Lessons from a preschool intervention study carried out during the Covid-19 pandemic

Agneta Gulz and Magnus Haake

Lund University Cognitive Science, Helgonavagen 3, SE-22220 Lund, Sweden

agneta.gulz@lucs,lu.se; magnus.haake@lucs.lu.se

Abstract. The article describes how a series of adaptions enabled us to carry out a controlled intervention study in 15 preschools, with 420 children and about 40 preschool teachers, during the Covid-19 pandemic restrictions. The original overarching aim of the study was to develop and evaluate an early math intervention supporting children from low-SES environments to develop basic mathematical skills. The two main research questions addressed preschool children's early math development using a digital play-&-learn game (anonymized), and the pedagogical impact of an integrated teacher resources package. Four guiding principles complemented the research questions: accumulation of new knowledge, collaboration & participatory design, experimental control & ecological validity, and real-world applicability. The focus of this article is on how data collections methods and analyses were adapted to handle the constraints induced by Covid-19 without deviating from the original research questions and the four guiding principles. The adaptions clearly entailed methodological limitations. Yet the study demonstrates the possibility to conduct a remotely controlled effect study encompassing both ecological validity and real-world applicability.

Keywords: early math, low-SES, educational software, preschool, collaboration and participatory design, experimental control and ecological validity, Covid-19 and methodological adaptations

1 Introduction

With the rapid 2020 spread of Covid-19, much of the empirical educational research came to an abrupt stop. This article describes how a series of adaptions and modifications eventually enabled us to carry out a practice-oriented intervention study in 15 preschools during the Covid-19 years of 2020 and 2021. In this article, we focus on the methods for data collections and analyses, and how they were adapted to the situation while still sticking as closely as possible to the original research questions and guidelines under which the study was originally designed.

Hopefully the gruesome and chaotic years of the Covid-19 pandemic are now mostly behind us, but similar situations may bedevil any research project at any time. For researchers working with practice-oriented preschool studies, it is a strength to be familiar with alternative means to go about when the regular and preferred methods cannot be applied. It is our hope that this article can help or inspire other researchers in times of need.

1.1 Background to the study and original research questions

In 2018, the Swedish Institute for Educational Research (*Skolforskningsinstitutet*) granted us funding for a practice-oriented intervention study centered on a digital play-&-learn game in mathematics for preschool children named Magical Garden [1, 2, 3]. The goal of the project was to address whether systematic use of this digital play-&-learn game in preschool better support children's development of early math abilities compared to ordinary preschool practice. A central feature of the project was to develop and evaluate a novel teacher resources package to support children's learning of early math in the context of the digital play-&-learn game.

An additional, secondary, research question was whether the systematic use of the digital play-&-learn game in math (anonymized) in preschool practice would support children's development of basic self-regulation skills with better results than with ordinary preschool practice? The background of the additional research question is that young children's proficiency in mathematics and self-regulation are strongly correlated with one another. While it is likely that the skills mutually strengthen the growth of one another, more recent research suggest a somewhat stronger influence in the direction from strengthened math skills to strengthened self-regulation skills [4, 5].

The research questions, thus, were the following:

1. Can use of the digital play-&-learn game Magical Garden support the development of basic mathematical skills to a larger extent than ordinary preschool practice (business as usual)?
2. Can children's use of the game Magical Garden together with *supplementary support for teachers* (possibility of follow-up and various forms of educational support material, explanatory, descriptive texts, in-depth texts, video material, tips, and games, etc.) support their development of basic math skills better than regular preschool pedagogy (*business as usual*)?
3. (Secondary research question): Can use of the digital play-&-learn game Magical Garden also support the development of basic self-regulation skills to a larger extent than ordinary preschool practice (business as usual)?

1.2 Why develop resources for preschool teachers?

There is ample evidence indicating that preschool teachers[1] can have a considerable influence on preschool children's learning and development [6, 7] and accordingly, preschool teachers need to be supported and strengthened in their pedagogical work. When it comes to preschool mathematics, specifically, there is even more to it. Studies show that preschool teachers chose this career on the assumption that they will not have to worry about mathematics, as this is of secondary importance in preschool pedagogy [8, 9]. Many preschool teachers also have a weak interest as well as negative experiences of mathematics from their own school days combined with low confidence in their own abilities (low self-efficacy) to work pedagogically with mathematics.

Accordingly, it is both important and relevant to investigate whether a play-&-learn game such as Magical Garden with integrated pedagogical resources for preschool teachers can support and strengthen them in their work with preschool math as well as provide them with useful and meaningful tools for working with children based on the children's use of the play-&-learn math game.

[1] In this article we use the term "preschool teacher" to refer to caregivers, certified preschool teachers, and other paid adults who supervise children in preschool settings.

1.3 The overarching motive: education as compensatory

The overarching motive for the project lies in the importance of an informed compensatory agenda. During the past decades, our understanding of the importance of social-economic and socio-cultural factors for children's schooling has grown strongly and research shows that early compensatory efforts in mathematics education with respect to children's background have a large potential to support their future schooling and learning.

A child's ability in basic mathematics when entering compulsory school has proved to be a very strong predictor for further success with mathematics in school as well as for success in school in general [10, 11]. Studies show large differences in mathematical ability between children already when they enter first grade [12, 13]. At the same time, there is an abundance of evidence that efforts in preschool can reduce these differences [14, 15, 9, 16, 17, 18]. This is hardly surprising as the amount of exposure, training, and practice is assumed to be a central factor behind the differences. While some preschoolers virtually bathe in early math in their everyday home environment, others get very little exposure and practice [12, 19). Thus, the present project is explicitly situated in a compensatory framework with a focus on opportunities for learning early math to compensate children from less resourceful home environments.

Accordingly, given an overall purpose of generating new knowledge to counteract the conspicuous differences in mathematics that are seen already in primary school and then tend to grow, our study targeted preschool districts with predominantly low socioeconomic and sociocultural status.

The pedagogical activities included in the study were, furthermore, designed to be inclusive and enable all children in a preschool group to participate. The play-&-learn game itself has an inclusive design in that children generally experience that they all play the same game with no child exposed as being behind or ahead. At the same time, each child is offered challenges according to her or his individual learning curve [20, 1]. In this, the game is both adaptive and inclusive, providing compensatory support (*adaptivity*) at the individual level without exposing the differences between the children in a group (*inclusiveness*) [1].

1.4 Practice orientation

The entire project was set in a practice-oriented context, with the aim to be closely in line with preschool practice in the following respects: (i) the resources for the preschool teachers were developed with a participatory design approach, (ii) researchers and preschool teachers had continuous contact and meetings during the whole study, from planning and development to the very data collection, and (iii) the interventions were carried out by the preschool teachers within the framework of ordinary preschool practice.

Expanding on (iii), the researchers' undertakings during the interventions included keeping in touch with the preschool teachers in charge, in the roles of supporters and trouble-shooters. For the project, it was essential that the interventions as such should be possible to initiate and implement by the profession within the framework of ordinary practice. In other words, the interventions should not be of such a nature that they require external or additional people, e.g., researchers, need to initiate and guide the activities.

1.5 The guiding principles

The guiding principles for the project are listed below.

1. **Accumulation of new knowledge**. To contribute new knowledge on how to improve preschool math instruction in order to promote children's development and learning, with a focus on children from lower SES backgrounds.
2. **Collaboration and participatory design**. To collaborate with and involve the profession in the project and utilize their knowledge and expertise, specifically with respect to preschool practice.
3. **Experimental control combined with ecological validity.** To aim at the combination of high scientific quality in a systematic well-controlled empirical intervention study with high ecological validity and practice orientation[2].
4. **Real world applicability**. To investigate whether and how the interventions can stand on their own and live on after the end of the project. This means that the pedagogical interventions must be possible to implement and carry out by professionals themselves without the support or help of researchers or other external actors.

1.6 The project's three study phases and Covid-19

The study can be subjugated into three phases to be described below. All of them, partly or completely, coincided with the outbreak of the Covid-19 pandemic and its devastating two first years.

Development (autumn 2018 – summer 2020). The novel teacher resources were developed by means of a participatory design process involving researchers and preschool teachers from a Swedish municipality.

Pilot study and finalization of study design (autumn 2020). A pilot study with about 30 preschool children and 8 teachers at two different preschools was carried out during early autumn, followed by final adjustments of the teacher resources and the finalization of the study design.

Main study (spring 2021). A comparative intervention study with three conditions was carried out at 21 preschool units including approximately 420 preschool children ages 4 to 6 years and 40 preschool teachers. The study addressed the children's progress in early math, and the preschool teachers' attitudes to early math and their views on the children's progress and their own work to support them.

This article represents our report of the challenges we faced and how we, given the circumstances, tried to adapt approaches and methods to answer our research questions and maintain the project's guiding principles.

Next, we will discuss the three phases one by one, whereafter the article is summed up with a general discussion of our experiences carrying out this study under the constraints of the Covid-19 restrictions.

[2] In relation to the project goal of deepening the understanding of real-world everyday practice in preschool and of what is possible to realize within these frames

2 Phase one: Development

The development phase spanned the period from autumn 2018 to summer 2020, i.e., the last third of this phase was affected by the Covid-19 pandemic. As to its content, the developmental phase included preparations for the study design and the development of the teacher resources in three parts.

- A ‘follow-up’ support module (dashboard) for the teachers to monitor the use of the game (Magical Garden) by individual children as well as the whole group of children.
- Educational resources (text and video) about early math as well as on preschoolers as learners in relation to the play-&-learn game (Magical Garden) such as ‘individual and group learning’ and ‘learning-by-teaching’.
- Educational resources (text and video) with suggestions for complementary (non-digital) activities that complement and enrich the content of the play-&-learn game and can be used for additional pedagogical support.

The goal was that all teacher resources should be relevant, needed, and useful for preschool teachers. To attain this goal, the developmental phase – from early conceptual frameworks to the actual implementation of the resources – spanned two years alternating participatory workshop sessions with preschool teachers and researchers, with longer periods of development by the researchers. In addition to preschool teachers and researchers, preschool administrators from the participating municipality (in central Sweden) were involved in the workshops.

The development followed an iterative design process workflow with a first stage of idea generation and systematisation ending in a conceptual design proposal. The second and third stages were oriented towards stepwise content and content formats. The fourth and fifth stages were devoted to the stepwise implementation of the web-based teacher resource support tools. These five stages were integrated with the five participatory and collaborative workshops.

With the employment of the participatory workshop sessions, we followed a well-established approach for the development of digital artefacts targeting a specified domain and user group [21, 22, 23]. This was important since the domain as such (early math) might be at odds with the interest of the user group (preschool teachers), both from a pedagogical as well as organisational point of view. Not only may preschool teachers (as mentioned above) have a low interest in math, but there are also often severe constraints as to resources in terms of time and personnel. In short, this means that the ‘teacher resources’ must be experienced as a meaningful and supportive tool adding ‘real world value’ in sometimes very constrained conditions.

When using a participatory design methodology, it is imperative not to interfere with each other’s areas of expertise. Here, the researchers represented the design and development domains, while the preschool teachers and preschool administrators represented the preschool domains and preschool perspectives. Specifically, researchers, in their role as design and development expertise, should help and support the preschool teachers to reflect upon and articulate their expertise, thoughts, and opinions all through the process. The final goal was a teacher resources package that enables teachers to initiate an early math programme centred around the play-&-learn game (Magical Garden) without specific training.

2.1 Workshop I: Brainstorming, functional analysis, and LoFi-prototyping

The aim of the first workshop was to generate conceptual design ideas for the teacher resources in the form of dynamic LoFi-prototypes. The researchers had prepared a presentation of the background, context, framing, and goals of the workshop together with instructions for the design methods to be used: brainstorming, functional analysis, and LoFi-prototyping.

The workshop started with a presentation of the ideas behind the workshop and a demonstration of the play-&learn game (Magical Garden). The teachers[3] were then split into smaller groups and instructed to generate as many ideas as possible using a 'democratic brainstorming' methodology. Next, they were instructed to carry out a 'functional specification', categorizing the generated ideas in groups of necessary, plausible, and unnecessary. The categorized ideas were thereupon organized and systemised into a structured, conceptual design map of content, functionality, and services. The conceptual design was then realized into a dynamic LoFi-prototype by means of paper sheets, cardboards, pencils, scissors, paper glue, etc.

The workshop ended with each workshop group presenting their design process and final LoFi-prototype, whereafter the researcher collected the LoFi-prototypes and summed up the workshop event.

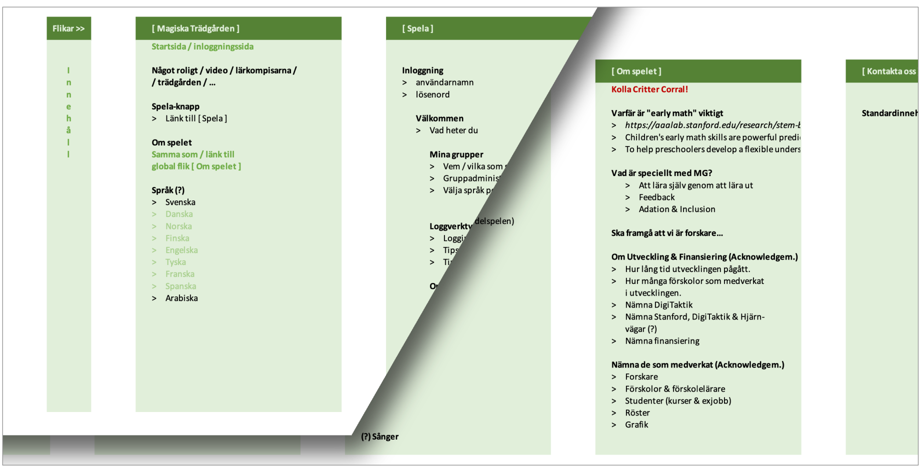

Figure 1. Parts of the preliminary conceptual design for teacher resources following Workshop I.

Following the workshop, researchers worked further with notes and collected material to come up with a preliminary conceptual design of the teacher resources (Figure 1).

2.2 Workshop II: Content and content formats

The theme for the second workshop was to discuss and reflect upon the preliminary conceptual design resulting from Workshop I (Figure 1) and to address the actual

[3] About half of the participating preschool teachers had previous experience of working with the game with groups of preschool children.

content and potential content formats, i.e., how the content in the teacher resources (such as material about early math, implemented pedagogical strategies, pedagogical tips, and follow-up tools) should be mediated in terms of format (text, video, and charts), interactivity, complexity, extent, etc. Preparing for the workshop, researchers wrote example texts and recorded example videos.

The workshop started with a walkthrough of the preliminary conceptual design (Figure 1), followed by a general discussion. After that, participants were organized into groups of three to five and instructed to evaluate the prepared example texts and example videos on wording, terminology, length, relevance, complexity, etc. After that, the groups were instructed to write or record their own suggestions for text or video materials – or edit the text and video examples prepared by the researchers (Figure 2).

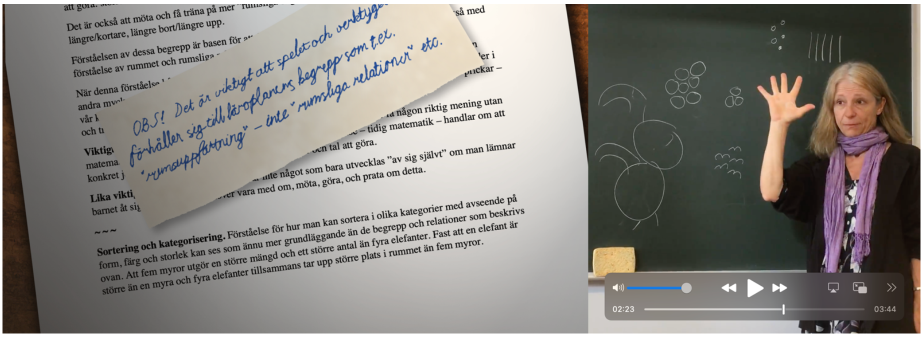

Figure 2. Text (with note) and video clip from Workshop II.

The workshop concluded with all groups presenting their works and findings, followed by (intensive) discussions as the participants had quite a lot of reflections, comments, and opinions.

Following the workshop, researchers refined the conceptual design and started to develop basic text and video materials for the teacher resources.

2.3 Workshop III: Refinements and the 'follow-up' module

The third workshop was split into two parts. The first part contained a discussion of the refined conceptual design with respect to the new text and video contents for the teacher resources produced by the researchers following Workshop II. The second part of the workshop centered on the 'follow-up' module (dashboard) presenting information and graphics of preschool children's progress in the play-&-learn game. Prior to the first part of the workshop, researchers prepared a slideshow for part one to have a 'common ground' to discuss, reflect, and comment upon. The second part of the workshop was managed by a master student who joined the project as a part of a course project. In time for the workshop, the master student had prepared a demonstration of what a follow-up module could look like.

The workshop started with the slideshow presenting the new text and video materials. After that, the workshop participants were handed printouts from the slideshow, split into groups, and instructed to discuss the text and video materials. This first part of the workshop was concluded with group presentations, followed by a general discussion and summing-up. The second part of the workshop started with the master student presenting the concept of a follow-up module, whereafter the participants were divided into smaller groups and engaged in the design of their own LoFi-prototypes for a follow-up module (Figure 3). Also this second part concluded with presentations of the LoFi-prototypes and discussions.

Figure 3. Parts of the ideas for a follow-up module.

After the workshop, researchers took on the actual implementation of a preliminary wed-based homepage for the teacher resources (including a set of short introduction videos) and a dashboard bridging the existing play-&-learn game module and the newly developed teacher resources homepage.

Up to this stage of the project basically nothing had to be modified. The first three workshops were basically unaffected by any Covid-19 related constraints. On a reflective note we ask ourselves whether we could have carried out these three workshops with similar output and results if we had been forced to carry out the workshops on-line, though still with possibilities to interact and to discuss around workshop materials. It is difficult to tell, but we would inevitably have encountered constraints regarding the social interaction and the possibility to walk around and (informally) take part in the discussions during the productive phases of the workshop. We also know that the actual workshops were quite successful. Years later workshop participants still remembered and brought up details from them, communicating a sense of "having contributed" to the product (the teacher resources) that in the end was developed, along with a desire to know more about other preschool teachers' experiences using the teacher resources. The shared atmosphere in a physical space is difficult to re-create in an online environment, and we may have been very lucky in that we were able to have the early project phases unaffected by the Covid-19 constraints. It would, furthermore, have been practically impossible to organize that many (groups of) participants at each and one of these three workshops; something that would have affected the outcome as well.

2.4 Workshop IV: Evaluations of the whole teacher resources package

At this stage a full preliminary implementation of the preschool teacher recourses package was at hand, and the fourth workshop was committed to the presentation and evaluation of this implementation. Specifically, the workshop focused on the follow-up module (dashboard), the introduction videos and the early math mathematics materials (from the teacher resources homepage), as well as the teacher resources homepage as a whole.

We were, however, now fully confined by the first wave of Covid-19 and 'social distancing' restrictions ruled out any form of workshop in a shared physical space why we, like many others, decided to go online with the fourth workshop. This proved to be easier said than done, especially as the whole preschool system was in a state of organised chaos and taking decisions on a day-by-day basis. As a result, the (online) workshop itself could only muster a handful of participants, mostly researchers and preschool administrators. When concluding the workshop, it was decided that two preschool principals would oversee a distribution and evaluation of selected workshop materials to the preschool teachers participating in the workshop series. The selected workshop materials were accompanied by instructions for testing and evaluation, and the results were then reported back to the two preschool principals and further to the researchers.[4]

Based on the workshop and the testing and evaluation collected from preschool teachers, a pilot-ready version of the teacher resources was developed and implemented during summer.

2.5 Workshop V: Presentation of the implemented teacher resources

Following the fourth workshop, a concluding fifth workshop was scheduled for the beginning of autumn 2021 to have a closure of the collaborative developmental project of the teacher resources. With Covid-19 still prevailing and reinstated restrictions, the preschool teachers were not able to attend.

With the workshop being more of a social event with researchers and the municipal preschool administrators, there was also discussions of the developmental project as such as well as some minor last-minute assessments of selected issues.

After this fifth and last workshop, the teacher resources package underwent some minor refinements before it was ready for pilot testing, adding a dashboard and a teacher resources website to the play-&-learn game.

3 Phase two: Pilot study

3.1 Implementation of the pilot study

The original pilot study was scheduled to take place during October to November 2020 in two separate preschool units with children and preschool teachers. The two main aims of the pilot study are listed below.

Aim 1: Test the functionality of the developed resources for preschool teachers in daily practice. This included:

(i) more technical aspects such as login and administration of teacher and children accounts, the robustness and comprehensibility of the follow-up module, functionality and usability of the links between the follow-up module, the

[4] In Sweden, it was at most times during the Covid-19 pandemic allowed – but not encouraged – to have physical work-related meetings in smaller groups. For preschool personnel, however, contacts with people outside a preschool context should be kept at a minimum.

play-&-learn game module, and the teacher resources web page (including pedagogical background, tips, and other information) as well as

(ii) educational aspects: that the resources aimed at preschool teachers are meaningful, needed, and useful for a preschool teacher who works with children using the play-&-learn game. Although this had to some extent been evaluated by several preschool teachers during the development phase, it was essential to test and evaluate this with preschool teachers without any previous experience of the digital play-&-learn game.

Aim 2: Test and secure all elements of the main study. The study being a comparative intervention study, pre- and post-tests should be pre-evaluated in smaller scale in relation to the target group. In such a pre-evaluation, in a pilot-study, on may for instance learn that the size of the test battery needs to be divided into separate sessions and identify potential ceiling and floor effects.

At the beginning of the autumn semester 2020, while planning the pilot study, we confronted a situation that we had never experienced before when working with intervention studies in preschool and classroom environments. On the one hand, unlike many other countries, preschool activities in Sweden continued essentially as usual for preschool teachers and children[5] while, on the other hand, no researchers were allowed to enter preschools on the premises to, for example, conduct pre- and post-tests. Nor could they be on site to observe how the interventions were realized in practice and have dialogues with teachers.

In this situation, we chose to exclude large portions of Aim 2 (see above) and cancel the pre- and post-tests that required our presence and direction on site, retaining only two web-based tests of preschool math, but no tests of executive functions.

Thus, while large portions of Aim 2 had to be left out for the pilot study, we estimated that we would be able to attain our goals for Aim 1, and this turned out to be the case. The follow-up tool and teacher resources could be tested in practice with groups of children making use of the play-&-learn game administrated and supervised by their teachers.[6] In this way, the pilot study provided us with an understanding of how the play-&-learn game with its added teacher resources was used and experienced by preschool teachers and children, and of how it worked technically on a slightly larger scale in a real-world setting. The pilot study also provided a first independent evaluation of the pedagogical meaningfulness of the follow-up tool as to content, functions, and context.

3.2 Decisions on the main study towards the end of the pilot study

As autumn 2020 passed, it became evident that the Covid-19 situation would not ease before the main study beginning in January to February 2021 and eventually, we had to decisively drop the originally planned pre-post-test battery (described below). With this decision we faced a significant challenge: How could we now study the children's development of mathematical knowledge and understanding in the three conditions?

In view of such a challenge, it seemed obvious that we should focus on the preliminary research questions addressing mathematical knowledge and

[5] The main difference for them was that parents were not allowed to enter the premises. Instead, drop-off and pick-up took place outside or at the entrance. Also, communication between parents and teachers moved to digital platforms.

[6] The intervention period for the pilot study was considerably shorter (6 weeks) than the scheduled main study period of approximately 14 weeks (whereof 10 weeks gameplay.)

understanding (Research questions 1 and 2) and leave out the additional research question targeting executive functions (Research question 3).

However, as the research team had an interest in executive functions and self-regulation, we decided to include an element of self-regulation training for the preschool children in the study, with associated resources for the teachers (see section 4 "Main study", below).

4 Phase three: Main study

Turning to the main study, the Covid-19 pandemic by now threatened to render our research questions and the whole study to naught. We will in this section start with a description of the two remaining research questions and the design of the three conditions which were to be compared in the study. This is followed by a description of the original methodological set-up. Thereafter, we address the challenges we faced with the situation imposed by the Covid-19 pandemic and how we had to rethink and adapt the methodological set-up in order to heed forward and answer our research questions.

4.1 The remaining research questions and the three conditions

As related above, the secondary research question addressing self-regulation in relation to math (Research question 3) was ruled out due to the Covid-19 restrictions at hand. The two other research questions were, however, still in place.

The research questions, thus, were the following:

1. Can use of the digital play-&-learn game Magical Garden support the development of basic mathematical skills to a larger extent than ordinary preschool practice (business as usual)?
2. Can children's use of the game Magical Garden together with *supplementary support for teachers* (possibility of follow-up and various forms of educational support material, explanatory, descriptive texts, in-depth texts, video material, tips, and games, etc.) support their development of basic math skills better than regular preschool pedagogy (*business as usual*)?

The three conditions that were compared in the study were:

MG-condition. Participating children used the digital play-&-learn game Anonymized in small groups, 5 to 8 children, for about 20 minutes, two-to-three times a week during a period of 14 weeks with 3 to 4 weeks off (without gameplay). The teachers did not have access to the newly developed teacher resources but were left with a minimal piece of summative information for each child, presenting the total time spent on solving math tasks and how much of the play-&-learn game the child had completed in per cent (%).

DT-condition. As in the MG-condition, participating children used the digital play-&-learn game Anonymized in small groups, 5 to 8 children, for about 20 minutes, two-to-three times a week, for a period of 14 weeks with 3 to 4 weeks off (without gameplay). This intervention featured the newly developed teacher resources and the preschool teachers had access to the follow-up module (dashboard) for the play-&-learn game and a rich resources homepage with tips on pedagogical math activities together with in-depth information on early math. Added to the DT-condition was also a self-regulation intervention called Kropp&Knopp (Eng. *Body&Brain*).

CT-condition. Participating children and teachers worked with early math according to their regular curriculum and were not subjected to any experimental intervention. Teachers were instructed to follow their regular pedagogical work (including math) and to keep a continuous documentation of their everyday activities and pedagogical work as information for the researchers. This information was important since Swedish preschools follow a very general curriculum for preschool math with considerable freedom how to translate the curriculum into their own pedagogical activities.

4.2 Original design of the main study

The main study was designed in accordance with a classic pre- and post-test approach, and the plan was that trained research assistants should visit the pre-schools and carry out the tests with the children. The pre- and post-tests on mathematics and self-regulation (executive functions) were both to be administered over a period of two weeks before and after the 14-week intervention period. Parental consent was required for children to participate in the pre- and post-test sessions. Given previous experience from studies with similar design, we expected the number of children with parental consent to be around 90% or 380 out of a total of 420 children in the participating preschool units.

With respect to math, the original plan was to conduct two pre- and post-tests in mathematics using a semi-digital test developed by the research group combining relevant parts of *TEMA 3* [24] and *Number Sense Screener* [25], and the likewise semi-digital *Ani Banani Math Test* (*ABMT*) which is a digital math test in a game-like format and validated in Norway for 5- to 7-year-olds [26]. Associated with the 'added (secondary) research question' addressing the possible relation of self-regulation skills with the use of the play-&-learn game in mathematics, we also intended to conduct a pre- and post-test battery for self-regulation skills and executive functions employing *Head-Toes-Knees-Shoulders* [27, 28], *The Dimensional Change Card Sort* and *The Flanker Fish Task* from the NIH toolbox of neuro-behavioural measurements [29]. To control for the influence of children's linguistic capabilities, we also planned to use *The Peabody Picture Vocabulary Test* [30].

Another part of the main study data collection relied on behavioural data logging of the children's interaction with the play-&-learn game reflecting the children's activities and development in preschool mathematics; how often a child played, how much time s/he spent on solving math tasks, and the child's path or progress through the difficulty levels.

We also planned to have regular conversations with the preschool teachers in the two intervention groups (the MG-condition and the DT-condition) to learn about their observations and opinions about the interventions as well as their thoughts about working with early math and preschool children. We also planned for similar conversations with the preschool teachers in the CT-condition, but in this case with a focus on the different math activities they engaged in with the aim to gain better knowledge of what "business as usual" could mean. An additional rationale for the interviews with teachers in the CT-condition was to compensate for possible Hawthorne effects in the intervention groups.

Still another planned data collection was a pre- and post-test questionnaire survey to be administered to the preschool teachers immediately before and after the 14-week intervention period. The questionnaire was developed to target the teachers' attitudes towards working with mathematics in preschool groups and confidence in their own ability to teach mathematics (self-efficacy).

In addition to these more targeted forms of data collection, we intended to personally visit all preschool units to gain a broader knowledge of the environments and the circumstances under which the study was conducted, as well as to meet with teachers and children, learn about their regular activities and procedures and take part of their perspectives on the interventions.

In other words, we had quite a detailed plan for our study – and then came Covid-19.

4.3 The – seemingly insurmountable – challenges

Since the main aim of the study was to evaluate two approaches to support preschool children's development in early math (a digital play-&-learn-game, and the game together with support for teachers, respectively) compared to regular preschool practice, we faced two seemingly insurmountable challenges.

1. How would we estimate the *initial status* in the three experimental conditions with respect to the participating children's early math abilities, when we would not be able to could visit the preschools to conduct *pre-tests* or some kind of screening of their abilities?
2. How would we possibly measure *learning*, when we would not be able to enter the preschools to conduct *any tests* (neither initial, nor follow-up-tests)?

4.4 Adaptations in relation to the challenges

4.4.1 Estimating the initial status in the three conditions

It was clear that we could not conduct regular on-site pre-tests with all participating children as such an approach would require the researchers or research assistants to enter the preschools and interact with the children. Were there any alternative methods to estimate the preschool children's initial status regarding mathematical ability in the tree conditions (MG, DT, and CT), so that we could compare them and thus map out a possible effect of one, or both, of the two experimental conditions (MG and DT)?

In this situation, one researcher in the team with extensive experience in data collection, proposed the possibility to use the play-&-learn game log data from initial game rounds to screen the participants' mathematical ability at the onset of the main study. In previous studies [1] using the play-&-learn game, we had observed an agreement between children's progress during the initial rounds (math tasks) and their scores on the standardized math test *Number Sense Screener*. Thus, by assessing the participating children's log data from the play-&-learn game for the nine initial rounds, we could screen all participants and get an estimation of the comparability between the three conditions.

For the participants in the MG- and DT-conditions, this data was collected automatically as soon as the children started using the play-&-learn game at the onset of the intervention period. To retrieve corresponding data from the participants in the CT-condition, we decided to slightly change the directive for this condition. They were instructed to use the play-&-learn game for two sessions of 20 minutes at the very beginning of the intervention period, thus enabling us to also analyse their first ten rounds. After these two 20-minutes sessions with the play-&-learn game, the participants in the CT-condition did not have any further access to the game.

In this way, we obtained comparable data sets for the three conditions – all collected at the very start of the main study intervention period of 14 weeks.

4.4.2 Measuring learning

For the two experimental conditions (MG and DT), we had an in-game learning measure (see above) in that the log provided information about children's progress in the game. Although this is relevant, it does not suffice as a learning measure. First, there was no comparable learning measure for children in the 'business as usual' control condition (CT). Second, when working with digital learning games it is necessary to have an external measurement separated from the learning game environment; only then can we assure whether learning effects gained in the game transfers to real-world situations outside of the game environment.

Here, one of the tests included in the originally planned test battery offered an opportunity. The *Ani Banani Math Test* (*ABMT*) [26] was a candidate to be one of two math tests for the original pre/post-test design, in which trained research assistants should have administered the tests with all participating children. Facing the Covid-19 restrictions, the research group began to discuss the possibility of having preschool teachers administer ABMT – as a follow-up test to measure the preschool children's math abilities directly after the 14-week intervention period. Further discussions with the preschool administrators and the preschool teachers involved in the study opened up for the possibility to introduce and train the preschool teachers to administer ABMT for a subset of children. Based on previous experience [31, 32] we aimed for about 35 children from each condition.

The decisive rational was that we, by using the data collected in screening all children, could filter out three matching and comparable subsets of children, one for each condition.

4.4.3 Filtering out participants for the follow-up test with ABMT

Our aim was now to collect 'follow-up data' on math development by means of ABMT for about 35 children per condition (MG, DT, and CT). The three conditions included the following number of children with parental consent: 113 in the DT-condition, 131 in the MG-condition, and 125 in the CT-condition.

To filter out matching and comparable subsets of children, a first step involved the exclusion of children in the MG- and DT-conditions who had not spent sufficient time with the play-&-learn game to be likely to demonstrate any treatment effects. The threshold for exclusion was set to 180 minutes of active engagement in solving math task[7]. In a parallel step, children in the CT-condition were excluded if they had engaged in the play-&-learn game for 60 minutes or more; this in order to minimize possible treatment effects (confounds) from the play-&-learn game[8]. Likewise, children in the CT-condition were also excluded if they had not been using the play-&-learn game long enough to reach ten rounds which was required for the screening (cf. above).

The next, second, step involved the exclusion of children with annotated special needs (e.g., language difficulties and different types of cognitive impairments) for all three conditions.

[7] NB. The 180-minute threshold corresponded to 'active engagement in solving math tasks' in the play-&-learn game and not time spent in other parts of the game, e.g., tending to the garden with its magical flowers.

[8] The instruction to the preschool teachers subject to the CT-condition was that children should not use the game for more than 40 minutes, but this proved difficult to maintain for all children.

In a third step, we excluded the most high-performing children as to their results on the screening. (The CT-condition contained a relatively lager proportion of high-performing children, resulting in a relatively smaller subset for the CT-condition, see below.)

After these three filtering steps, our samples sizes for the ABMT were as follows: 71 children in the MG-condition, 74 in the DT-condition, and 49 in the CT-condition.

Regarding the third step, our rational comes from earlier studies where approximately the top third of participating children repeatedly show no treatment effect. These children already perform at a high level and are seldom susceptible to any significant improvements from interventions [33]. Another benefit with the exclusion of the top third high-performing children was that differences between the distributions of the three subsets (as to the initial baseline measurements) now evened out. Yet another benefit concerns the overall aim of the project and that is our strive to contribute with new knowledge on how to use educational interventions to compensate children who, for various reasons, have difficulties and lag behind in mathematics. It is shown [10, 11] that children who are behind at the start of preliminary school are those most susceptible to fail in mathematics (as well as other school subjects). At the same time, we also know that these children can benefit significantly from early mathematics interventions [14, 15, 16, 10].

Finally, from each of the three subsets of 71, 74, and 49 children, children were randomly listed for testing while proportionally representing all 18 preschool units, resulting in three lists of 47 children, one for each condition. (The lists included more names than needed for the sake of the data collection, to allowing the teachers to skip over a child if, for instance, the child was unwilling, absent at the time, etc.)

4.4.4 Follow-up data collection using ABMT

Prior to the ABMT data collection directly following the 14-week intervention period, the preschool teachers received training on how to administer the test. The test consists of 18 tasks generating an individual test score from 0 to 18, and it is administered on a tablet, allowing for the children to interact with the tasks by means of a touch screen. Each task is, furthermore, introduced by the 'tester' reading the instructions aloud and the child then tries to solve the task. From the preschool children's perspective, ABMT looks much as a digital game to play together with their preschool teacher.

The training was set up as an hour and a half online workshop and included background information, general instructions, a walkthrough of ABMT and the test protocol, information of the inclusion criteria, time for the preschool teachers to practice for themselves, and the possibility to ask questions about anything that was unclear.

Prior to the actual data collection, the preschool teachers in question received lists with the children in their preschool unit selected for ABMT. The teachers were instructed to start with the child at the top of the list and then proceed down. All lists contained more names than the number of children required from each preschool unit, allowing for the preschool teachers to jump to the next child on the list if any of the following applied: a child was absent from preschool, a child did not want to participate, a child might have a negative experience of ABMT due to personal circumstances. Furthermore, if a 'not listed' child wanted to 'play' ABMT, the child was welcomed to do so, but we did not include the result in our data.

4.4.5 Data collection by means of questionnaires and meetings with preschool teachers

The second main research questions addressed whether the use of teacher resources integrated with the digital play-&-learn game in math can support preschool teachers in their pedagogical work with early math (with groups as well as individual children) so that as many children as possible develop basic mathematical skills.

Not to be mistaken, also this second research question has its focus on the potential effects on the preschool *children's* learning. At the same time, as discussed in the introduction section, teachers have a central and important role in supporting, supervising, and encouraging children's development and learning. The project, consequently, also had the goal to learn more about teachers' experiences and opinions on using the digital play-&-learn game, and specifically the teacher resources for the game, in a real-life context with groups of children. Furthermore, as already discussed, we were also interested to explore whether it would be possible to influence teachers' self-efficacy and attitudes towards math.

Our original plan was to conduct a pre/post-questionnaire survey with all participating preschool teachers on their attitudes on math, working pedagogically with math, math self-efficacy, etc. In addition, we planned for regular on-site meetings with the preschool teachers at the different units where we could probe for answers to questions such as: "Would there be any difference between the experimental conditions (MG and DT)?" and "Would preschool teachers in the DT-condition, having access to the teacher resource package, be more likely to change their self-efficacy and attitudes towards math in a positive direction?"

Having on-site meetings would also permit us to 'gently push' the preschool teachers to fill out the pre/post-questionnaires, as this can be quite 'vexing'. From previous studies [32, 34, 2] we were well aware that preschool teachers generally work with tight schedules, and already having them joining our study and engage in the pedagogical interventions with the digital play-&-learn game is actually 'more than enough'.

To go on with the planned meetings and the pre/post-questionnaire survey in face of the Covid-19 restrictions, we decided to go online. While the administration of the questionnaires themselves posed a minor problem, the possibility for us to 'nudge' the preschool teachers to fill them out was quite diminished. Our adaption to this was to send notifications both by regular e-mail and through the online questionnaire system but the absence of direct, real-world physical communication did have a negative impact on the questionnaire return rate.

As to the planned on-site meetings, we also here went online with continuous meetings on Zoom approximately every second week, with more frequent meetings during the initial and final phases of the intervention. In general, two researchers and two to four preschool teachers participated in each meeting. At the end of the 14-weeks intervention period we conducted a final, slightly longer, semi-structured interview with the preschool teachers at each preschool unit.

Altogether, the continuous meetings, including dialogues and interviews, with the preschool teachers generated a rich amount of information about the teachers experience and thoughts about the children's use of the play-&-learn game, math related activities in the larger preschool context, and the children's gradual development of mathematical abilities. From the teachers in the DT-condition, we also received information about their experience of using the teacher follow-up support, thus complementing the online pre/post-questionnaire survey.

4.5 Behavioural data logging from the play-&-learn game

While the Covid-19 restrictions affected most of our planned data collections, the behavioural data logging of the preschool children's interaction with the play-&-learn game would not be affected as long as the preschools remained open and the children played the game. Thus, the securing of screening data for the participating preschool children allowed us to make use of behavioural log data for direct comparisons between the two experimental conditions MG and DT.

The data logging as such captures timestamps and interactions (clicks and drag-&-drops) allowing us to extract measures for (among others) how much a child played (in hours and minutes), how far the child reached in the play-&-learn game in terms of difficulty levels (from 0 to 100%), how well the child performed in the play-&-learn game, and how much difficulty the child had with different kinds of math tasks.

The log data also enabled comparisons (MG vs. DT) as to the proportion of children that were enrolled in the study but never used the game, the proportions of children who spent more or less time interacting with the play-&-learn game given chosen thresholds, the proportions of children who reached specified levels of difficulty (thresholds), and the proportion of children who had difficulties playing the game.

5 Final discussion

We have described how we under the constrains of the Covid-19 pandemic managed to carry out a practice oriented comparative study under circumstances much different from those expected when we planned the study. In retrospect, we can see that we have learned a lot about what can be done and what is difficult or impossible to do remotely. In this final discussion, we return to and reason about the carrying out of the project relation to the guiding principles we had stated for it (Section 1.5.). To what degree were we able to follow these 'guiding principles'? How did the fact that we had to refrain from on-site activities affect the possibility to stick to the principles?

5.1 New knowledge

The first guiding principle was "To contribute new knowledge on how to improve preschool math instruction in order to promote children's development and learning."

Overall we managed to live up to this overarching goal and principle, that is to collect data that can provide new knowledge on preschool math instruction and children's early math learning. With possibilities to be on-site, we could have collected additional data and likely strengthened our contribution. Yet, under the circumstances the knowledge goal was met both in terms of quantity (multiple data sets and a sufficiently large number of participants) and quality (reliability and validity). Full reporting of collected data, statistical analyses, and results will take place in separate articles. In these papers we will discuss and reason about how use of the learning game had a clear positive impact on children's development of basic mathematical skills, specifically so for children from low SES-environments.

5.2 Collaboration and participatory design

The second 'guiding principle' was: "To collaborate with and involve the profession in the project and utilize their knowledge – specifically regarding preschool practice."

By the outbreak of Covid-19, we were fortunate to already have completed the three first workshops (Workshop I-III) of the participatory design, as these three workshops heavily relied on collaborative group activities in a shared space and time. For the two remaining workshops, centered on evaluations of the by then implemented teacher resources, the transfer to online activities was not entirely disadvantageous; the fact that the teacher resources now were evaluated by preschool teachers in their professional work environment was beneficial for the finalization of the teacher resources.

While the participatory design phase was more or less unaffected by the Covid-19 outbreak, it was a totally different matter with the data collection, especially as we (the researchers) and the research assistants could neither conduct pre/post-tests, nor be onsite for observations and interviews. From a collaborative perspective, however, this was not a negative turn of events. As we, for the main study, were forced to go online, we came to depend on the preschool teachers to actually carry out the study in the preschools with all the ifs and buts, as well as parts of the data collection.

This is not to say that the collaborative experience as such exceeded our expectations; rather the 'guiding principle' of collaboration became absolutely crucial for the project not fall apart. The introduction and start-up of the spring 2021 main study was both laborious and sometimes confusing, both for researchers and preschool teachers. The online meetings via Zoom were first quite cautious and formal, but as time passed, they became more and more relaxed and spontaneous. It was also clear that a mutual learning, between researchers and preschool teachers, took place in these dialogues. This mutual learning would, however, most likely have benefited more from the expertise of the preschool teachers if we had been able to visit the preschools. We would also have gained a more direct and better understanding of the preschool practice and how the interventions were realized in these practices. A detail that may have helped positively in establishing the connection and engagement, despite the distance situation, is that one of the researchers actually did go out to all preschools early on to hand out tablets, sheets with instructions and consent forms. Even though she only met one or two teachers, outside of the building, there was this direct and personal face-to-face meeting in real life.

5.3 Experimental control and ecological validity

The third 'guiding principle' was: "To aim at the combination of high scientific quality in a systematic well-controlled empirical study, and high ecological validity and practice orientation."

In essence, this was achieved. A rich amount of quantitative as well as qualitative data was collected under ecologically valid circumstances. The play-&-learn game was used within an everyday practice framework, entirely under the initiative and supervision of the preschool teachers. Likewise, the ABMT data collection was reportedly perceived by the children as an ordinary part of their preschool activities and many children enjoyed the game-like test. Also, for this guiding principle, the ecological validity most probably increased due to the Covid-19 situation in that neither we (the researchers) nor the research assistants were involved in any activities at the preschools. Under normal circumstances we would have interacted with the preschool children both during the pre/post-tests, as well as during the 14-weeks main study period. On the other hand, Covid-19 tricked us on our original objective to conduct a large scale pre- and post-test study with more than 400 children, and we also missed the opportunity to directly observe the use of the play-&-learn game and to collect more follow-up data. Furthermore, Covid-19 also constrained our means to address the preschool teachers experience of using the play-&-learn game, their attitudes towards preschool math, and their self-efficacy in the domain.

5.4 Real-world applicability

The fourth 'guiding principle' was: "To investigate whether and how the interventions can stand on their own and live on after the end of the project."

Once again due to the Covid-19 situation, this principle was more strongly put to test than originally planned. As we (the researchers) could not visit the preschools, the actual implementation of the intervention onsite in the preschools was *all* left to the preschool teachers. This compelled us not only to design better and more detailed introductory materials, but also to develop a short introductory course for ICT-administrators.

As of now, after the conclusion of the project, the municipality have started to implement the play-and-learn game in the entire preschool organization. This would probably not have happened if it had not already been shown possible for the profession themselves to initiate and implement the use of Magical Garden with its pedagogical framework within the preschool practice, without requiring external peoples such as researchers to be involved in initiating and guiding the activities.

Acknowledgments. We are grateful for funding from the Swedish Institute for Educational Research (*Skolforskningsinstitutet*), Marcus and Amalia Wallenberg Foundation, and a Collaborative Initiative at Lund University. Gratitude also goes to Associate Professor Susanne Kjällander, Stockholm University who was central for managing the project. We also warmly thank all children, preschool teachers, and preschool administrators who all participated in the study with so much engagement and patience in spite of the prevailing Covid-19 chaos.

CRediT. Agneta Gulz: Conceptualization, Methodology, Resources, Writing: original draft, review, and editing, Supervision, Funding acquisition. **Magnus Haake**: Conceptualization, Methodology, Software, Data curation, Resources, Writing: original draft, review, and editing, Visualization, Supervision, Funding acquisition.

References

1. Gulz, A., & Haake, M.: No child left behind, nor singled out: Is it possible to combine adaptive instruction and inclusive pedagogy in early math software? *SN Social Sciences*, *1*, Article 203. (2021) https://doi.org/10.1007/s43545-021-00205-7
2. Gulz, A., Londos, L., & Haake, M.: Preschoolers' understanding of a teachable agent-based game in early mathematics as reflected in their gaze behaviors – an experimental study. *International Journal of Artificial Intelligence in Education*, *30*, pp. 38–73 (2020). https://doi.org/10.1007/s40593-020-00193-4
3. Husain, L., Gulz, A., & Haake, M.: Supporting early math-rationales and requirements for high quality software. *Journal of Computers in Mathematics and Science Teaching*, *34*(4), pp. 409–429. (2015) https://www.learntechlib.org/primary/p/149820/
4. Clements, D. H., Sarama, J., & Germeroth, C.: Learning executive function and early mathematics: Directions of causal relations. *Early Childhood Research Quarterly*, *36*, pp. 79 -- 90 (2016) https://doi.org/10.1016/j.ecresq.2015.12.009
5. ten Braak, D., Lenes, R., Purpura, D. J., Schmitt, S. A., & Størksen, I.: Why do early mathematics skills predict later mathematics and reading achievement? The role of executive function. *Journal of Experimental Child Psychology*, *214*, Article 105306 (2022) https://doi.org/10.1016/j.jecp.2021.105306
6. Clements, D. H., & Sarama, J.: Myths of early math. *Education Sciences*, *8*(2), Article 71 (2018) https://doi.org/10.3390/educsci8020071

7. Tymms, P., Jones, P., Albone, S., & Henderson, B.: The first seven years at school. *Educational Assessment, Evaluation and Accountability*, *21*, pp. 67--80 (2009) https://doi.org/10.1007/s11092-008-9066-7
8. Palmer, H.: *Hur blir man matematisk? Att skapa nya relationer till matematik och genus i arbetet med yngre barn*. Liber. (2011)
9. Schacter, J., & Jo, B.: Improving preschoolers' mathematics achievement with tablets: A randomized controlled trial. *Mathematics Education Research Journal*, 29(3), pp. 313–327 (2017). https://doi.org/10.1007/s13394-017-0203-9
10. Jordan, N. C., Glutting, J., Dyson, N., Hassinger-Das, B., & Irwin, C.: Building kindergartners' number sense: A randomized controlled study. *Journal of Educational Psychology*, *104*(3), pp. 647-- 660 (2012b) https://doi.org/10.1037/a0029018
11. Desoete, A., Ceulemans, A., De Weerdt, F., & Pieters, S.: Can we predict mathematical learning disabilities from symbolic and non-symbolic comparison tasks in kindergarten? Findings from a longitudinal study. *British Journal of Educational Psychology*, *82*(1), pp. 64 -- 81 (2012) https://doi.org/10.1348/2044-8279.002002
12. Jordan, N. C., Kaplan, D., Ramineni, C., & Locuniak, M. N.: Early math matters: kindergarten number competence and later mathematics outcomes. *Developmental psychology*, *45*(3), pp. 850--867 (2009) https://doi.org/10.1037/a0014939
13. Hannula, M. M., Lepola, J., & Lehtinen, E.: Spontaneous focusing on numerosity as a domain-specific predictor of arithmetical skills. *Journal of Experimental Child Psychology*, *107*(4), pp. 394--406 (2010) https://doi.org/10.1016/j.jecp.2010.06.004
14. Bullough, R. V., Jr., Hall-Kenyon, K. M., MacKay, K. L., & Marshall, E. E.: Head start and the intensification of teaching in early childhood education. *Teaching and Teacher Education*, *37*, pp. 55--63 (2014) https://doi.org/10.1016/j.tate.2013.09.006
15. Clements, D. H., Sarama, J., Spitler, M. E., Lange, A. A., & Wolfe, C. B.: Mathematics learned by young children in an intervention based on learning trajectories: A large-scale cluster randomized trial. *Journal for Research in Mathematics Education*, *42*(2), pp. 127--166 (2011). https://doi.org/10.5951/jresematheduc.42.2.0127
16. Greenes, C., Ginsburg, H. P., & Balfanz, R.: Big math for little kids. *Early Childhood Research Quarterly*, *19*(1), pp. 159--166 (2004). https://doi.org/10.1016/j.ecresq.2004.01.010
17. Ramani, G. B., & Siegler, R. S.: Reducing the gap in numerical knowledge between low- and middle-income preschoolers. *Journal of Applied Developmental Psychology*, *32*(3), pp. 146--159 (2011). https://doi.org/10.1016/j.appdev.2011.02.005
18. Ramey, C. T., & Ramey, S. L.: Early intervention and early experience. *American psychologist*, *53*(2), pp. 109--120 (1998). https://doi.org/10.1037/0003-066X.53.2.109
19. Mononen, R., Aunio, P., Koponen, T., & Aro, M.: A review of early numeracy interventions for children at risk in mathematics. *International Journal of Early Childhood Special Education*, *6*(1), pp. 25--54 (2014). https://doi.org/10.20489/intjecse.14355
20. Haake, M., Husain, L., Anderberg, E., & Gulz, A.: No child behind nor singled out? Adaptive instruction combined with inclusive pedagogy in early math software. In C. Conati, N. Heffernan, A. Mitrovic, & M.F. Verdejo (Eds.), *Lecture notes in computer science: Vol. 9112. Artificial intelligence in education*, Vol. 9122, pp. 612—615 (2015). Springer. https://doi.org/10.1007/978-3-319-19773-9_74
21. Bødker, K., Kensing, F., & Simonsen, J.: *Participatory IT design: Designing for business and workplace realities*. The MIT Press. (2009)
22 Simonsen, J., & Robertson, T. (Eds.): *Routledge international handbook of participatory design*. Routledge. (2013)
23. Spinuzzi, C.:The methodology of participatory design. *Technical communication*, *52*(2), pp. 163--174 (2005)
24. Ginsburg, H. P., & Baroody, A. J. (2003). Test of early mathematics ability (3rd ed.). Pro-Ed. (2003
25. Jordan, N. C., Glutting, J. J., & Dyson, N.: *Number Sense Screener (NSS) user's guide, K–1* (research edition). Brookes. (2012a) https://brookespublishing.com/product/nss/
26. ten Braak, D., & Størksen, I.: Psychometric properties of the Ani Banani Math test. *European Journal of Developmental Psychology*, *18*(4), pp. 610--628 (2021) https://doi.org/10.1080/17405629.2021.1879046
27. Cameron Ponitz, C. E., McClelland, M. M., Jewkes, A. M., Connor, C. M., Farris, C. L., & Morrison, F. J.: Touch your toes! Developing a direct measure of behavioral regulation in

early childhood. *Early Childhood Research Quarterly*, *23*(2), pp. 141--158 (2008) https://doi.org/10.1016/j.ecresq.2007.01.00
28. McClelland, M. M., Cameron, C. E., Duncan, R., Bowles, R. P., Acock, A. C., Miao, A., & Pratt, M. E.: Predictors of early growth in academic achievement: The head-toes-knees-shoulders task. *Frontiers in psychology*, *5*, Article 599 (2014) https://doi.org/10.3389/fpsyg.2014.00599
29. Zelazo, P. D., & Bauer, P. J. (Eds.): *National Institutes of Health Toolbox cognition battery (NIH Toolbox CB): Validation for children between 3 and 15 years*. Wiley-Blackwell (2013)
30. Dunn, L.M., & Dunn, D.M. *PPVT-4: The Peabody Picture Vocabulary Test* (4th ed.). Pearson Assessments (2007) https://www.pearsonassessments.com
31. Haake, M., Axelsson, A., Clausen-Bruun, M., & Gulz, A.: Scaffolding mentalizing via a play-&-learn game for preschoolers. *Computers & Education*, *90*, pp. 13–23 (2015). https://doi.org/10.1016/j.compedu.2015.09.003
32. Axelsson, A., Andersson, R., & Gulz, A.: Scaffolding executive function capabilities via play-&-learn software for preschoolers. *Journal of Educational Psychology*, *108*(7), pp. 969–981 (2016). https://doi.org/10.1037/edu0000099
33. Schwartz, D. L., Cheng, K. M., Salehi, S., & Wieman, C.: The half empty question for socio-cognitive interventions. *Journal of Educational Psychology*, *108*(3), pp. 397--404 (2016) https://doi.org/10.1037/edu0000122
34. Gulz, A., Kjällander, S., Frankenberg, S., & Haake, M. Early math in a preschool context: Spontaneous extension of the digital into the physical. *IxD&A: Interaction Design and Architecture(s)*, *44*, pp. 129–154. (2020) https://doi.org/10.55612/s-5002-044-007