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What is a successful implementation in mathematics education? On sustainable innovations and the role of textbooks

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This paper concerns what a successful implementation of an innovation in mathematics education can be and how that can be achieved. Focus is on sustainability of an innovation and the role of textbooks. We use two historical Swedish development projects in mathematics education for the discussion. The material is official reports and governmental documents concerning the projects.

Keywords: Implementation, sustainability of an innovation, textbooks.

Introduction

This paper is part of the project *Implementation research as an emerging field of mathematics education*. The project's aim is to create a theoretical framework for implementation research (IR) in the field of mathematics education research (MER), in particular for research on large-scale development projects. The overall project examines which existing IR theories and which parts of these are applicable to implementation and development projects related to mathematics. To verify this, we test the theories and related concepts that we find relevant through comparisons of five development projects.

This paper concerns two of those projects—New Math and PUMP¹—and the aim is to understand how the concept of *sustainability*, a key IR concept, is applicable in MER. This concept is essential for how to conceive what a successful implementation of an innovation is. The analysis is focused on textbooks, since that is a characteristic of school subjects. Textbooks also involve a type of stakeholders—publishing companies—that we do not find in many other subfields of IR. Our research question concerning the New Math and PUMP projects is: *What was the role of textbooks in the implementation process, and how were textbooks related to efforts of sustaining or maintaining an innovation?*

Previous research

In their overview of IR on large-scale innovation, Century & Cassata (2016) identify a number of factors that influence whether an implementation of an educational innovation is a success or a failure. In what respects an implementation is a success can be understood in different ways. One way is to consider outcomes in terms of student results or changed behaviours of teachers or students. However, there are two other aspects of success, which the outcome perspective is

¹ PUMP = *Processanalyser av Undervisning i Matematik/Psykologlingvistik* (Process analyzes of Teaching in Mathematics/Psycholinguistics)

depending on. One aspect is *fidelity* to the innovation or the reform program. That is, to succeed in getting a great number of teachers to use the innovation as planned. The rationale is that teachers need to apply the innovation as planned, if it is to make sense to talk about positive or negative effects on outcomes. The second aspect is to succeed in getting the teachers to apply the innovation for a long time, or at best, forever. In that perspective a successful innovation endures. The rationale here is that positive effects are pointless if the innovation does not endure.

These two other aspects or perspectives on success can to some degree be conflicting. One way to obtain endurance is to have innovations that allow for adaptations to local and changing circumstances over time. Such innovations are then considered sustainable. However, adaptation is in conflict with fidelity. In a fidelity perspective, endurance is then a matter of maintenance in order to preserve the innovation. The weakness of that perspective is that the context of an innovation can and do change, which means that adaptations may be necessary.

This paper concerns factors and conditions that may contribute to innovations in mathematics education (ME) becoming sustainable or maintainable for longer periods of time.

The overview of Century & Cassata (2016) is efficient as it guides us to essential issues in IR, for instance the ideas concerning sustainability. However, it is not possible to discern if there are certain factors or conditions that are more or less relevant to achieve sustainable or maintainable innovations in different areas. Neither is it clear in what respect textbooks and publishing companies constitute factors or conditions that facilitate or inhibit successful implementation of an innovation. A similar problem we find also in the publications Century & Cassata (2016) refer to. Regardless of field—for instance mathematics education (Clements et al., 2015), kindergarten (Lieber et al., 2009), positive behaviour support (McIntosh et al., 2013), sex education (Rijsdijk et al., 2014), and science education (Century & Levy, 2002)—the researchers apply concepts and theories from IR as if they were applicable in all fields. Some of them do address the role of textbooks or other teaching materials to obtain sustainability (Century & Levy, 2002; Lieber et al., 2009; Rijsdijk et al. 2014), but others do not.

In some cases, such as positive behaviour support (McIntosh et al., 2013), it seems natural not to include textbooks and other teaching materials as a factor for obtaining sustainability; the teachers in the McIntosh et al.'s (2013) study were supposed to follow a certain program for positive behaviour support and it did not concern the teaching of school subjects. In the other extreme, we find mathematics education and science education. These are contexts where textbooks have existed for a very long time and should not be considered non-essential parts of the teaching practices. However, only Century & Levy (2002) address the role of textbooks, in science education, not Clements et al. (2015) in their paper on mathematics education.

Our contribution to previous research is about deepening the understanding of how textbooks can be managed in different ways in development projects to sustain or maintain innovations. In particular, we are interested in how project managers or reformers tackled the publishing companies. These companies must be considered stakeholders in educational reform processes as their existence rests on teachers and schools buying their products. Moreover, we should not assume that the purpose of an innovation coincides with the interests of publishing companies.

Theory and method

Our analysis of strategies for obtaining sustainable or maintainable innovations is based on Coburn's (2003) theory of scaling up an educational reform, which in our view also includes implementation of innovations. According to Coburn (2003), scale comprises four interrelated dimensions: depth, sustainability, spread, and reform ownership.

Depth concerns in what respect teachers change beliefs, norms of social interaction, and pedagogical principles. This is in contrast to so-called superficial changes such as changes in materials, classroom organization, or the addition of specific activities.

Sustainability concerns time and schools' ability to make innovative changes to remain in the teaching practice. This often means allocating tools and resources (e.g., financial, staff, and administration) for that end. In our analysis, we also use the concept *maintenance* in order to capture different ways to make an innovation endure, see previous section.

Spread is what traditionally is associated with scaling up. The implementation of an innovation is scaled up when an increasing number of classrooms and schools get involved.

Reform *ownership* is a matter of external reformer handing over control to districts, schools, and teachers. Or more precisely "creating conditions to shift authority and knowledge of the reform from external actors to teachers, schools, and districts".

By our study, we want to supplement Coburn's (2003) theory by relating textbooks and other teaching materials to the four dimensions just mentioned. We argue, from a theoretical point of view, that textbook and teaching material can be involved in the four dimensions in a substantial way. As to *depth*, textbooks and teaching material are designed according to some pedagogical principle; explanations and exercises are not developed and organised at random. Thus, using a textbook is then a matter of applying that principle. Innovations brought by textbooks are then sustained or maintained by publishing companies, not just school authorities. As to *spread*, that is the *raison d'être* for commercial publishing companies. Nobody has to remind them of that. And a textbook can give more or less *ownership* to teachers.

An important point is that school authorities, which often initiate and drive reforms, and publishing companies, can have different interests. And those interests may be in conflict with each other. Our assumption is that if you try to scale up the implementation of an innovation and make it sustainable, the chance of success is affected by the extent to which you work with or against publishing companies. And if you are not working with them, it can be a good idea to have a strategy of managing potential conflicts and fending of companies.

In our analysis, two development projects are compared. For each project we identify a strategy for managing textbooks and publishing companies and each strategy is tied to an aim of sustaining or maintaining innovations. The analysis includes Coburn's (2003) other three dimensions of depth, spread, and ownership. The materials are official reports and governmental documents concerning the development projects and to minor extent communication with people involved in the projects. The material has been treated as narrative sources concerning what intentions people had and what happened during the development and implementation of innovations. None of the sources contain

an explicit strategy for managing textbooks and potential conflicts with publishing companies. But some sources do concern textbooks, quite a lot and very explicitly in fact, and we have then sought to identify how the treatment of textbooks gave the reformers an advantage over publishing companies. As to the New Math project, we rely on findings presented in already published studies. But the studies are also based on official reports and governmental documents.

New Math project (1960–1975) and the role of textbooks

If we consider the plans for the New Math reform in Sweden, it contained a lot of innovations that altogether were deep. By far, it was not a matter of adding sections of set theory in some school years. On the contrary, it was a matter of providing new principles for structuring and teaching all school courses in mathematics (1–12). Set theory was supposed to constitute a foundation on which the other school topics should rest. In teaching, concepts should be introduced and explained by means of concepts, expressions, and illustrations related to set theory. In this way, coherence between all topics should be created. This would also facilitate a teaching focused on understanding rather than just procedures, which was in line with the theory of cognition, learning and mathematics that guided the reform. But, apart from set theory, New Math also brought other innovative concepts, for instance from vector geometry, trigonometry, and functions (Prytz, 2018).

The spread was supposed to be total in the sense that the innovations concerned all school years 1 through 12 and all Swedish schools. The way to achieve this was to implement the innovations in connection with the national curriculum reform of 1969, which then brought a radically new course program for mathematics.

To maintain the innovations, textbooks were an essential component. Much of the development phase (1961–1968) concerned textbook development, which was financed and driven by central school authorities. The overarching aim was to develop textbooks that could fit the radically new curriculum. The idea seems to have been to provide the publishing companies with an extensive example of what a new type of textbook should look like. In practice, many publishing companies managed the conversion by hiring people involved in the New Math project. However, compliance with the new curriculum was secured by a mandatory textbook review. And if we consider the content of the textbooks published in connection with the curriculum reform of 1969, the compliance with the new course program in mathematics was indeed good. Since the textbooks review was a matter of controlling the fidelity with the innovations, we find it relevant to talk about maintaining rather sustaining innovations when it comes to New Math (Prytz, 2018).

As to transfer of ownership, teachers were given in-service training concerning the New Math, which is a clear example of providing teachers knowledge of the innovation. However, the focus was on mathematical content rather than teaching methods. And in comparison, e.g. to the Boost for Mathematics project, it was brief. And do not forget the national textbook review that limited the possibilities to deviate from the curriculum. Thus, the central school authorities will and ability to transfer ownership do not appear to have been great (Prytz, 2018).

Regarding textbooks and the strategy to maintain the innovations, the New Math project's attitude versus publishing companies was of a brutal kind. In the devolvement phase during the 1960s, all

people involved authoring the experimental textbooks, except one, had a background as textbook author for school years 1 to 12. So, there were no ties to publishing companies in that respect. The trials and testing were done in a scientific context with researchers in charge and almost without involvement of publishing companies. Thus, the companies had little influence on the process that led to the example they had to follow. On top of that, there was the textbook review (Prytz, 2018).

If we then consider the demise of New Math in Sweden, this brutish attitude towards the publishing companies appears to have been functional. A few years after the 1969 curriculum reform, the central school authorities decided not to drive important components of New Math, not least the parts concerning teaching principles. However, the mathematical course program did not change. And in 1974, the textbook review became optional. After that, publishing companies began to issue more traditional textbooks, in parallel with New Math textbooks (Prytz, 2018).

This shows how willing and able the publishing companies were to act quickly and produce textbooks that were in conflict with the innovative components of New Math. Most likely they aimed at making a profit of teachers' dissatisfaction with New Math. To what extent teachers were dissatisfied is hard to estimate, but critique was aired well before the reform. This indicates how important the mandatory textbook review was to prevent publishing companies from interfering with the original plans for the implementation.

PUMP project (1970–1985) and the role of textbooks

In comparison to the innovations of the New Math project, the PUMP innovations can appear to have had little depth. They concerned just arithmetic in school years 1 through 6 and the central innovative component was an assessment material. Moreover, no particular pedagogical principle for teaching was prescribed. On the other hand, the assessment material and its underpinnings were very carefully crafted, tried, and tested. And they prescribed a detailed sequence in which exercises in arithmetic should appear in teaching. There were also good arguments for this sequence since the material had been tried and tested empirically. In addition, there was a cognitive theory about working memory to further support the sequencing of the content (Kilborn, 1979). Our point here is that this type of sequencing concerns the very basics of teaching. How and what a teacher communicate with the students is depending on how the content, for instance exercises, are sequenced (cf. Bernstein, 1974). So, in that respect the PUMP material had depth, but it was another type of depth than in the New Math material. In brief one could say that the New Math gave principles and examples for the sequencing of the content and principles for teaching; PUMP gave the sequence for the content.

The spread of the PUMP material was very modest in comparison to the New Math reform. There was no policy demanding all teachers to use the material (Kilborn, 1979). But the fact that a developed version of the PUMP material is still in use today indicates that the material had spread.

This endurance suggests that the efforts to sustain the material were successful. Different aspects of how that was done will be studied in our project. In this paper, we consider more closely how the PUMP people could avoid threats to their sequencing of the content from publishing companies.

Here it is important to notice that textbooks in essence constitute a sequencing of the content. So, there is a potential conflict.

For the PUMP people, the fight had two fronts: on the one hand the publishing companies, on the other, the New Math curriculum. And they launched massive critique in both directions. It was massive in the sense that they had a solid and detailed assessment material; this material was used in classroom studies to detect what type of difficulties students had in arithmetic, many of the difficulties appeared to be connected to textbooks and the curriculum; and the material was finally used to study the structure of textbooks. The analysis of the textbooks was thorough. The PUMP people mapped the amount of exercises the student encountered each week for a whole school year. And the level of difficulty of each exercise was estimated by means of the assessment material. In this way, they could estimate in what respect the progression was too steep or too flat. Often the textbooks raised the level of difficulty very fast. The PUMP people tied these problems to the New Math curriculum which they considered too unclear in terms of progression. They also found some directives misleading (Kilborn et al., 1977).

According to one of the leading persons in PUMP (personal communication), their textbook critique had great impact on the publishing companies. There was even an expression for it: textbooks were “pumped” before they went to the market. However, this claim needs further studies of the textbooks to be corroborated.

As to transfer of ownership, the PUMP assessment material was a readymade tool for the teachers to use. It was not something a teacher could own in the sense that they could gain knowledge about it and modify it. That was not the intention. However, the PUMP people argued that the material would make teachers less dependent of publishing companies and their textbooks. The idea was that teachers could use the PUMP material to plan their teaching and choose textbooks that fitted their plans. For that end, the material could also be used by teachers to evaluate textbooks (Kilborn et al. 1977). So, here we see another type of ownership. This is also the reason why we find it relevant to talk about sustaining rather maintaining innovations when it comes to PUMP.

Conclusions

We have applied Coburn’s (2003) theory of scaling up an educational reform to characterize the implementation of innovations in two historical Swedish development projects in mathematics education: the New Math project (1960–1975) and the PUMP project (1970–1985). This theory comprises four dimensions: depth, sustainability, spread, and reform ownership. In addition, we have made a distinction between maintaining and sustaining an innovation. We have also analysed the role of textbooks in strategies for sustaining or maintaining innovations in the projects. Our characterisation of the projects is summarised in Table 1 below.

Our analysis of strategies for sustaining or maintaining innovation has also involved the reformers attempts to manage publishing companies—the producers of textbooks—and potential conflicts of interest. In both projects, this management was done in a purposeful manner. In the case of New Math, textbook development was the centre piece in the development phase. A process publishing companies had very little influence over. And in the implementation phase, the companies were

forced—through a national curriculum and a mandatory textbook review—to follow the examples set by the textbooks that were the results of the development phase. In the PUMP project, we can observe another strategy. Textbook development was not part of the PUMP project, but it included a comprehensive textbook review, based on the detailed assessment material (a key innovation) that had been developed and empirically tested. This material laid out a very detailed sequence in which exercises should appear in teaching. The review resulted in harsh critique of the textbooks. We have indications that this criticism had a great impact on the publishers. But further research is needed.

Table 1. Characterization of the New Math and PUMP projects

<i>Project</i>	<i>Maintain or Sustain</i>	<i>Spread</i>	<i>Depth</i>	<i>Ownership to teachers</i>
New Math	Maintaining innovations, mainly through formal curriculum and textbook control	Whole country through curriculum and textbook control. Concerned all schoolyears and all mathematical topics.	Through general principles and examples that sequenced the content	Limited in-service training of teachers.
PUMP	Sustaining innovations by giving a tool (an assessment material) for developing teaching methods and evaluating textbooks	Modest due to voluntary use of assessment material. And it concerned school years 1–6 and arithmetic.	Through a concrete and detailed sequencing of the content	Teachers should use assessment material for pedagogical development. Not possible to modify the material

We also have evidence of these strategies being necessary in the sense that publishing companies pursued aims other than those of the reformers. This became visible later on in the implementation phase of New Math, when the central school authorities made the textbook review optional in 1974 and refrained from driving key innovative elements of the New Math reform, even though the New Math curriculum was still in effect. The companies reacted quickly and were able to start production of more traditional textbooks. This is an example of how publishing companies respond to market force and how it can undermine the maintenance of an innovation. If there is a demand for a certain type of textbooks, the publishers tries to meet demand without losing the market share that rests on product recognition. Consequently, publishers balance on a fragile thread between the diametrical poles of change and tradition, when considering which path yields the most profit.

Regarding contribution to previous research, in particular Century & Cassata (2016) and Coburn (2003) which concern IR in general, we stress the theoretical relevance of our findings. In a previous section we have explained that existing IR models does not in greater detail concern the role of textbooks and publishing companies in processes of sustaining or maintaining innovations. We argue that this is something to consider when developing IR models specific to mathematics education and large scale implementation projects. Our findings indicate that the characteristics of the process of implementing innovations on a larger scale (sustainability/maintainability, spread, depth, and ownership) can be related to strategies for managing textbooks and publishing companies in the implementation process. Our findings also indicate that success in sustaining/maintaining innovation and achieving spread may be depending on such strategies.

These indications point at more general issues of innovation, education, and market forces. Issues we find extra relevant for mathematics education research since not only textbook companies but also technology companies have influenced school mathematics for a very long time.

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References

- Bernstein, B. (1974). *Class, codes and control Vol. 1 Theoretical studies towards a sociology of language*. (2nd ed.). Routledge.
- Century, J., & Cassata, A. (2016). Implementation research: Finding common ground on what, how, why, where, and who. *Review of Research in Education*, 40(1), 169–215. <https://doi.org/ggf5sv>
- Century, J., & Levy, A. (2002). Cross-site report: *Researching the sustainability of reform: Factors that contribute to or inhibit program endurance*. National Science Foundation.
- Clements, D. H., Sarama, J., Wolfe, C. B., & Spitler, M. E. (2015) Sustainability of a scale-up intervention in early mathematics: A longitudinal evaluation of implementation fidelity. *Early Education and Development*, 26(3), 427–449. <https://doi.org/hpm7>
- Coburn, C. E. (2003). Rethinking scale: Moving beyond numbers to deep and lasting change. *Educational Researcher*, 32(6), 3–12. <https://doi.org/fj4g29>
- Kilborn, W. (1979). *PUMP-projektet: bakgrund och erfarenheter* [The PUMP-project: Background and experiences]. LiberLäromedel/Utbildningsförl.
- Kilborn, W., Lundin, O. & Johansson, B. (1977). *Läromedlens uppbyggnad* [The structure of teaching materials]. Göteborgs universitet.
- Lieber, J., Butera, G., Hanson, M., Palmer, S., Horn, E., Czaja, C., Diamond, K., Goodman-Jansen, G., Daniels, J., Gupta, S., & Odom, S. (2009) Factors That Influence the Implementation of a New Preschool Curriculum: Implications for Professional Development, *Early Education and Development*, 20(3), 456–481. <https://doi.org/c99cf4>
- McIntosh, K., Mercer, S., Hume, A., Frank, J., Turri, M., & Mathews, S. (2013). Factors related to sustained implementation of schoolwide positive behavior support. *Exceptional Children*, 79(3), 293–311.
- Prytz, J. (2018). The New Math and school governance: An explanation of the decline of the New Math in Sweden. In F. Furinghetti & A. Karp (Eds.), *Researching the history of mathematics education. ICME-13 Monographs* (pp. 189–216). Springer. <https://doi.org/gcpr48>
- Rijsdijk, L. E., Bos, A. E., Lie, R., Leerlooijer, J. N., Eiling, E., Atema, V., Gebhardt, W. A., & Ruiter, R. A. (2014). Implementation of The World Starts With Me, a comprehensive rights-based sex education programme in Uganda. *Health Education Research*, 29(2), 340–353. <https://doi.org/f5vxbr>