, evidence-based by Cook's and Cook's definition (2011), means practices that are supported by replicated studies of high methodological quality and designs that show prescribed effect levels.

The main principles of randomization methodology in intervention research rest in creating equivalent groups of participants pre-intervention (for example groups with similar decoding levels), randomly assigning participants to different conditions and then to introduce an intervention under controlled conditions (e.g., practicing word decoding). By assessing all participants on predetermined outcome variables (e.g., reading accuracy) and keeping all other factors constant,

the group who received intervention can be compared to the group who did not (controls) post-intervention and because of randomization causal conclusions can be drawn about intervention effectiveness (Shadish et al., 2002). Contrary to correlational designs, which has been frequently used in the field of educational research to uncover relationships between interventions and academic outcomes, the randomization to conditions inherently does not depend on finding the right control variables to justify non-random selection of participants (Watts et al., 2019).

A widely aired criticism against RCT research designs in education is that the outcome of such research, when used to label practices evidence-based, may not be applicable in practice because of students' variability that calls for individualized and tailored support, whilst an RCT transmits average group estimates of the effects of instruction (Shadish et al., 2002). Relying on such research designs to inform educational practice has been considered instrumental and a response to policy calls for effective, accountable instruction that may ultimately become a threat to teachers' autonomy of instructional decision making (Biesta, 2010; Hammersley, 2005). Also, implementation of RCTs in school environments, contrary to controlled research or laboratory settings, seems complicated and at conflict with needs to adapt to local contexts and it reduces the generalizability of findings (Maggin, 2022; Odom, 2021).

Fidelity

A factor important to the evaluation of RCT studies' outcomes is fidelity aspects to ensure implementation adhered to the planned intervention (Odom, 2021). There is treatment fidelity, for example carrying out an intervention in accordance with the program plan and there is implementation fidelity, which addresses the steps taken to ensure the process of implementation adheres to a plan, involves necessary stakeholders is well documented and can be evaluated (Durlak, 2010; Fixsen et al., 2005).

Researchers frequently report on theoretically and experienced obstacles to implementing interventions in real life context (Harn et al., 2013; Wheldall et al., 2020). In these cases, the organized support from researchers seem to facilitate implementation (Fixsen et al., 2005) and may positively influence the outcome of an intervention for participating students (Owen et al., 2021). Fidelity data are, however, not routinely reported in special education research and few studies use data on treatment fidelity to analyze the effects of interventions (Capin et al., 2017; O'Donnell, 2008). Reports of treatment fidelity facilitate study replication and is considered a quality indicator of experimental special

education research (Capin et al., 2017; Gersten, Jordan et al., 2005). Measuring fidelity of an intervention also supports interpretation of its effect and can be done by qualitative measures such as observations or quantitatively by a study protocol or statistical evaluations of relations between implementation factors and study outcomes (Capin et al., 2017; Harn et al., 2013). The importance of long-term evaluations and sustainability of interventions will be outlined next.

Follow-Up of Intervention Studies

Educational intervention research emphasizes the importance of providing systematic and explicit training to children considered at-risk for reading and mathematics difficulties in early school years. This is because low initial reading and mathematics performance is associated with subsequent individual negative learning trajectories (Aunola et al., 2004; Jordan et al., 2009; Koponen et al., 2018; Nelson & Powell, 2018; Landerl & Wimmer, 2008; Snow et al., 1998). Few reading and mathematics educational intervention studies with a randomized controlled design are longitudinal, and thus, it is difficult to value the programs' long-term impact on student achievement (Watts et al., 2019). Some studies are designed to follow-up on interventions with a longer time interval after completing an intervention, but the time frame is commonly set to less than a year in mathematics and reading studies (Powell, Berry et al., 2022; Suggate, 2016; Xin & Jitendra, 1999). Ideally, these studies should track students' development over several school years to investigate individual and group changes and moderating factors (Bailey, 2019; Vadasy et al., 2008).

For children in elementary grades, the period between post-test and follow-up implies new learning encounters, cognitive development as well as socio-environmental changes which might impact learning (Bailey, 2019; Lemons et al., 2014). Therefore, an investigation of the long-term effects and potential transfer of skills at delayed post-test may illuminate the effectiveness of the programs in school-settings. Keeping the advantages made on specific skills as a result of intervention seems to be difficult, as follow-up studies report that the impact of training fade-out over time (Bailey et al, 2017). This has been documented from reading programs (Suggate, 2016) and mathematics programs (Bailey et al., 2020; Hassler-Hallstedt et al., 2018). Results are mixed though, with reports of sustained effects after or exceeding one year reported in reading studies (Blachmann, 2004, 2014; Wolff, 2011).

In search of explanations and solutions to the decline, Bailey et al. (2019) listed potential causes: inappropriate test-scaling was unable to capture sustained effects, cognitive processing may be overloaded so that extensive repetition hindered integration of new subject content after the

intervention, forgetting may result in restricted effects at follow-up, peer caught up to students in intervention because of similarities between regular teaching and the supplemental support; there was insufficient support after the intervention to sustain what was learned or the fade-out could result from a combination of these sources. A few examples can illustrate the different tactics applied in follow-up studies and exemplify the diversity of maintenance efforts:

Nelson et al. (2018) designed an experiment that evaluated the effects of providing K-3 grade students with extra practice as they ended a Tier 2 phonics and fluency intervention, to boost maintenance of effects. They randomized participants to a treatment or control group and administered very brief (1-minute) weekly sessions for the rest of the school year. The material used was equal to regular curriculum-based measures that measured the number of correctly read words per minute. Results were compared to a spring semester benchmark during the same academic year. Irrespective of grade, they found a stronger relation between post-exit reading monitoring and end of term achievement, compared to a control group that did not receive this support. Authors attributed the benefits of ongoing support to maintaining feedback from teachers and pointed out that it was not an intervention per se, only providing opportunity to continue reading with a tutor at a reached reading level. In a randomized controlled trial involving third graders with mathematics difficulties,

Powell, Berry et al. (2022) tried a word-problem intervention under two conditions, one intervention group received a “standard protocol” and the other an enhanced protocol with a pre algebraic component, while one control group had teaching as usual. The program spanned 16 weeks with one-on-one sessions. Participants were pre- and post-tested and had the follow-up assessment 6-12 months after the training ended. Importantly, the regular classroom condition did not include the content delivered in the intervention. At follow-up significant effects maintained favoring the enhanced program group for the core outcome of the intervention, which was word problems. The researchers discussed the importance of tailoring training program to include malleable components, with potential to leverage students’ learning in the future and not easily learned within the regular classroom instruction.

Lopez-Pedersen et al. (2023) implemented a numeracy intervention in first graders at risk for MD. After an initial 8-week training program in small groups, students received booster sessions once a week for six weeks to prevent fading effects. Analyses indicated that the extra training was unsuccessful in keeping effects from the

intervention. Notably, at post-test, students in this RCT study outperformed controls only on a measure of problem solving.

Method

Procedures

Data collection comprised screening measures (5 timepoints), extended testing, that is, pre-test, posttest, and follow-up tests (3 timepoints) over a 2-year period. A brief interventionist questionnaire (1 timepoint), an intervention protocol and a progress monitoring measure for reading and arithmetic calculation (36 timepoints). All data were collected at the participants' schools by classroom teachers (screenings) and special education staff (the extended testing). The special education teachers carried out the 36 lessons which were supplemental to reading and mathematics instruction, not a replacement for these subjects. The author of the thesis conducted both intervention programs with some of the students at three schools (3 reading and 3 math) and conducted the extended testing with three participants.

To test lesson outlines, instructional materials, timing and to get a sense of how students would respond to the reading program, a pilot (unpublished) was conducted in the fall of 2019. The main parts and number of lessons in the program were delivered by the present author. The pilot testing included five students from two second grade classes identified by their special education teacher as weak in reading, based on local annual reading screenings. Adaptations of the lesson phasing was made because of the trial and the number of instructional segments per lesson were reduced. The mathematics program was not piloted as the present author was coached by a mathematics teacher educator at the Department of learning and behavioral sciences, Linköping university in adapting the mathematics lessons to the present study. Also, the mathematics program had been evaluated in a kindergarten study by that same teacher (Westerholm & Samuelsson, 2020) hence the material and procedures had been previously implemented, although with a younger age-group with fewer lessons and restricted content.

Elementary schools in two municipalities of southern Sweden were contacted in 2019 for the first cohort of students participating in the intervention project. In the initial planning phase of the project, we decided to approach schools via their central administration managed by the municipalities head of schools, whilst the extended recruitment for cohort 2 participants, which resulted in additional municipalities, were approached at the level of special education teacher and principals. Access to schools means going through different levels of gatekeepers

that provide access to the field. In the first cohort this was more of a top-down process considering proximity to the study focus, the student, than in the second recruitment where special education teachers were approached who are generally closer to the student and classroom teachers than school administration representatives.

The first recruitment of students resulted in 196 students with written consent to participate of which 27 were randomized to the interventions control and intervention groups in the spring of 2019. The decision was made to enroll a second cohort for the following spring, 2020, since the sample was considered too small to obtain a sufficient sample size based on power analysis. Therefore, for the second cohort four additional municipalities were approached. This resulted in 557 participants of which 104 were randomized to the control and intervention conditions. The population of first grade students in the participating schools were screened twice, beginning in January, and finishing in May (2019, 2020). Children who scored at or below the 25th percentile on both screening occasions were eligible for randomization. Local special education teachers reported whether any child met exclusion criteria and should not be part of the randomization procedure. Exclusion criteria were less than two full years of schooling in Swedish (attending preschool and preschool class) and attention or concentration difficulties that would hamper participation during testing and instruction based on teacher judgement. The allocation to the control and intervention groups was made in June, just before summer break and schools, students and their legal guardians were informed of the placement at the same time. Starting the autumn semester of second grade these students together with their classmates conducted a third screening and for those participating in intervention and control groups extended pretests were conducted in the beginning of September immediately followed by intervention. Due to individual randomization, some schools had no students in intervention or serving as controls, meanwhile others presented both conditions and both interventions.

The intervention programs were designed to last for 9 weeks with 4 weekly lessons. Autumn break extended the period to 10 weeks. Some single students had an intervention or control period prolonged due to sick leave. Schools were instructed to use a maximum of 12 weeks to complete the intervention, leaving room for brief temporal variations and were given a date when they were allowed to start collecting pre-test data. During the third and fourth screening periods (September, December) which lasted two weeks, pre- and post-test data were simultaneously collected. For context, the third timepoint for screening and post- and follow-up testing in November/December coincided with mandatory national assessments that some interventionists managed in

grade 6, which meant special education teachers experienced a heavy workload.

Participants

In the present investigation the focus has been inclusive in terms of directing intensive reading and mathematics intervention to students at low reading or mathematics performance levels with the ambition to present ecologically valid results. Therefore, children were not selected by individual cognitive nor language profiles. The total sample consisted of 753 students (cohort 1 and 2) and the students allocated to control and intervention groups were 30 vs. 32 for the mathematics intervention and 34 vs. 34 for the reading intervention. In all, 13 teachers, most of them special education teachers, functioned as interventionists in the reading and mathematics interventions, respectively. The majority held positions at their intervention schools. A total of three teachers were not part of the school's regular staff but were engaged for the course of the project. They all had extensive experience of teaching at elementary grade and were, with one exception (a teacher assistant), certified teachers.

Ethical Considerations

The study plan was approved by the Swedish National Research Ethics Committee (ref.no 201904084) before data collection began. The guardians of all first-grade students were contacted with an information and consent letter administered by school administrators for the first cohort and by classroom teachers for the second cohort. The information did not disclose exclusion criteria or ask for information regarding individual students' background, language, or abilities as we were interested in enrolling a representative group of early elementary students for the screening procedure. Ethical considerations when involving young children shall be receptive to their needs and preferences (Graham et al., 2013). Hence, it was important to directly address them in an information letter that guardians were encouraged to read with or for their child. An effort was made to translate the written information to English and Arabic to increase access to information and schools were encouraged to ask teachers proficient of other languages working in their school to, when considered helpful, orally translate the content to guardians. Information about the project and more specifically the screening procedures would also be possible for caregivers and students to obtain from classroom teachers since they administered those tests repeatedly during the project.

It was acknowledged that the procedure of randomization to different conditions for instruction may be unfamiliar to school staff and guardians and even negatively denoted (Alderson & Morrow, 2011). Therefore, the written information was carefully worded to be transparent about the study design but nonetheless keeping a neutral, non-valuing tone considering the different conditions. Because the interventions, in a child's perspective, could be viewed as teaching-as-usual together with a teacher familiar to most participants and hence be thought of as mandatory (David et al., 2001; Gallagher et al., 2010), it was important to inform teachers that it was fully optional for the child to decline participation at any time-point. We anticipated that the testing procedures could be demanding for some students, and hence, allowed for adaption by test leaders concerning breaks whenever asked for or in need of. To maintain local special education staff resources for the entire school during the implementation of the study, the project entitled participating schools to receive a financial compensation for each student that was served in one of the intervention groups. No incentives were given to the participants.

Screening Measures

The screening procedure was iterated five times for the total sample of 753 students. Timepoint 1 and 2 served to identify students who performed at or below a cut-off set to percentile 25 on standardized and non-standardized measures described below. All screening tests were paper-and pencil tasks and were taken by all participants. Screening 3-5 were conducted to follow the cohorts' reading and mathematics development over time and data from these tests are not included in the thesis. For the screening six measurements were administered in whole class, except for the reading comprehension test that was conducted in small groups.

Reading Tests

Word recognition was measured with the Word-chain Test (Jacobson, 2014) which is a norm-referenced, 2 minutes timed test. The child was required to silently read strings of words that are co-written and to find and mark word boundaries.

LäSt Spelling (Elwér et al., 2016) is a norm-referenced dictation test where the teacher reads aloud a sentence with a target word that the student writes. Testing was terminated after 25 words in the first grade screening and after 35 words in the third grade screening.

Reading comprehension was assessed with LäSt Reading comprehension which is normed from second grade and consists of

increasingly longer and more complex passages with multiple choice questions, that children read silently for 35 minutes (Elwér et al., 2016). The test has 80 items. Since the first two screening tests took place in the first year of reading instruction, floor effects were anticipated and demonstrated. Therefore, the test was dismissed as an identification test to detect low performance.

Mathematics Tests

Number Series (Woodcock et al., 2001) was used as a measure of conceptual knowledge to test children's ability to complete a series of numbers that requires quantitative reasoning. The test was terminated after 5 minutes. The test lacks norms for Swedish students.

Arithmetic Fluency (Woodcock et al., 2001) was used to measure procedural knowledge presents rows of 160 addition, subtraction and multiplication problems that are to be solved within 3 minutes. The test lacks Swedish norms.

Number-line estimations (Laski & Siegler, 2014) was administered in two untimed forms; identify the number marked on a number line from 0-100 and identify where a specific number (3-97) fits on the blank 0-100 line. This test revealed floor effects at the initial screening and were therefore not used as an identifying test.

Extended Testing

Students in both study arms-reading and mathematics-participated in an extended testing which was an individual procedure at three timepoints that functioned as the pre-, post and 1-year follow-up test. All were paper-and pencil tests. The following outcome measures were administered:

Reading Tests

Word recognition was measured by the norm referenced LäSt test (Elwér et al., 2016) with the subtest word recognition, that measures reading efficiency of a wordlist with successively complex real words. Form A and B were administered with 100 words each. Reading time is 45 seconds per list. The child was instructed to read aloud as quickly and as well as possible.

The LäSt subtest of decoding (Elwér et al., 2016) was used to measure phonological decoding efficiency in the form of nonwords. Form A and B each contains 63 nonwords read aloud as quickly and correctly as possible for 45 seconds each.

Reading comprehension was assessed with the subtest Passage Reading (Woodcook, 1987) adapted to Swedish and consisting of 68 passages of increasing length. The student was instructed to read passages silently and fill in a blank space in a sentence with a missing word. The missing word was to be read aloud by the student. Testing was interrupted after six consecutive errors. The test has not been normed with Swedish students.

Mathematics Tests

A two-part numeracy skills test measuring conceptual and procedural knowledge respectively was administered. Part one, number knowledge was a 22-item test (McIntosh, 2008) that contained items measuring number relations, number magnitude, place value and number line estimation.

Part two, number procedures (McIntosh, 2008) assessed arithmetic calculations in a 26-item test covering single and multidigit addition and subtraction problems. The time limit was 6 minutes for each test and students were required to give their written answers. The test is not norm-referenced for Swedish students.

Problem-solving was tested with a subtest of the Wide Range Achievement Test (Wilkinson & Robertson, 2006) adapted to Swedish. The test consists of 42 increasingly complex items which were read aloud to the student who was simultaneously presented with the problems and accompanying illustrations in a test booklet. For the first third of items, students were expected to do mental calculations but were offered paper and pencil as working materials. Solving the problems requires arithmetic skills within addition, subtraction, and subsequently multiplication, and division. Testing was terminated after six consecutive errors or and the test has a total time limit of 15 minutes. The test is not normed with Swedish students.

At a single timepoint (pre-test), students' cognitive abilities were assessed with a Swedish adaptation of subtests from Wechsler Intelligence Scale for Children-Fifth Edition, WISC-V (Wechsler, 2014). Block Design consists of blocks that were arranged and modelled to the child who was required to copy the demonstrated patterns. The subtest Vocabulary assesses a child's knowledge of words by picture naming and oral explanations of word meanings. The combined score was used as a proxy for verbal and non-verbal skill and can be used to estimate general cognitive ability (Silverstein, 1990).

Program Descriptions, Monitoring and Fidelity

Intervention Programs

The two programs were modelled on a selection of instructional contents, materials and procedures that has been found to improve reading and mathematics.

The reading intervention focused on teaching grapheme and phoneme connections and fostering fluency in word reading by establishing a firm decoding strategy and providing extensive repetition of learned content. In a phonics-oriented program different ways of manipulating graphemes with phonemes contribute to strengthening the connections between abstract sounds and concrete letters through phonological awareness exercises, decoding, and spelling simple word (Graham & Santangelo, 2014; van Rijthoven et al., 2021). Fluency built at the word level is essential for efficient text reading (Torgesen et al., 2001) hence wordlists, flashcards and repeated reading of sentences was incorporated in daily lessons to create extended opportunities to repeat grapheme-phoneme correspondences. To keep students engaged throughout the program and to create a context for introducing grapheme-phoneme correspondences or recapitulate previously encountered content the reading sessions was designed with a framing story that was read aloud one section per lesson by the tutor. The story also functioned as a platform for meta-cognitive discussions on why it is important with reading skills, how one can do to read words, what one's feelings towards reading can be like such as to model this kind of thinking and providing time and prompts for reflection and guidance on how to manage these issues. In preparation of the lesson content, numerous of basal readers and commercially available intervention materials were consulted for inspiration on disposition of lesson content. The reading program was originally developed for the research project.

The math intervention's main foci were basic number knowledge and skills and arithmetic calculations of number combinations, in other words, addition and subtraction problems within the number range 0-20. Explicit instruction is a dominant feature of Number Sense Interventions (Jordan et al., 2012). It is a 24 scripted lesson program based on experimental studies of a small-group mathematics intervention for at-risk kindergarteners (Dyson et al., 2013), which aimed at increasing number competencies in number knowledge, number relations and number operations (Jordan & Dyson, 2014). In

Swedish mathematics education context, an adapted version of the program, TUFF, was successfully implemented and evaluated in preschool class by Westerholm and Samuelsson (2020). The present math program was an extended and adapted version of the lesson scripts used in the Westerholm and Samuelsson study to 36 lessons and a number range from 0-220.

Implementation

The research team met with local school administrators, classroom teachers and special education teachers in separate and joint meetings when schools had accepted to participate in the project. Classroom teachers were invited to an information meeting at their school or municipality to be informed and communicate with the research team about the project and requirements concerning test administration and timeline. Similarly, special education staff had a workshop where they were introduced to the extending testing procedures and practiced administering the WISC-tests under supervision to ensure fidelity at implementation. The same teachers were also given a two-hour introduction to each branch of the project where the lesson packages were presented. These preparational meetings were held during spring semester in first grade to prepare teachers for an immediate start in August of second grade. For cohort 1 it was possible to meet in person for this program preparation but with cohort 2, in 2021, we were forced to use digital meetings because of social distancing rules of the pandemic.

The screenings and extended testing were executed within set timeframes. Intervention sessions were likewise scheduled with specified start and stop weeks but was within these frames conducted at the convenience of school scheduling, meaning students could have their intervention lessons located at different school hours and locations. The teachers were encouraged to find a quiet location where the student and teacher would be minimally interrupted during the testing and intervention sessions.

Each student's extended testing, intervention attendance and behavior was monitored by the tutor in an intervention protocol. A summary of the protocols suggests high adherence to the lesson scripts. Lesson duration was initially planned to be 30 minutes, which was also implemented with the first cohort. Teacher evaluations revealed that time was considered insufficient in both intervention arms, which resulted in an extension to 35 min/lesson with the second cohort.

Progress Monitoring Measures

For each intervention arm, 46 timed one-minute tests were developed to monitor fluency development of word recognition and single-digit and double-digit addition and subtraction. The reading lists comprised 50 words and the mathematics tests had 25 items. These tests were intervention specific so that a student participating in the mathematics intervention only completed the mathematics tests and reading intervention participants did the reading tests. Some of these timed tests were integrated in the extended testing: Three were performed by the intervention and control students at pre-testing, two at post-test and follow-up respectively. For the present thesis the pre-, post- and follow-up test were analyzed for group (intervention vs. control) means in the follow-up study.

Intervention Protocol

The intervention teachers were asked to mark student attendance, potential disruptions and causes during lessons as well as an estimation of lesson completion operationalized as percentage of each lesson completed. Attendance was generally high and deviations few. Most lessons were delivered as a whole, with all lesson segments completed. When occasionally deviations occurred, they were due to student fatigue or shortage of time on behalf of scheduling. Teachers indicated that the last lesson part, which was a game in the reading intervention and arithmetic word problems in the mathematics intervention, was shortened in these cases.

Interventionist Questionnaire

Four questions were compiled with the web-based document administration software Google Forms and handed via e-mail to the intervention tutors directly after the interventions were completed. The questions to be answered in free text were: What do you think is positive with the intervention from a students' perspective? What do you think is positive with the intervention from a teacher's perspective? Which challenges did you face working with the intervention(s)? How would you like to develop the lessons (supplement/change/delete)? The questionnaire was completed 26 times indicating a high response rate. Several teachers highlighted the time spent with one student as positive for the student and an opportunity for the teacher to analyze the student's performance in close-up over time. Some teachers mentioned the benefits of pre-planned materials and a lesson sequence as positive. Some comments on both interventions referred to individual students

and to what extent the intervention fit the individual student's needs. The administration of the material and the time-limit for each lesson was challenging to some teachers and the number of lessons was mentioned as time-consuming. Suggestions for alterations in the programs were few but included suggestions to reduce the number of lessons and to add a gaming element to the mathematics intervention for student motivation.

Data Analyses

The data analyses for each study are described in detail in each manuscript. The effect size was estimated with Cohen's d in Study I and III, and with Hedge's g in Study II. The latter is due to recommendations in the peer-review process of Study II. Both measures represent standardized mean differences of independent groups and are often used and interpreted interchangeably, however, Hedge's g corrects for bias in small samples (Lakens, 2013).

Summary of Studies

The aim, method and results of the included studies I-III is summarized below.

Study I

Aim

Study I investigated the effects of a supplemental, intensive reading program with second grade students at risk for reading difficulties. The purpose was to test the impact of phonics-oriented intervention on students' word reading and reading comprehension, hence developing and evaluating a phonics intervention in Swedish orthography with a strong research design.

Method

The study employed a randomized controlled design and involved students from 21 schools in two cohorts. A total of 753 students were screened in first grade on reading, spelling, and reading comprehension measures. From this pool, students performing at ≤ 25 th percentile were individually randomized to an intervention ($n=34$) or a control group ($n=34$). Students in both groups were pre- and post-tested on measures of reading and mathematics. Mathematics tests were included to enable analyses of transfer effects between reading and mathematics, which is described in Study III. The reading program spanned 36 lessons and was administered 4 times a week at the beginning of second grade by special education teachers. The intervention was one-to-one and included decoding, fluency training, spelling, and a listening component.

Results

At post-test, improvement in word recognition, word decoding and reading comprehension in the intervention and control groups was confirmed with *t*-tests. Regression analyses were used to investigate differences in improvement between groups on the three outcome measures and the magnitude of the mean difference between groups was

estimated using Cohen's *d*. The impact of training in the intervention group was significant and of medium to large effect sizes compared to controls on measures of word decoding, word recognition and reading comprehension.

Study II

Aim

Study II investigated the effects of an intensive and supplemental mathematics intervention with students at risk for mathematics difficulties in second grade. The aim was to evaluate the impact of an early numeracy and basic arithmetic intervention on students' conceptual number knowledge, arithmetic calculation and problem solving using a rigorous study design.

Method

Study II was conducted as a randomized controlled study in 21 schools and included two cohorts. A sample of 753 first grade students were screened for performance ≤ 25 th percentile on measures of conceptual and procedural knowledge. Students identified as performing at or below the cut-off level were individually randomized to an intervention ($n=32$) or control ($n=30$) condition. Students in both conditions were pre- and post-tested on measures of mathematics and reading. The reading tests were included to allow for analyses of transfer effects between mathematics and reading. The result of that analysis is described in Study III. The mathematics program was implemented at the beginning of second grade and spanned 36 lessons with 4 weekly sessions. Special education teachers administered the one-to-one intervention emphasizing early numeracy understanding and arithmetic calculation.

Results

Improvement in the intervention and control group on the outcome measures was analyzed with *t*-tests. Regression analyses were conducted to investigate the difference between groups on the three outcome measures. Hedge's *g* was used to estimate the magnitude of the mean difference between groups. Results showed that the intervention had a significant, medium effect on conceptual knowledge, arithmetic calculation and problem solving in the intervention group.

Study III

Aim

Study III first aimed at investigating the long-term impact of two intervention programs (evaluated in Study I and II). The second aim was to analyze, in the intervention and control groups from Study I and II, potential transfer effects from a reading intervention to mathematics skills and vice versa from a mathematics intervention to reading skills.

Method

The students randomized to intervention and control conditions in Study I and II were followed-up in third grade, one year after the intervention programs in mathematics and reading ended. Participants with post-test data from the reading study's intervention ($n=30$) and control ($n=33$) groups and from the mathematics study's intervention ($n=32$) and control ($n=28$) groups were re-tested with the same mathematics and reading measures used for pre- and post-testing.

Results

Outcomes from the testing in grade three were analyzed with regression analyses for identification of group differences from post-test to follow-up. Cohen's d was calculated to estimate the improvement. Results revealed that the effects of intervention in the reading and mathematics program had faded and the difference between intervention and control conditions had decreased. Most between group differences were not significant at follow-up except for conceptual knowledge in the mathematics intervention group and a measure of reading fluency in the reading intervention group. No transfer effects between reading and mathematics were detected.

General Discussion

Main Results

Two instructional programs were implemented in second grade students to improve their early reading and mathematics skills and outcomes were evaluated. To study the long-term effects of these intervention programs students' mathematics and reading skills were re-tested after 1 year. This thesis shows that students who trained with the programs outperformed controls on reading and mathematics outcomes after an intensive intervention. While the intervention led to improvements in trained skills, at follow-up the impact of intervention was weakened on most measures, with a decline in the difference between intervention and control groups results. This research shows that implementing a rigorous research design to test educational reading and mathematics interventions is feasible and resulted in immediate and significant improvements. The results also show that the impact declined in the following school year which warrants reflection about intervention efforts and a need of continuous student support. In the following paragraphs I will discuss the results, implications and limitations.

First the results of study I and II are discussed below and related to theory of learning to read and arithmetic learning. Thereafter I will discuss the results of Study III, long-term effects of the intervention programs, followed by considerations of the RCT design and common instructional features of the programs.

Improved Reading Skills

The reading intervention study was based on one single research question: What are the effects of an intensive phonics reading intervention on decoding, word reading and comprehension in a group of second-grade Swedish students at risk for reading difficulties?

The results showed that students who participated in the intervention program as a group increase their word decoding and reading comprehension skills corresponding to a medium effect size compared to the control group. The intervention group also improved in word recognition equal to a large effect of being in the intervention.

These results are relative to the control group who engaged in classroom instruction and school delivered support subject to individual student's needs. Our results corroborate and exceeds the impact of intervention found in meta-analyses of previous intervention studies that targeted foundational reading skills and selected participants based on low reading and spelling performance (Gersten et al., 2020; Hall et al., 2023; Neitzel et al., 2022).

Word Decoding and Recognition

Students who participated in intervention received individual instruction that emphasized decoding by the sounding out strategy. That means smoothly connecting phonemes to graphemes, a procedure inherent to beginning reading instruction in transparent orthographies (Lander & Wimmer, 2008; Melby-Lervåg et al., 2012). The strategy seems successful because it directly points to the, most often, invariant connections between graphemes and phonemes in Swedish that enables reading at the alphabetic level. According to theory of a staged development, multiple exposures to printed words increases the amount of stored orthographic patterns which enables immediate recognition (Ehri, 2005). In the intervention program, students were required to read the same words up to four times during a lesson, which we consider as extensive training providing an opportunity for establishing orthographic recognition. We also consider the explicit description of how to decode by sounding out a basis for new word encounters. The hypothesis of self-teaching (Share, 1995) stipulates that through repeated word exposure the child who has knowledge of grapheme-phoneme correspondences and possesses phonemic awareness can independently figure out how to decode new words and eventually stores qualitative representations of orthographic patterns in memory, which will facilitate lexicalization of a word's orthography (Perfetti, 2007). Training the sounding out strategy gave students easy access to a procedure that they could use during lessons as well as when reading independently, for example in class. In that way the training to blend words provided opportunities for exposure, which facilitates the orthographic level of reading (Ehri, 2005).

Blending was accompanied by phonemic awareness exercises, which introduced the principle of reading words, for example to convert a string of sounds to a spoken word. Because efficient phonics instruction is grounded in knowledge of letters and awareness of their sound equivalents (Ehri et al., 2001a; McArthur et al., 2018), we used phonemic awareness in segmenting and blending tasks first as a pure PA, listening exercise but immediately asked students to write words or to watch the

tutor write. The outcome on the word decoding measure indicated a medium effect of the program.

Orthography and Phonics

Of special interest was to relate our outcomes to the scarce literature on reading interventions in the semi-transparent alphabetic orthographies such as Swedish and Norwegian, specifically in relation to studies that employed a randomized controlled design. The outcomes of Study I are in line with previous intervention studies in accelerating word reading and adds to the knowledge base of effective reading instruction in Nordic orthographies by showing that medium to strong effects on reading and reading comprehension can be reached with an intervention that is relatively shorter than some previous programs (Wolff, 2011). The results strongly indicate that structuring learning content according to phonics principles represents an effective approach to boost reading skills in a more transparent orthography, which is an important finding since previous research has been dominated by phonics studies in the opaque English orthography (Share, 2021). The impact of intervention thus seems to translate well to beginning readers in Swedish. As anticipated, both groups of children irrespective of condition made gains as measured by the outcome tests. However, the acceleration of performance displays the potential of a focused effort to raise the skill level of struggling students with learning gains similar to average student reading achievement in the year between second and third grade (Bloom et al., 2008), which is considered a substantial impact.

To speculate, from research on learners of different orthographies, decoding seems less troublesome to individuals with reading difficulties (Seymour et al., 2003) in a transparent orthography. Therefore, it would not be surprising to find less of an impact on decoding of a phonics intervention because the alphabetic reading is also practiced in regular classroom instruction and is mainly used as a strategy to access word recognition (Alatalo, 2011; Taube et al., 2015). Fluent reading, however, requires immediate, accurate and fast phased recognition of orthographic segments (Perfetti, 2007; Torgesen et al., 2001). In the program, repeated word list readings and sentence readings with feedback followed established methods to increase fluency (Hudson et al., 2008; Rasinski, 2014). The outcome measure used for evaluation of word recognition skill showed the greatest effect of the program. The result is interpreted as an indication of the program's focus and as evidence for the intervention being supportive of orthographic word reading development where the fluency component should be an important target in a transparent orthography. A specific feature of the program was the integration of morphological patterns in the format of

word endings. We added a limited number of word endings to practiced words to expand word length and raise awareness of word structure as it has been found related to word reading (Goodwin & Ahn, 2013) but the present investigation cannot explain the impact of separate intervention components.

Spelling was not included in the outcome measures since the goal of instruction was to primarily enhance reading. However, as reinforcement of decoding training and an integral part of the PA exercises, we consider it an aspect of phonics. Adding a spelling component to a phonics intervention has shown to have a significant effect on reading and have resulted in favorable outcomes for struggling readers (Graham & Santangelo, 2014; Neitzel et al., 2022; Van Rijthoeven et al., 2019). Because the Swedish orthography is relatively transparent, research suggests that second grade spelling could be more dependent on phonological abilities than reading for children with reading difficulties. That is because underlying phonological difficulties have been related to spelling skills rather than reading once children have learned grapheme-phoneme correspondences, that is accurate word reading (Landerl & Wimmer, 2008). In the present intervention, the words students wrote were the same ones read beforehand, and as such at the same level of orthographic complexity. The spelling practice thus enforced the phonics principle. Adding a spelling outcome measure would have provided an estimate of the impact.

Transfer to Reading Comprehension

The intervention group displayed significantly improved reading comprehension at post-test compared to the control group with an impact of intervention corresponding to a medium effect size. Learning to effortlessly recognize a word is suggested to free up cognitive capacity to reading comprehension processes (LaBerge & Samuel, 1974). Before discussing the impact of training on reading comprehension it should be noted that our program did not emphasize reading comprehension practice. However, the outcome was considered logic because of increased decoding and word recognition skills when considering the simple view of reading formulae (Gough & Tunmer, 1986). Reading comprehension is viewed as the result of decoding x language comprehension. Sufficient oral language comprehension and decoding are necessary components for reading comprehension (Hoover, 2023) and oral skills were not salient features of the intervention. We did not investigate participants language skills, but teachers reassured all participants conformed to our criteria of at least two full school years in Sweden. The only measure that approximates language ability was the WISC-V Vocabulary subtest, used as a baseline test in this study

(Wechsler, 2014). There was no significant difference between the intervention and the control groups on that assessment, but notably the level was considered low in both groups. It is quite possible that oral language skills were boosted in classroom interaction as early grades' reading instruction is commonly a mix of oral and textual literacy activities (Alatalo, 2011; Aminoff, 2021). A brief encounter with oral dialogue was, however, offered in the intervention program during each lesson when talking about the story that was read aloud to the student. The instructor asked a question about content for inference or used it as starting point for connecting the text to the student's own experiences and thoughts. Research supports engaging in text-talks to improve reading comprehension (Baker et al., 2013; Nation, 2019), hence the relatively short but important component of the program could have influenced reading comprehension positively. Probably, that component resembled text-talks that the students were acquainted with from their classroom instruction as reading comprehension strategies are emphasized in the course syllabus of Swedish and recommended practice for Swedish reading instruction (Swedish National Agency for Education; 2022b; Taube et al., 2015).

Improved Mathematics Skills

Study II set was out to answer the following research question: What are the effects of an intensive early numeracy and arithmetic intervention on number knowledge, arithmetic calculation and problem solving in a group of second-grade Swedish students at risk for mathematics difficulties?

The underlying theory guiding the execution of the intervention was that of early numeracy (Andrew & Sayers, 2015) as essential to succeed in future mathematics learning and as foundational competencies in arithmetic (Aunio & Räsänen, 2016; Geary, 2011; von Aster & Shalev, 2007), hence the intervention targeted early numeracy skills and arithmetic.

Number Knowledge and Calculation

Outcomes confirmed that the intervention group advanced their performance with number knowledge and arithmetic compared to controls with medium effect sizes. Number identification, sequencing, and finding the number before and after, knowing which number is bigger and smaller, strengthened concepts of the numerical magnitude and number relations. These tasks are found in conceptualizations of numeracy instruction of successful mathematics interventions (Andrews & Sayers, 2015; Aunio & Räsänen, 2016; Jordan, et al., 2012; Sterner et

al., 2020). Contrary to independent work in a mathematics textbook, reported to be common practice in Swedish classrooms (Van Steenbrugge & Ryve, 2018), the current intervention was highly interactive with a focus on teacher modelling and giving immediate feedback. That approach allowed for little expression of and variation in students' own counting strategies because the strategy of counting on when adding was emphasized, and use of decomposition with the base 5 and 10. The instructional sequence leveraged the strategy of finger counting which children experiencing mathematics difficulties tend to use for a prolonged time (Geary, 2012; Jordan et al., 2003), to demonstrate how to shift to a more efficient counting strategy that requires conceptual understanding of counting. Thus, training marginalized potential immature strategies by explicitly prompting and demonstrating an alternative route reinforced by conceptual understanding. The procedure was demonstrated using different representations of number before internalized as a purely verbal instruction. Seemingly, students benefitted from the use of representational material, that has been found important for supporting conceptual and procedural knowledge in previous studies (Carbonneau et al., 2013; Witzel & Allsopp, 2007). The strong focus on conceptual understanding was iterated for place value tasks, simple number sentence additions and subtractions and in arithmetic word problems. Meanwhile fact retrieval was practiced throughout the program both with and without conceptual elaboration, after the teacher having first established an understanding of underlying principles. To practice the direct retrieval strategy has been found effective to develop mathematics facts in intervention research (Östergren et al. 2023).

Simple Arithmetic Word Problems

In word problem solving, the intervention group also made moderate improvements compared with controls. The interrelationship between concepts of knowledge (Kilpatrick et al., 2001; Rittle-Johnson, et al., 2015) was an assumption that is mirrored in the exercises of the program so that instruction provided both the conceptual understanding and the procedural knowledge of mathematics tasks. To boost profound understanding of the foundation of addition and subtraction, numbers in the 1-10 range were used to build a number line, first with concrete objects, followed by visual representations and by digits following the sequential progression outlined by von Aster and Shalev (2007). Interestingly, problem solving tasks were practiced at a basic level and as application tasks for trained number combinations in an effort to situate mathematical thinking in a context similar to everyday encounters with mathematics. This is considered an important step to

bridge informal and formal number knowledge and procedures (Purpura et al., 2013). The impact of intervention may have supported knowledge over and above the number combinations as the stepwise and visual display of adding or subtracting was modelled to the student and subsequently produced by the student in response to short story problems. Mathematics development entail acquiring and using refined procedures while keeping track of the conceptual basis of word problems (Fuchs et al., 2015). Training at the basic level may have facilitated such mental processes, though beyond the scope of the study to investigate. In all, the effect of the intervention resembles and corroborates previously reported effects of interventions with a focus on whole number, early numeracy, and basic arithmetic training (Chodura, et al., 2015; Lein et al., 2020; Nelson & McMaster, 2019) and problem solving (Dennis et al., 2016) showing that foundational skills intervention in Swedish special education translates well to the impact reported in international mathematics intervention studies.

Sustainability

Study III showed that the intervention group in the reading and mathematics programs maintained a positive development of reading and mathematics 1 year after the intervention as measured at follow-up. There was similarly and expectedly a positive development of the same skills in the control groups. In line with previous studies in both subject domains (Bailey, 2019; Suggate, 2016) the advantage for the intervention groups had, however, decreased to be insignificant compared to controls despite the intensive intervention. The effect that still maintained at a moderate level favoring an intervention group was found in mathematics for conceptual knowledge. It may be indicative of a strong impact of the intervention, a focus in classroom instruction in second and third grades which helped maintain a high level, and potential continuous special education support. In the reading condition, the intervention group showed superior performance on a timed word reading measure at follow-up. These results were not mirrored in the word recognition test, that showed the strongest effect at immediate post-test. However, it may be that the 1-minute measure which did not contain the same level of increasing word complexity, better captured the relative strength in word reading acquired during intervention and utilized in the year after.

An important question concerns reasons for fading effects, which have been outlined in previous research on long-term intervention effects. We find it relevant to consider explanations hypothesized by Bailey (2019) that peers catch up to the students in intervention, that teachers may have implemented parts of the training in the year post intervention, that classroom instruction provided an arena to

consolidate or recapitulate learned content. This is specifically plausible in early grades, which even unintentionally aligns with content in the intervention programs because the Swedish mathematics syllabus mandates foundational skills instruction (Swedish National Agency for Education, 2022b). The average rate of learning in mathematics and reading seems to be most intensive in K-2 grades measured by annual gains, declining from 3rd grade and onwards (Bloom et al., 2008) irrespective of supplemental intervention. Hence, children in second grade are in the midst of general, and rapid, learning.

In relation to Study III, previous studies in Scandinavian school contexts provide some references for example, Wolff (2011) for third grade reading and Lopez-Pedersen et al. (2023) for first grade mathematics.

Wolff found sustained effects on reading comprehension and spelling after 1 year, while Lopez-Pedersen found that effects declined already at a near-time follow up. Clearly individual studies vary considering sample, grouping, grade, measurement, and follow-up interval but these studies utilized explicit instruction, pre-scripted lessons, and a duration, which resembles Study I and II. A common and unifying reflection is that deeper interpretation of outcomes at follow-up depends on knowledge of the control condition during intervention and after, which has been pointed out in previous studies (Bailey, 2019; Lemons et al., 2014; Lopez-Pedersen et al., 2023; Wolff, 2011) and should be considered a limitation of the present study.

It seems planning an intervention according to theoretical and empirical underpinnings of effective instruction and even implementing and evaluation the same intervention with positive effects is not enough to secure longtime maintenance at the post-test level compared to peers who did not receive the intervention. Information about the extent, content, and quality of general special education efforts in early elementary grades needs to be scrutinized. Research indicates the need for sustained support (Bailey, 2019; Daniel et al., 2021; Powell, Berry et al., 2022) and in an RTI framework part of organizing student support is identification of progress, to exhibit when a student should exit a certain Tier of instruction to move to more intensive support or revert to general instruction (Nilvius & Svensson, 2022). That approach resembles a cyclic evaluation of performance and instructional needs that was not possible to create under the constrained conditions of the present study. However, it is considered important to evaluate what level of support is necessary for students to keep progressing and prevent a negative learning trajectory. From the list of causes of sustainability break-down (Bailey et al., 2019), several causes were not possible to investigate with the present study design, and methods to boost continuous learning

while keeping the advantage gained in intervention seem to be an area requiring more investigation (Lopez-Pedersen et al., 2023; Nelson et al., 2018; Nelson et al., 2021).

Transfer

Study III showed that no transfer between intervention domains was found when analyzing the outcomes of reading in the mathematics intervention group and mathematics outcomes in the reading intervention group. Several assumptions could be made from cross-sectional and longitudinal correlation studies about the nature of relationships between the subjects, their development and underlying joint and separate abilities, but our data were restricted to consider manifested reading and mathematics performances. In accordance with other studies (Sterner et al., 2020), the results indicate that training intensively makes individuals better equipped to perform the tasks that were practiced and within domain skills may develop. There may be possible benefits that were not captured by the current outcome measures at follow-up but research on longitudinal intervention effects across domains is limited (Dowker, 2005).

Methodological Considerations with the RCT Design

A randomized controlled study design was chosen to control for systematic differences between intervention and control groups and avoid selection bias, given that the variability in student characteristics and skills present in general classrooms could result in very heterogeneous groups without random assignment (Shadish et al., 2002). It is well recognized that conducting a randomized controlled study in an educational context is a method to uncover the impact of instruction on students' outcomes but also that an RCT presents challenges for researchers and participants (Kyriakides & Creemers, 2017). The RCT design is consequently more seldomly used in school-based research due to difficulties associated with implementing random assignment and because the experiment falls short of explaining why an intervention is effective (Davies et al., 2008; Kyriakides & Creemers, 2017). A main argument to pursue a random allocation to groups lies in the potential to gain valid results of program effectiveness (Shadish et al., 2002), which can inform practice of what works. The individual randomization is considered suitable to that end (Davies et al., 2008). There is abundant evidence of medium to strong effects of both reading and mathematics intervention as presented in the Background chapter, which made us anticipate similar effects in our sample given a sufficient sample size.

We have interpreted the magnitude of effect sizes in accordance with accepted practice in educational science, with effects at .20, .50 and .80 (Cohen's *d*) described as small, medium, and large effects (Cohen, 1988). Some research suggests that effect sizes should not be compared with the general interpretation of effects proposed by Cohen (Kraft, 2020). This is because small effects are often obtained in educational interventions, hence effects of smaller magnitude could be considered educationally meaningful. However, an important factor when choosing what benchmark to refer to is what effects are measured, how and in what context (Kraft, 2020). Alternative ways of describing effects have used annual gains in school-subjects based on national achievement tests (Bloom et al, 2008). While the results of Study I were briefly compared with these benchmarks, no Swedish data were available to make a comparison. The studies which the results of Study I-III are aligned with, exemplified in the Background chapter used an experimental design and outcomes were measured with standardized and non-standardized instruments, and interpreted with Cohen's benchmarks. Hence, referring to these magnitude of effect sizes seemed reasonable. It should be noted that the use of a randomized controlled design when the difference is considered large between what is offered in terms of training in the control condition compared with the intervention group might inflate effect sizes and that the use of non-standardized outcomes, as in Study II, is associated with larger effects (Kraft, 2020; Slavin & Madden, 2011).

Some unintended adaptations of the intervention programs may be the result of teachers' use of the materials. However, the intention with conducting the studies with random assignment and strict procedure of delivery was to test content and instructions build on reading and mathematics development theory to gain knowledge of how these would work under ideal, controlled, conditions. Reasonably, how participants considered the set-up and the collaboration with the research team will be indicative of their inclination to pursue with the programs (Gersten et al., 2000). The brief teacher questionnaire displayed positive appraisal and some critical commentaries on implementation and suggestions for modification of the content and procedures. Although incomprehensive as a qualitative measure, no commentaries were received regarding the research methodology, taken as an indication of a shared notion that experimental research may benefit students and teachers. On a general level, educational intervention studies with an RCT design aim at contributing to the body of evidence-based practices (Cook & Cook, 2011). Study I and II replicate effects found in previous studies and should be viewed as contributions to rather than single-standing proofs of effective practices. Replication

studies, where the same intervention is tested in new participants and environments help strengthening the external validity of RCTs in special education research (Shadish et al., 2002; Lopez-Pedersen et al, 2023)

Intervention Features

Moderating Variables

The small sample sizes of Study I and II did not enable moderator analyses of instructional variables as would have been possible with a larger sample. It would have been interesting to contrast the one-on-one tutoring to tutoring in pairs, contrasting a shorter intervention to the full length 36 lesson package, and including information on students' socioeconomic status to explore if effectiveness changes with specific student group or intervention features. Student characteristics have been confirmed as moderating factors in intervention studies including students' socio-economic status (Nelson & McMaster, 2019), and previous meta-analyses of intervention effects showed that foundational skills programs conducted one-on-one instruction moderated effects (Neitzel et al., 2022).

Multicomponent Programs

The impact of intervention resulted from programs made of several components. The conceptualization of foundational skills as overarching term allows for a combination of specific features to form a package of mutually influential or sequentially skill-building aspects. Questions can thus be posed about what the most correct definition of a multicomponent program is? Contrary to for example Wanzek et al. (2016), who defined multicomponent as including vocabulary, oral skills and reading comprehension, we considered the multiple components used in our programs as parts of phonics training and parts of early numeracy and early arithmetic training. For example, spelling can be used to highlight the alphabetical-phonological relations practiced in reading and because reading interventions containing a spelling component yield higher effects than without (Hall et al., 2023), it seems closely connected to the phonological aspect of letters and sounds. In the reading program except for the listening comprehension component, we chose to define all tasks as phonics-based or phonics-oriented which covered about 80% of the program content. Similarly, in the mathematics program, early numeracy tasks focusing number knowledge covered about 60% of instructional time and 40% was devoted to procedural aspects in number combination and arithmetic

problem solving. The outcomes in this thesis are understood as the response to the whole, an approach also found in classroom instruction where lesson content and procedures are created with multiple representations of content and multiple ways to engage with and respond to instruction.

Packaged programs are uncommon in special education and on one hand argument against pre-scripted lesson plans would be that they do not adapt to individual student's needs and that they could restrict professional autonomy of the teacher in designing a tailored sequence of tasks for the student (Werler & Tahirsylaj, 2022). On the other hand, the programs were additional to general classroom instruction also emphasizing foundational skills in second grade and would be expected to provide increased practicing opportunities and elaboration on basic knowledge and skills. As special education is commonly eclectic in choices of methods (Guckert et al., 2016; Odom, 2016), the responses from participating teachers were positive about the convenience of accessing a preplanned material where the research team had collected instructional sequences and materials, rather than perceived as a hindrance to instruction.

Intensity

The intervention programs were arranged as relatively short interventions compared to interventions reported in research syntheses (Wanzek et al., 2016, 2018). Yet, in line with effect sizes based on aggregated data of multiple intervention outcomes, even intervention spanning a limited number of weeks, seem to effectively improve foundational reading and mathematics (e.g., Dietrichson et al., 2021; Hall et al., 2023). Duration is one aspect of what defines the specific features of a program, covered under the umbrella term intensity, which has no unitary operationalization (Coddling & Lane, 2015). We used as a reference point effectiveness studies of similar content and length (e.g., Hassler Hallstedt et al., 2018; Wolff, 2011). However, choosing a different length would probably have resulted in altered content, procedures, or a need to adapt content to what is taught in the latter part of second grade. The phasing of lesson content was kept relatively constant, as was the general order of lesson segments in both intervention conditions. This allowed for predictability in terms of structure and thus contributed to an overall organization of lesson components that have been found an important factor of phonics and early numeracy intervention (Ehri et al., 2001b; Gersten et al., 2009). Implementing an intervention is altering business as usual in the school context, which may take some time to adapt to for the individuals involved. A lengthier intervention, implemented during two school

years, may have deprived the project of temporarily positive effects attributed to novelty and enthusiasm known as the Hawthorne effect (Shadish et al., 2002).

Alignment

We considered it safe to design the intervention programs without diligent alignment with the syllabus in second grade mathematics and reading for two reasons. First, the content of our intervention had a clear focus on essential knowledge and skills and was therefore seen as addressing the skill building aspects salient in the curriculum and thus no deviation from what the focus of early instruction should be was made. Second, the syllabi are vague about what specific content teachers should address in a specific time-period, instead they state end of third grade goals, meaning there can be variations in what content is addressed and emphasized at certain timepoints and hence no clear picture of the actual classroom instruction during the first part of second grade could be derived from policy documents (National Agency for Education, 2022b). However, when interpreting the results from Study III that showed fading effects of intervention, it is relevant to consider how continuous support, and specifically classroom aligned support, would have impacted students' progression in reading and arithmetic in the year after the intervention.

Alignment in terms of scope and sequence of content and teaching approach between supplemental and ordinary instruction have the potential to offer students well-needed repetition with teacher feedback. Alignment between supplemental reading instruction and classroom instruction in terms of scope and sequence, skills and concepts have been found more effective than unaligned instruction in promoting decoding, reading fluency and reading comprehension in struggling second grader readers (Wonder-McDowell et al., 2011).

Implementation

Implementation of the programs was a main endeavor of this research project. It could even be seen as an essential and integral part of educational research on effective teaching (Cai & Hwang, 2021). As such implementation informs research about what works and under which circumstances while research, building on theory of effective instructional methods and essential content engages in theory testing. Ideally, implementation integrated research is a reciprocal, ongoing process where practice helps refining and deepening the understanding of how, for example, lesson plans work with varying student groups and environments and that knowledge feeds back to researchers and

generates theory development (Cai & Hwang, 2021). Beyond the context of the schools involved in the project, traditions in education seem to be a factor related to the design of the intervention. It borrows features from the Anglo-American curriculum tradition emphasizing method (Werler & Tahirsylaj, 2022), which is realized as progress monitoring, prescribed lesson plans and a packaged intervention designed to increase students' outcomes. This resulted in the intervention being presented as a package to the stakeholders in schools and the underlying theory of instructional choices was described in preintervention meetings. That means the teachers were recipients and transmitters of the programs rather than co-constructors or independent agents. If that aspect of the program design resulted in resistance due to the Swedish school context pertaining to a didactic tradition, it was not communicated to the research team. Considering the majority of schools were engaged in the project from direct contact with interested principals and special education teachers, the likelihood of resistance towards the packaged interventions, which was explicated from initial contacts, was considered low.

Another salient issue is the organization of general special education support considering the interventions implemented. Since there is no official structure of tired support as found in RTI frameworks, the introduction of high intensity intervention was an obvious contrast to most special education teachers administration of their caseloads. It seems plausible that lengthy, packaged programs would more easily find its way to the practitioner's toolbox when organizational conditions are responsive of and facilitates such practices (Fixsen et al., 2005). In connection to implementation the research-team stressed that intervention would possibly intervene with ordinary practice, but resources were allocated to schools in order for the project to disrupt special education services minimally. Study I and II's results indicate that the amount of time students spent in intervention yielded return on investment in terms of achievement but for interventions to be implemented and sustained in schools, practitioners and administrators might need continuous support from the researchers (Gersten et al., 2000).

Fidelity monitoring, as planned from the outset of this project was hampered by restrictions caused by the global Covid-19 pandemic and therefore is a limitation of both intervention studies. We implemented the intervention from a distance, occasionally meeting teachers and principals in real life in the two school years of 19/20 and 20/21. Contacts were however not limited, since digital meetings, allowed for instructional training and planned teacher meetings before, during and after the intervention period. In interpreting the result of Study I and II

it is noticeable that data of implementation are absent, making valuable information about the functioning of the program implementation and its relation to student outcomes limited (Harn et al., 2017).

Conclusions

Summary of Contributions

Three main contributions related to the field of special educations come from this thesis. These contributions are directly connected to the main aims of the thesis. First, the studies showed that intensive reading and mathematics intervention accelerated the performance levels of a random sample of low-performing second grade students, inferring that the intervention programs, were generally effective in raising student achievement. Phonics-based intervention substantially improved the word reading skills in struggling readers and showed that a phonologically based method in Swedish reading instruction is beneficial for word reading accuracy and speed and that results transferred to reading comprehension. In the mathematics intervention, performance with number knowledge and procedures showed considerable improvement in students at risk for mathematics difficulties indicating the importance of extensive joint practicing of conceptual knowledge and procedural skills. These results from the two programs collectively signal the importance of special educational support of broad and foundational skills to advance performance in basic reading and mathematics, which could help students come on track from early on.

Second, being in either the reading or the mathematics intervention did not result in transferred skills across subject domains which indicates that intervention in the current studies only affected performance in the targeted domain. These results should not be generalized as few studies have investigated cross domain transfer as a consequence of intervention. However, the results point to the importance of basic skills training as a foundation of comprehensive operations. It was seen in increased performance with mathematics problem solving in the mathematics program and reading comprehension in the reading program, that is within-program transfer effects.

Third, finding strategies in schools to sustain the positive development of supplemental intervention is pivotal as the gains made in the interventions were for the most part not sustained after one year. On the one hand it indicates how intensive supplemental intervention may act as a leverage to accelerate learning, and on the other hand that

several circumstances may contribute to fade-out as pointed out in previous research. Keeping track of the type and frequency of supplemental support in the intervention and control groups during and in the year following intervention would probably elucidate some of those circumstances valuable for interpretation of causes for fading effects.

Considering the thesis aim of designing structured intervention materials for use in special educational instruction, at present the full sets of reading and mathematics scripts, tasks, manipulatives, visuals, and games have been materialized and evaluated for the purpose of the research project. Future work will be needed to make the interventions accessible to practitioners.

Theoretical Implications

The outcomes from reading study underscore that phonics is an effective method of reading instruction in the Swedish orthography, as indicated from previous research (Levlin & Nakeva von Mentzer, 2020; Wolff, 2011). Intense word reading practice based on explicitly training PA accompanied with letters, analyzing and segmenting sounds had a substantial effect on reading comprehension in this intervention. That indicates and replicates findings suggesting decoding is an important base for reading fluency and early age reading comprehension (Adlof et al., 2006; Hoover & Tunmer, 2018; Landerl & Wimmer, 2008; Seymour et al., 2003). It also reflects that students seem to benefit equally from basic phonics intervention in the semi-transparent Swedish orthography as in the opaque English orthography. Relative to previous empirical research, the estimated effect sizes from this program parallels or exceeds reported impact of intervention (Hall et al., 2023; Wolff, 2011). However, keeping the advantages from intensive instruction seemed difficult and speaks to the need for monitoring the continuous reading or mathematics support when investigating long-term effects as well as developing efforts to sustain the gains made in intervention (Bailey, 2019). The mathematics program pointed to sustained benefits of early and intensive instruction in conceptual number knowledge and procedures, which suggests and confirms that conceptual knowledge makes a stable foundation for later mathematics learning that is malleable to target in intervention (Bailey et al., 2017).

The current interest in preventative and remedial instruction, according to the RTI framework, has relevance for the framing of this study. The current research is a hybrid of service delivery aspects and intensity found in Tier 2 and 3 reading and mathematics programs. A theoretical implication would be that mixing a packaged program with the length and content of 2 and 3 Tiers provide intensive intervention

early on, preventing a wait to fail approach (Al Otaiba et al., 2014). However, the specific impact of intensity aspects on student outcomes is not yet well understood (DeFouw et al., 2019; Vaughn et al., 2010). An important implication resides in the methodology of the interventions. Attempts to conduct randomized controlled trials outside of the medical-psychological field are few and the current research was, by Nordic means in terms of sample size and the longitudinal design, a large endeavor. The results show the feasibility of conducting rigorously designed studies in schools. The interventions were implemented at multiple sites which made logistics and the collaboration with involved stakeholders vulnerable during the implementation phase that coincided with the Covid-19 pandemic. Nevertheless, during such constrained conditions school administrators and teachers managed to pursue with preparation, testing and tutoring. A theoretical, yet practical implication is that RCT intervention research in schools might in fact be less difficult to conduct than suggested in the literature (Gersten et al., 2000; Maggin 2022) when working closely with special education teachers and school leaders.

The ethical aspect, often referenced when discharging RCTs in education, should not be a hinder when agreements are made between stakeholder on resources allocation and when relying on schools' responsibility and obligation of providing adequate support to all students inclusive of students allocated to control groups during a research study. I further believe efforts to communicate transparently to all stakeholders, not least students' guardians, clarified some potential misconceptions of random assignment implying some students would be rejected special education support when identified as at-risk.

Practical Implications

A main implication of the reading intervention is that structured phonics is a functional way of supporting beginning readers who are low performing in reading, evidenced by poor decoding and spelling after participating in initial school instruction. Schools are obliged to meet the needs of students who are struggling as early as in their initial preschool-class year (Swedish National Agency of Education, 2021). The question is what the support consists of in practice. In search of effective ways to target foundational skills one-on-one, phonics-based intervention during a limited period seems a valid candidate. In relation to the balanced approach to reading instruction prevalent in Swedish classrooms (Alatalo, 2011), the present program should be viewed as representing elementary components vital to other aspects of literacy.

The mathematics study showed that instruction in conceptual and procedural knowledge is pivotal for enhancing performance in number

knowledge and arithmetic. It suggests that numeracy instruction emphasizing understanding number and their relations, which belong to the earliest formal mathematics instruction, plays an important role in second grade instruction when accompanied with procedural practice and math fact retrieval. An implication for special education based on the present study would be to extend or recapitulate early numeracy teaching parallel to procedural strategies and problem-solving that is addressed in the curriculum in second grade. Since research has indicated that mathematics instruction is oftentimes closely tied to textbooks and performed with a student-responsive rather than teacher-oriented approach (Roos & Bagger, 2022; Van Steenbrugge & Ryve, 2018), a consequence could potentially be that instruction and the chance to engage with early numeracy concepts and procedures in second grade are governed by the book and by the student's ability to signal perceived difficulties. In such circumstances, when classroom instruction limits access to explicit numeracy practicing it seems essential that adequate material and methods are available for supplemental instruction.

The materials from the study were developed to be made available for teachers upon encouraging study results. In the transition from a research study material to a teacher ready to use package it is important to consider the tension between using the material as intended and potential teacher adaptations. The impact of each program was based on usage in a researcher-controlled situation. Hence, references to evidence-based practice in relation to program content and instructional approach should be viewed solely in light of the intended usage.

Future Directions

Some questions and suggestions for future research arise from this thesis. Rigorously designed experimental studies are uncommon in educational settings in Scandinavia. To extend the field of intervention research and to obtain replication studies from contextually similar school and teaching environments, future research that evaluate the effectiveness of reading instruction and mathematics is needed. Larger sample sizes, creating increased study power would make moderator analyses possible which could be informative of sub-group differences in response to instruction and disentangle what specific aspects of the intervention programs and participant characteristics are related to outcomes.

Meta-analyses of interventions provide guidance for designing such moderator analyses. Specifically, intensity needs to be better understood related to students' outcomes in intervention and future studies could consider varying the time and group-size variables and to

investigate student characteristics associated with rate of progression during and following an intervention. The optimal timing of intervention should further be addressed as well as determinants of sustainability in the school environment with the implementation of continuous booster or maintenance intervention. In coming intervention studies teachers' perspectives on scripted and packaged instructional material and progress monitoring for special education should be addressed in more detail.

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