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► To cite this version:

Lena Lindenskov, Katrine Kirsted. Theoretical constructs for early intervention programs in mathematics: Who cares?-A Danish example. CERME 10, Feb 2017, Dublin, Ireland. hal-01950518

HAL Id: hal-01950518

<https://hal.science/hal-01950518>

Submitted on 10 Dec 2018

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Theoretical constructs for early intervention programs in mathematics: Who cares? – A Danish example

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“There is nothing so practical as a good theory”. The statement from Kurt Lewin is frequently cited, also in mathematics education. The statement invites for and requires close cooperation between different agents, whatever their specific relation to practice and theory is. It is not a straightforward endeavour. One reason is that the term theory as well as the term practice may very well be given different meanings by different agents. This variation is, in our view, to be considered in “implementation research” and Lewin’s statement ought to be qualified by two questions: “Who cares about a good theory?” and “What makes a good theory good for whom?”

This paper explores the variation of how theory is perceived by mathematics teachers and by mathematics researchers involved in a developmental project on early intervention in mathematics education in Denmark. The paper exemplifies how agents’ different work conditions and work requirements seem to constitute qualitatively different needs for theoretical constructs, despite some common interests.

Keywords: Early intervention programs, teaching principles, theoretical constructs.

Background for the early mathematics intervention project

We noticed a long tradition of integrating early mathematics intervention programs into compulsory education practice like, e.g. Mathematics Recovery (MR) (Wright, 2006; Wright et al, 2007) and Extending Mathematical Understanding Intervention Program (EMU) (Gervasoni, 2016), in Australia, Ireland, the UK and the USA. A similar tradition exists in Denmark for early reading intervention programs, as such programs are implemented at a regular basis in all schools in Denmark. Either as part of a municipal policy or a matter of choice, schools launched early (from the first grade) intervention processes in reading to support individual children, who show signs of reading difficulties.

At the ministry level in Denmark concerns were raised about pupils failing at mathematics in the National Official Guidelines in the 2003 National Mathematics Curriculum from the Ministry of Education (UVM, 2003). In 2004 the need to support failing pupils in mathematics in the first school years was emphasised (Mortimore et al.) and the national official guidelines to the revised 2009 national curriculum (UVM, 2009) described, for the first time, the issues in detail. Still, no intentions of integrating programs for early mathematics intervention into compulsory education practice were seen in Denmark until recently (Lindenskov, 2007).

In 2009 the material Early Intervention in Mathematics [Danish: Tidlig Indsats i Matematik, TIM], written to primary school mathematics teachers was published and used in some places. Just before, in 2007 local politicians and school authorities in the municipality of Frederiksberg in the capital area, decided to give priority to mathematics teaching and learning in their 9 public schools in the period 2007-2013. Priority was given to a development project on early mathematics intervention

for their 9 schools in collaboration with the researchers Lena Lindenskov and Peter Weng. It soon became clear that the existing intervention framework and written materials solely focused on numbers and arithmetic, which were insufficient to comply with the Danish Mathematics Education Philosophy and Curriculum. Also, approaches in the existing intervention framework and written materials were insufficiently inquiry and problem based to correspond with the curriculum. Finally, teachers' freedom and responsibility to adapt materials to their own students were too limited in the existing frameworks and materials.

With this background a research-based developmental project with four design cycles was prepared in order to develop a Danish program for early intervention in mathematics that would fit into the Danish Mathematics Education Philosophy and Curriculum. The private Danish fund Egmont showed interest in a Danish early mathematics intervention program (personal communication), and together Egmont, Frederiksberg Municipality and Aarhus University assured the budget for this project. The project was named Early Mathematics Intervention at Frederiksberg with the Danish abbreviation TMF [Danish: Tidlig Matematikindsats Frederiksberg].

Perceptions of what is good theory – by mathematics school teachers

Our research question is, *what is a good theory for whom - teachers as well as for researchers?* Our analyses draw on our communication with the 18 teachers involved in the design cycles of the project. In the following these teachers are called pilot teachers. All pilot teachers were chosen by their school principal as among the most qualified and motivated mathematics teachers at the school. Some also were 'Mathematics Counsellors' with a one-year diploma course.

It is the use of theoretical constructs in the four cycles, which is analysed in the following. We analyse interactions between teachers and researchers. The data come from written materials and recorded minutes and notes from seminars¹, training sessions, coaching sessions and e-mails

Generally, Danish teachers have a relatively high self-confidence and a strong wish to influence. It is shown, for instance, that Danish teachers, more than British teachers, prioritise their students' personal development and see their students' mathematical development as a means for personal development (Kelly, Pratt, Dorf & Hohmann, 2013). Because of the way the 18 pilot teachers were chosen by their principals, we anticipated that the teachers would be involved, to a high degree, in the project's four design cycles. The specific choice of mathematical and other aspects for the framework and written materials for the early intervention was actually made in dialectic processes involving the researchers and the 18 pilot teachers. Further descriptions of the cycles are found in Lindenskov & Weng (2014).

¹ Mathematics Recovery Programme (MR) is a source of inspiration for the developmental project, see Wright et al., 2007. This is why we included a teacher seminar with Ms. Noreen O'Loughlin from Mary Immaculate College, University of Limerick focusing both on some hypotheses and issues in MR and on specific concerns at Frederiksberg.

The framework and materials developed through four design cycles

(1) From January 2009 to September 2009, Weng and Lindenskov developed the first draft material, based on theory, empirical results and their knowledge about mathematics in life and in primary and lower secondary schools in Denmark. They initially doubted whether the teachers would find it relevant to study the rationales and theory behind the choice of mathematical areas, materials and evaluating and teaching principles. That is why only a few theoretical constructs and justifications were in the first draft communicated to the teachers.

But, as the structure and each part of the draft material were critically explored and discussed during the teacher training sessions from 14 - 18 September 2009, this expectation of the teachers' perceptions of their needs for theory was wrong. The teachers endorsed the underlying ideas, but actually asked for further explanation of rationales and theoretical constructs. The teachers also asked for an extensive introduction to the program as such. The time teachers were expected to use in the development processes did not include reading articles, so the researchers presented articles orally and provided printed extracts or copies of some articles as handouts. The main printed materials were newly developed diagnostic test materials and the problem solving materials to be used with their students, plus general introduction and justification for the choice of mathematical areas and instruction approach.

At the end of the week, the teachers suggested that measurement as a mathematical area and the use of measurements in other mathematical areas should be expanded in the next draft.

(2) Lindenskov and Weng developed a second draft of material based on the pilot teacher feedback and feedback from the research assistant. This meant that for more mathematics areas further justification for and explanation of rationales and theoretical constructs were included. The second draft was sent to each school October 2009 for experimenting. Each pilot teacher tried out specific parts of the material in the fall of 2009. The distribution of the parts to each school was decided through discussions among all pilot teachers. Each pilot teacher was requested to try out two or three activities with as many pupils as possible. The age of the pupils was not important. If possible, more material was to be attempted. The pilot teachers were given a specific task in order to evaluate the materials: they were asked to document in as much detail as possible - by writing in pre-made tables - how each mathematics task and each mathematics and attitude question led to pupil-teacher conversations which could indicate the pupil's thinking. The experiments were concluded with a seminar on 3 December 2009, where each pilot teacher presented results. Anything that had particularly surprised the teachers was also presented and some common concerns were then discussed. It was put forward that the pages with descriptions of justifications and theoretical constructs were helpful, 'or else we do not know why the chosen mathematical areas, concepts and competences are important to focus on.'

(3) Based on these results Weng and Lindenskov developed the third draft material and introduced it at a seminar on 28 January 2010. Justifications and theory were included for all mathematical areas. In the following months, each pilot teacher tried out parts of the material with a number of pupils. This time all the pupils were in the second grade. The aim was to allow the pilot teacher to experience the structure of the material and to practice pupil-teacher conversation. Peter Weng

visited and coached every teacher once and the teachers were invited to contact the researchers at any time during the pilot study.

At a midway seminar on 9 March 2010, the teachers described their general impression as positive and generally considered the material adequate. Several pilot teachers said they found it motivating to work with the material together with the pupils and that they had heard from the pupils' ordinary mathematics teachers that the intervention seemed to have a positive impact on the pupils' learning process.

The individual schools' prioritization of subjects was also discussed: how to decide between pupils' participation in a class excursion or a TMF session?

At the seminar a representative from the Egmont Foundation was present, as the Foundation had decided to fund the project. In the developmental project, the choice of pupils was left to the schools and the criteria differed between schools. The Egmont representative was particularly interested in the discussions on ethical issues: Whether pupils with very weak home support should be chosen over pupils with better support from home, who would probably benefit more? It is well known from research that socioeconomic factors are important for pupils' learning and development. Maybe particular pupils need this intervention the most, but are they really the ones chosen?

Issues regarding the scope and range of the material were discussed, for instance how to prioritise between presentations of many mathematical aspects or assuring success in fewer mathematical areas. The risk that the material put severe strain on teachers, especially when they were unfamiliar with it, was also discussed. To illustrate this discussion, we have listed three pilot teacher transcripts and one researcher transcript below:

Teacher 1: I feel pinned down by the material. I feel like, 'Now I must do this, then I must do that,' and you have to look for concrete material yourself. It is very restraining. While I look for extra material, I give the pupils small tasks on the computer to work with, OK.

Teacher 2: The material could be constraining. But the material is important as a database of ideas. The material gives me ideas. It supports my own inspiration process and it helps me to include everything in my practice.

Teacher 3: The material is useful, when I prepare the intervention sessions.

Researcher Weng:

Try to think about the material as something that provides you with opportunities and inspiration. We invite you to a flexible adaptation to specific pupils.

(According to the minutes, authors' translation)

The final seminar on 27 May 2010 discussed organisational and psychological issues in detail. The teachers wanted organisational and psychological aspects of individual pupils' learning and instruction to be emphasised as equally as the mathematical aspects.

Also the teachers again asked for more geometry and measurement in future versions, as well as a compiled list of recommended materials, but they did not mention any further need for justification and theory. (According to the minutes, authors' translation)

(4) The fourth draft was developed by 12 August 2010 and was to be used from 2010 onwards in the regular TMF for individual second grade pupils in all of Frederiksberg's public schools. The research assistant, Tina Kjær, examined the material and ensured that the teachers' suggestions were taken into account. Strongly supported by the pilot teachers' feedback, organisational and psychological aspects of individual pupils' learning and instruction were included as just as important as mathematical aspects.

Example of how researchers' theoretical understanding is communicated to teachers

As an example of how the researchers communicated their theoretical understanding underpinning the developmental project to the pilot teachers, we have chosen the mathematics area "Basic Strategies for Numbers in Addition and Subtraction". The table below shows in the left column four of the theoretical constructs chosen by the researchers to underpin the project. The right column shows how the constructs were being communicated and discussed between researchers and teachers. The right column consists of citations from the final written materials, which was published in 2013 and meant to be studied and discussed among teachers involved in intervention projects.

| Researchers' choice of theoretical constructs and justifications | Citations from the published intervention materials (Lindenskov & Weng, 2013) |
|---|---|
| Relational understanding (RU) and instrumental understanding (IU): Although IU in its own context is often easier to understand and gives correct answers with less knowledge involved, RU is more adaptable to new tasks and easier to remember. (Skemp, 1976/2006). | When the pupil experiences a productive development in his/her basic strategies in addition and subtraction, it opens the pupil's possibilities of becoming capable in doing relevant addition and subtraction and to use it in many contexts. Also, potentially this experience will contribute to another highly relevant math competence: good estimating skills for big numbers. |
| Constructivist teachers' primary activity is communicating with students. In the constructivist view, teachers should continually make a conscious attempt to "see" both their own and the children's actions from the children's points of view. (Cobb & Steffe, 1983). | Some teachers might, for the last decades, have misunderstood the core of constructivism. Some teachers might have been inclined not to interfere when the pupils calculated and developed their calculation skills and strategies. Some teachers might have believed that the pupils by themselves would develop at the pace that was most optimal for them individually. But we know, it is a risky affair. |

| | |
|---|--|
| <p>Pupils who engage in strategy development decisively perform better in the long run than pupils who do not.</p> <p>(Ostad, 2008).</p> | <p>Pupils, who from an early age, start developing his/her strategies, tend to continuously improve existing strategies and increase the number of strategies. In contrast, pupils, who stick to their strategies, tend not to start improving them until later on. It is shown that pupils, who stop developing their strategies, will toil hard and will still lag behind.</p> |
| <p>Strategies, strategy development and teaching strategies should be the core of fundamental mathematics instruction and learning.</p> <p>(Ostad, 2013).</p> | <p>Do not just present materials for the students to acquire new further learning. Let the pupil use materials and activities in order to consolidate what is almost or recently learnt as a means to improve the pupil's self-confidence and realistic self-perception of addition and subtraction skills. We recommend that the teacher talk with the pupil about his/her strategies, i.e. by regularly asking how long this strategy has been used, if the strategy leads to the right results, if the pupil uses other strategies, too, or thinks other strategies could be used. Appropriate further learning may well be about strategy development.</p> |

Conclusion

This paper has shed light on what is a good theory for whom - teachers as well as researchers, how to explain theory and justifications to the pilot teachers in a meaningful way and how to develop material in collaboration between researchers and teachers? During the four development phases the pilot teachers endorsed the underlying ideas of the intervention project and asked for the rationale behind every included aspect to be explicitly communicated. They encouraged more extensive introduction and to expand the included measurement aspects into two measurement aspects.

The teachers explicitly endorsed the theoretical construct and justifications in the material, as they said it helped them to acknowledge many opportunities to help the pupils and to identify pupils' potentials and motivation while exploring and developing their mathematical needs. The teachers appreciated that the material gave a firm frame and at the same time invited and inspired the teachers to adapt and further expand the materials to the specific learning situations with the pupils. The teachers recommended the material to be expanded with more mathematical concepts and competences, which are considered relevant in the Nordic contexts (Dalvang & Lunde, 2006; Niss & Højgaard, 2011) and by the teachers as potentially troublesome for the weaker pupils, and to expand the materials on measurements and part-whole.

The teachers asked for further ideas and materials which could be used as they were or could be adapted in order to fit their own pupils' needs and motivations. The teachers did not suggest more clarified theoretical constructs and justifications underpinning the program than were communicated to them already.

For the educational researcher the task was to find and select theoretical constructs to underpin the intervention and communicate these to the teachers, as it is further described in Lindenskov et al (2016). It could not be communicated as in scientific journals, but as justified practical advices. Both theorists and practitioners care for theory, but in very different ways.

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