Who or what is to change? From changing teachers to changing teaching in early mathematics innovation

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Abstract: The focus of this article is on how change can be investigated and understood within the two research fields of beliefs and implementation. *Even though beliefs research and implementation research share the same goal – to improve (mathematics) education – the object of study and unit of analysis differs and thus also how change is viewed and investigated. The article uses a study as an empirical example, in which preschool mathematics education developed in a previous study was implemented on a larger scale in other preschools.* With this study, we elaborate on the object of study and unit of analysis in beliefs research and implementation research, and on how this imposes differences in the empirical material and in how this material is analysed. Finally, we elaborate on how these differences impose whether and how change has occurred.

Keywords: early mathematics, innovation, change, implementation, toddler mathematics

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1 Introduction and research question

Over the years, there has been a considerable amount of research on teachers' beliefs. The assumption is that teachers' beliefs are significant in terms of what is taught and how it is taught, and thus they influence what is learned in the classroom (Wilson & Cooney, 2002). Another field of research that investigates teaching and learning is implementation research, which is the study of how to create lasting change of innovations (Century & Cassata, 2016). Although beliefs research and implementation research share the same goal of improving (mathematics) education, their object of study and thus their unit of analysis differs. Previous studies have not compared the fields of beliefs research and implementation research, despite their shared aim of improving mathematics education. In this article we elaborate on how the differences in object of study and unit of analysis in beliefs research and implementation research imposes a shift of focus from teachers to teaching. More specifically, we will elaborate on how these differences impose

- differences in the empirical material developed within the studies,
- differences in how the empirical material is analysed, and
- differences in when a change is considered to have occurred.

To elaborate on these differences, we use as an empirical example *a study in which preschool mathematics education developed within one study* was scaled up in a second study. The first study was an intervention where mathematics education for toddlers (1- to 3-year-olds) was developed in collaboration between two researchers and three preschool teachers. There were both qualitative and quantitative developments in the use of numbers by the children in the intervention group compared to those in the control group (Palmér & Björklund, 2024). Based on these positive results, a new study was initiated with the aim of implementing the intervention on a large scale in other preschools. It is the second study that will be used as an empirical example in this article.

2 Beliefs research and implementation research

Beliefs research is a well-established research field within mathematics education. According to Ambrose (2004) and Pajares (1992), beliefs have two primary sources: emotional experiences and cultural transfer. It is the emotional part that distinguishes beliefs from knowledge. Most often, beliefs research focuses on the change and/or development of beliefs, where fundamental questions concern whether beliefs are changeable or static, and if they are changeable, how beliefs can best be changed. A review of 79 beliefs studies within engineering education research shows that the most commonly stated purpose for studying beliefs is that beliefs inform behaviour. The second-most commonly stated purpose is the claim that beliefs are related to how students learn and/or that beliefs can be used to inform teaching practices (Kramer et al., 2024). Based on a research overview on beliefs research in mathematics education, Phillip (2007) argues that changes in beliefs can result in changes in practice and vice versa, but there is no certainty that change in one of these will impose change in the other.

In several studies on beliefs, teachers' teaching appears inconsistent with their beliefs. This is explained in different ways, for example, by suggesting that beliefs are situated. According to Skott (2001), beliefs are not situated in that they change in different situations; instead, it is the goals of the teachers that change between situations. In every teacher-student interaction there are competing motives and

objectives, and these influence teachers' beliefs about mathematics – about mathematics as a subject and about the teaching and learning of mathematics – so that they are contextualized differently in different situations. Three other explanations for inconsistencies between teaching and beliefs are that the individuals are actually being inconsistent, that other not yet investigated beliefs are dominant in the situation, and that the individuals have unconscious beliefs (Wilson & Cooney, 2002). Advocating beliefs as unconscious or inconsistent raises important epistemological questions about the nature of knowledge and agency in teaching, suggesting that what teachers 'know' may not always be accessible to conscious reflection or consistent with their actions (Fives & Buehl, 2012). Wilson and Cooney do argue, however, that it is problematic when researchers claim inconsistency between teachers' beliefs and observed teaching as there can be several other explanations for beliefs not being in line with teaching. One explanation is that the researcher and the teacher have different interpretations of concepts. Another is that the teacher might not act according to their beliefs due to practical circumstances. A third explanation is that the researched beliefs are peripheral to the teacher and that other more central beliefs are the ones being expressed at the moment.

Based on a review of implementation research, Century and Cassata (2016) conclude that improving education requires processes for changing individuals, organizations, and systems. Even though there are a plethora of interventions where scaling up is critical from both a researcher and practitioner view, the process of scaling up is sparsely researched, and even though educational implementations have been studied for a long time, naming the field "implementation research" is relatively new. The field emphasizes that successful interventions are not easily transferred to a larger community of teachers and that all interventions undergo changes when implemented in new settings (Century & Cassata, 2016).

> […] implementation research [is the] systematic inquiry regarding innovations enacted in controlled settings or in ordinary practice, the factors that influence innovation enactment, and the relationships between innovations, influential factors, and outcomes. (Century & Cassata, 2016 p. 170)

In implementation research, not all elements of an intervention are seen as equal; some are considered core components, serving as key contributors to outcomes of interest and primary mechanisms for change. Further, the notion of scale may place a focus on quantities instead of qualities. However, Century and Cassata (2016) emphasize that studies that isolate, decontextualize, and simplify issues regarding the

complexity of education decrease the applicability of the results from implementation research. In line with this, Coburn (2003) argues that definitions of scale have traditionally had a restricted scope, focusing on expanding the number of schools or teachers reached by an implementation rather than the depth of change achieved through it. Coburn challenges this with an alternative definition of scale that places less emphasis on numbers and more on the nature of the change in classroom instruction; that is, on the nature of the teaching. This definition highlights four key aspects; depth (the nature and quality of change), sustainability (change over time), spread (within each setting), and ownership (autonomy of teachers).

3 The study

In this article, we elaborate on how differences in beliefs research and implementation research impose

- differences in the empirical material developed within the studies,
- differences in how the empirical material is analysed, and
- differences in when a change is considered to have occurred.

The first of these questions will be addressed based on previous research on beliefs and implementation. The second and third questions will be addressed with reference to empirical material from a study in which preschool mathematics education developed within one study was scaled up in a second study. Thus, the intention is not to analyse the study on preschool mathematics education per se but to illustrate how the unit of analysis differs depending on whether the analysis is based on beliefs research or implementation research. As a background for understanding the nature of the empirical material and thus the analyses, information on the study on preschool mathematics education is provided below.

In an intervention study, mathematics education giving the youngest preschoolers the best conditions for learning mathematics was developed and tried out in authentic Swedish preschool settings (see for example Björklund & Palmér, 2022; Palmér & Björklund, 2023). The study was a combined research-development project conducted in collaboration between researchers and preschool teachers in three Swedish preschools (financed by the Swedish Institute for Educational Research, grant no. 2018-00014). The aim of the combined research-development project was partly to investigate how ongoing preschool activities could become the starting point

for mathematics education in which toddlers are given the opportunity to distinguish necessary aspects of numbers, and partly to investigate how such activities can advance toddlers' development of numerical skills. In the study, teaching activities were developed in accordance with three design principles (Palmér & Björklund, 2023). First, the context of the activities ought to be based on children's experiences, needs, and interests, and they should be familiar so that the children can participate, relate to, and reason about the content based on their previous social and cultural experiences. At the same time, in line with variation theory (Marton, 2015), interference from irrelevant elements ought to be reduced. Second, the activities ought to make it possible for the children to discern essential aspects of numbers (i.e., representations, cardinality, ordinality, and part–whole relations). Third, the activities ought to allow the children to express different ways of understanding and allow a variety of experiences and expressions.

The intervention was successful, indicating quantitative as well as distinct qualitative differences in how children in the intervention group and control group used numbers. Based on these positive results, a new study was initiated with the aim of spreading the findings of the intervention. The focus of the new study was on how the successful intervention could be implemented on a large scale in preschools while maintaining its scientific basis.

The implementation study was conducted in line with educational design research, which implies implementation in cycles where preschools are successively included in an increasingly broad implementation. In the first design cycle, guiding material to be used by preschool teachers was developed in collaboration between researchers and preschool teachers. The first step was to identify the core components of the intervention as these were to comprise the content of the guiding material; that is, we needed to identify the "unique" and intervention-specific but also the "necessary but not unique" aspects (Century & Cassata, 2016, p. 182). The guiding material consisted of five parts, where each part focused on one of the core components from the intervention; part 1: mathematizing; part 2: contrast and generalization; part 3: representations; part 4: cardinality; and part 5: part-whole relations of numbers. Each part consisted of one text to read, one film where the content of the text was illustrated in authentic teaching situations, prompts for collegial reflection or professional discussion, one activity to be carried out with children and, finally, one activity to be planned and carried out by the teacher. In the second design cycle, this material was implemented in two preschools. In the third design cycle, six new preschools were

involved, and finally, in the fourth design cycle, all preschools from two municipalities implemented the material. Based on findings from each design cycle, the guiding material was revised, and design principles were gradually developed to facilitate implementation of the intervention on a large scale.

The data generated in the implementation that is to be used as an empirical example in this article were from individual interviews (design cycle two), focus group interviews (design cycles three and four), and video documentations from the teaching at the preschools (design cycles two, three, and four). The interviews focused on the guiding material and how it was used and experienced by the preschool teachers. The video documentations made visible how the theoretically driven new forms of instruction were adopted by the preschool teachers. These videos were also used during the interviews as a form of stimulated recall.

4 Result

In this section we elaborate on how implementation research imposes a shift in object of study – from teachers to teaching – when contrasted with beliefs research. We will elaborate on how this shift imposes

- differences in the empirical material developed within the studies,
- differences in how the empirical material is analysed, and
- differences in when a change is considered to have occurred.

As mentioned, the first of these questions will be discussed based on previous research, while empirical material from *the implementation study on preschool mathematics education* is elaborated on in the second and third questions.

4.1 Differences in the empirical material developed within the studies

A range of data sources are used in both beliefs and implementation studies, including observations, interviews, self-reported surveys, and teacher documentations (Phillip, 2007; Century & Cassata, 2016). Thus, it is not the data sources per se that differ between the two fields of research. However, the dominant data source does differ.

By tradition, beliefs studies have most often used questionnaires through which beliefs about, for example, mathematics education are revealed. Quite often, the questionnaires are based on Likert scales, where the respondents agree or disagree with statements (Phillip, 2007). Then, based on the answers on the Likert scale, a

profile of the teachers' beliefs is developed and based on this, conjectures are made about their teaching. Sometimes, their teaching is also observed. As shown in the literature review, inconsistency in surveys and observations is explained in different ways (for example, as resulting from inconsistent or unconscious beliefs).

In implementation research, observations of teaching have been regarded as the most direct, rigorous, and objective measure of practice. Even though interviews and self-reports are used, these are not seen as valid since social desirability may inflate self-ratings (Century & Cassata, 2016).

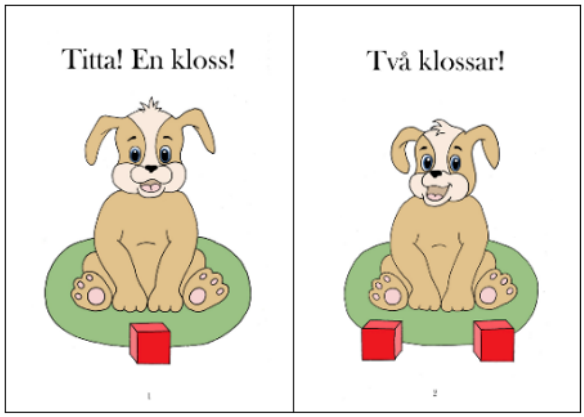
Thus, the data sources per se do not differ between the two fields of research, but the dominant data source does differ, and different data sources are valued differently regarding validity, where beliefs research emphasizes questionnaires and implementation research emphasizes observations.

4.2 Differences in how empirical material is analysed

Of course, different research questions and different empirical data require different analysis. Here we will focus on the relation between what is said and what is observed as this is an issue discussed in both beliefs research and implementation research. To do this, we will use an empirical example from the implementation study on early mathematics education using one observation and one interview from part 2 in the first design cycle. Thus, the teacher in the example had read texts and watched at video clips about mathematizing, contrast, and generalization and, based on this, she had planned her own teaching activity. Below is a description of the video clip of her planned teaching activity.

> The teacher is sitting at a table together with one child. On the table is a small toy dog. The toy dog represents the dog in a book that is part of the activities in the material of the intervention (see Figure 1). The teacher places two blue Lego blocks on the table. She makes a barking sound moving the toy dog towards the blocks. She asks the child if she can count the Lego blocks. The child is sometimes asked to count two and sometimes three Lego blocks. The child counts the blocks using number words ("one", "two") correlated with a pointing gesture towards the Lego blocks. Quite soon, the child starts to build with the Lego blocks, putting them together and then separating them again.

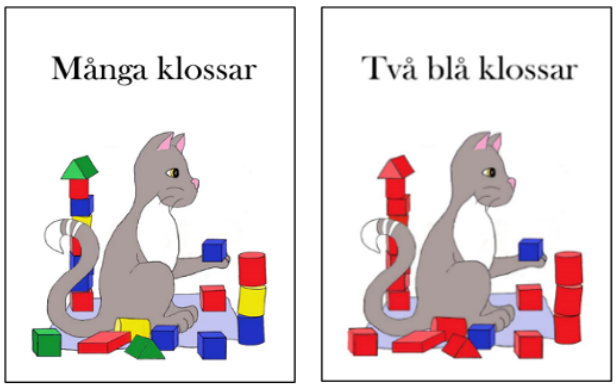
Figure 1. Example from a spread in the book used in one of the activities. In line with design principle 1, interference from irrelevant elements is reduced where the aim is to contrast "one" and "two".



In an interview some days after this video-recorded activity, the teacher is asked about this activity. She says that she in the activity made "a contrast between two and three blocks". She says that she could see that the activity caught the attention of the child, that she thinks that it was "the dog that attracted her", and that the barking was intended to get the child's attention. Further, she says that the children most often want to play with the blocks and that she lets them do that. When asked if there was something in the guiding material of the implementation study that she found unclear, she mentions a picture (see Figure 2).

> Like in the picture with the cat that has a lot of blocks. Then I think, since we have such young children, that many blocks may be too many. I felt that three blocks were absolutely excellent, three blocks were enough; I did not dare to do the other variation.

Figure 2. Example from one illustration used in the guiding material. In line with design principle 1, the aim is to illustrate irrelevant elements. Thus, the aim is to illustrate how number becomes hard to distinguish based on colours in the left picture, but in the right picture "two blue blocks" stand out in contrast to the red blocks.



As mentioned, beliefs research most often relates beliefs and practice by comparing teachers' beliefs with their teaching, and in several studies their teaching appears inconsistent with their beliefs. When teachers' teaching is not in line with their beliefs, this may be explained as inconsistency in beliefs or as unconscious beliefs (Ambrose, 2004; Pajares, 1992). Thus, based on the example above (observation and interview), a question would be whether the teaching observed was what was expected, based on the teacher's beliefs. If the observed teaching was not in line with the teacher's beliefs, the researchers might try to identify other more central or unconscious beliefs. If the beliefs and the teaching were in line, but not desired, the focus would turn to changing the teacher's beliefs with the expectation that this would then change the teaching.

If instead the empirical example was analysed based on implementation research, the focus would be on whether the intervention was enacted as intended (Century & Cassata, 2016), thus on whether the "unique" and the "necessary but not unique" aspects of the intervention were visible in the teaching, and if not, how the material used in the implementation needs to be developed. Thus, the observations would be analysed based on depth, sustainability, spread, and shift in reform ownership (Coburn, 2003). Based on the empirical material described above, one result would be that the picture in the material may not adequately illustrate what was intended and thus may need an explanation or revision. Another result would be that mathematizing, in the sense of the mathematics being necessary in the situation, needs to be strengthened in the material. Thus, the analysis and then the results would focus on whether and how the guiding material used in the implementation needs to be revised in order to impose depth, sustainability, spread, and shift in reform ownership.

4.3 Differences in when a change is considered to have occurred

In the introduction, we stated that both beliefs research and implementation research focus on change. As also mentioned, a fundamental question in beliefs research has been whether beliefs are changeable or static and how best to change beliefs if they are changeable. If we had based the study on beliefs research and thought that beliefs were changeable, based on the empirical example above we could have found that we needed to change the teachers' beliefs about mathematizing and allowance of play during teaching. To be able to change beliefs, according to Goldin (2002), one must know the individual's beliefs and how they hold these beliefs. Strong and resistant

beliefs are those shown to be usable and powerful for the individual. The strength of the beliefs is based partly on how important they are for the individual and partly on how deeply they are held by the individual. In his review, Pajares (1992) refers to studies which imply that time is important in relation to beliefs as the earlier the beliefs emerge, the stronger they are, while newer beliefs are more vulnerable and easily influenced. Other studies show that individuals are reluctant to change their beliefs and, instead, they try to interpret new experiences based on old beliefs. Thus, regardless of how new, old, or strong the teacher's beliefs might be, the focus would be on the teacher and on how to change their beliefs.

Our statement that both beliefs research and implementation research focus on change is true only to a certain extent. In implementation research, the question of change actually disappears somewhat as the focus is not on change but on outcome. When analysing the empirical example above, the focus is not on changing the ordinary teaching at these preschools but on the outcome of the observed teaching in terms of "unique" and "necessary but not unique" aspects in the innovation. The focus on change comes in the next step, when developing the guiding material used by the teachers in the implementation study. But then, the focus is not on changing the teacher but on changing the guiding material. Based on the empirical example above, the focus would be on how mathematizing can be explained and illustrated in the guiding material in a way that will later make it visible in teaching. Also, how the picture in Figure 2 can be changed to better illustrate what was intended to be focused on. Thus, regardless of how the teaching was conducted, the focus would first be on the teaching and then on changing the guiding material.

5 Conclusion

In this article, we have elaborated on how the object of study and unit of analysis differs in beliefs research and implementation research, even though they share the same goal of improving (mathematics) education. We have elaborated on this in relation to differences in the empirical material developed within the studies, how the empirical material is analysed, and when change is considered to have occurred.

In the article, we have shown that the data sources per se do not differ between the two fields of research but that the dominant data sources do differ, and that data sources are valued differently regarding validity. Further, we have elaborated on the relation between what is said and what is observed as this is an issue discussed in both beliefs research and implementation research. We have also described when and how

each field of research focuses on change. Our conclusion is that the difference in the empirical material developed within the studies, how empirical material is analysed, and when change is considered to have occurred impose a shift of focus from teachers to teaching. Century and Cassata (2016) conclude that implementation in the sense of changing teaching requires processes for changing individuals, organizations, and systems. Thus, beliefs may be part of changing individuals. But, changing individuals, regardless of focusing on beliefs or not, is not foregrounded in the studies but instead the outcome, the teaching. With this shift, the fundamental questions of beliefs being changeable or static and how best to change beliefs if they are changeable (see Ambrose, 2004; Pajares, 1992) somewhat disappear. If the focus is on teaching instead of teachers, teachers cannot appear inconsistent towards their beliefs. Thus, if we, similar to Wilson and Cooney (2002), find it problematic when researchers claim inconsistency between teachers' beliefs and observed teaching, implementation research (see Coburn, 2013; Century & Cassata, 2016) may be an alternative path.

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