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In this introduction, we briefly present the origin of a young Thematic Working Group 23 (TWG23) on implementation of research findings in mathematics education, and its development from CERME 10 to CERME 11. We then address the construct "implementation research" by looking at the model proposed by Century and Cassata (2016). Drawing from this model, we attempt to categorize the papers and posters of TWG23. In addition, we report on the results from two thematic discussions that focused on the topic of "Methodology in implementation research" and "Replication studies". Lastly, we offer a collective, still in-progress definition of implementation research as a result of the summarizing discussion in the TWG23 during CERME 11.

Keywords: Implementation research, research findings, replication studies, innovation, change.

Origin of the Thematic Working Group 23

During five decades, the field of mathematics education research has generated a multitude of products, such as theoretical frameworks, concepts, didactic designs, solid findings, etc. Although the research community has always been concerned with the theory-practice relationship, it remains an open and a challenging problem how such products could be used and applied in practice. Many mathematics education researchers work on (large) developmental projects that rely heavily on previously documented research results. However, reporting on these projects in mathematics education scientific outlets have proven to be challenging, since such projects do not necessarily fall under the usual paradigms of research in mathematics education. Before CERME 10, this issue was identified. More concretely, there was no forum to discuss important issues related to implementation of research findings. For that reason, TWG23 was founded with the idea of being a forum dedicated to presenting and discussing empirical and theoretical studies focused on elucidating the enablers and general conditions that favor or inhibit the implementation of research products generated in our field in practice as well as reporting on research-based designs themselves. The original concern of the group was "*How can we apply and implement stable research findings in «real life»?*" and "*How can we bring the accumulated research knowledge into practice?*"

These questions remained to be in the focus of TWG23 also at CERME 11. We were embracing for papers and poster proposals addressing, from both empirical and theoretical perspectives, issues related to the implementation of research findings. In particular, we wanted to focus on a wide variety of “good examples” of implementation of research findings and products into practice, aiming at improving the teaching and learning of mathematics at all educational levels. Moreover, we were interested in empirical research and theoretical discussions that address the challenges and possibilities of “implementation research”, as well as in-depth literature reviews that provide general and updated views of the state of development of this type of research in the field of mathematics education. Thus, the work of the group was organized around the idea of closing the identified “gap” and acting as a bridge between research and practice by focusing on multiple perspectives of implementation research.

Evolution of the TWG 23

At CERME 10, the working group undertook initial attempts to make sense of the construct of implementation. In the call for papers for the TWG23 at CERME 10, the construct “implementation research” was operationalized rather broadly, as a wide range of different kinds of didactical design, from task design, (model) lesson design, teaching modules and courses to design of entire programs at all educational levels. Furthermore, “implementation research” was inclusively treated as research on aspects of developmental projects, intervention projects, as well as research on aspects of the development and use of educational media, such as textbooks, apps, software and learning platforms. However, the call for papers required to make explicit connections between the reported designs and findings or insights from mathematics education research. As a result, many examples of implementation of research findings in mathematics education were presented, including process models, determinant frameworks, classic theories, implementation theories and evaluation frameworks (Jankvist, Aguilar, Bergman Ärlebäck, & Wæge, 2017). Many examples had been presented also at CERME 11, however, a new general theme in considering them have gradually emerged. At CERME 11, both the papers and posters as well as our discussions, reflected an effort to articulate more clearly what implementation research in mathematics education actually is, as well as the growing interest in theorizing it.

Understanding our emerging “paradigm” and its blind-spots and tacit assumptions

It was apparent at CERME 11 that many of the contributions shared certain ideas of what implementation in educational situations is. The ideas were shared both in terms of terminology and in terms of key references. Two key concepts apart from implementation are worth mentioning, namely *innovation* as described by Rogers (1962) and his famous work on the diffusion of innovations, and central factors of “implementation” as proposed by Century and Cassata (2016). This means that many of us considered “implementation” as innovation that causes a change when enacted in ordinary practice, and that the change is stipulated by relationships between the nature of the innovation, influential factors and key stakeholders.

Furthermore, we internalized the Rogers (1962) idea that innovations spread through different user segments, from innovators that participate in developing and realizing the innovation, over early adopters to a majority who instantly or relatively soon take up the innovation, and then to the late majority – taking the innovation up late – and laggards who might never change practice.

The five factors that influence innovation proposed by Century and Cassata (2016), were actively used in a number of the contributions in the group, as a lens to study the implementation and implementability of initiatives. These five factors are: characteristics of the individual users, organizational and environmental factors, attributes of the innovation, implementation support strategies, and implementation over time.

Apart from referring to the Rogers' and Century and Cassata's (2016) "standard models" for implementation (as something that causes a purposeful change, related to factors and stakeholders) in the group discussions, we also spent some time investigating the downsides of looking at changes in the educational sector through this lens.

First of all, we observed that the "standard models" tend to fetishize the "manifestation" of a change as an innovation. Change in the educational sector is typically not caused by one "thing". Rather, it is better studied as an interplay between many factors and forces. The constant focus on "innovation" in our work and discussions might have a problematic downside here. Another problem with the term "implementation as enactment of innovation" is that it overplays the intentional aspects of educational change. Many changes come as organic developments rather than as purposeful implementations.

We also began understanding the implementation paradigm by drawing a parallel to Stein, Remillard, and Smith's (2007) phases of curriculum, which was brought to the discussion by Boris Koichu. In Stein et al.'s (2007) model, the curriculum can be seen as consisting of different categories, namely written, intended, enacted, and attained curriculum based on what phase of the teaching and learning process one is focusing on. If we replace the written curriculum with (stable) *research findings*, a new model emerges (see Figure 1). Thus, in this new model published research refers to the research findings available to the teachers. *Intended implications* refer to the set of objectives to be accomplished in practice on the basis of research findings. *Enacted implications* refer to various learning activities or experiences of the learners on the basis of research findings in order to achieve the intended implications. Lastly, *attained implications* refer to the implementation outcomes with respect to student learning on the basis of the intended and enacted implications.

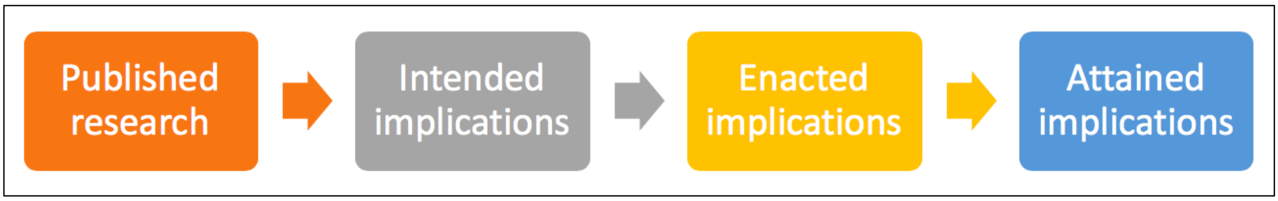

Figure 1: Phases of implementation of research findings into practice

Introduction to the papers and posters presented at the TWG23

Twelve papers and two posters were presented at CERME 11, all of them addressing a wide variety of topics and using different approaches. In this section we use the five categories proposed by Century and Cassata (2016) in order to present an overview of the works discussed in this thematic working group. Although not mutually exclusive, to some extent these categories allow us to group the works presented in the TWG23 according to their interests and perspectives.

Inform innovation design and development

The research study by Ioannis Papadopoulos and Nafsika Patsiala falls into this category. They describe a pilot study, aiming at capturing the landscape of problem posing in a Greek grade four classroom. It is intended that the information produced by this pilot study informs and helps to setup a year-long intervention in the classroom aiming to develop the problem posing abilities of the students.

Understand whether (and to what extent) the innovation achieves desired outcomes for the target population

Two papers belong to this category. The first work, by Inga Gebel and Ana Kuzle, presents a problem-solving innovation for students in grades 4-6 has been designed and evaluated. During the evaluation phase, the researchers analyze students' problem-solving solutions with respect to their fluency and flexibility, and present the (dis-)advantages of the innovation in regular mathematics lessons.

The second work is by Helena Gil Guerreiro, Cristina Morais, Lurdes Serrazina, and João Pedro da Ponte. These authors try to understand, in a context of teachers' collaborative group, how emphasizing multiple representations can contribute to the learning of the rational numbers by elementary school students.

Understand relationships between influential factors, innovation enactment, and outcomes

Three of the papers presented in the TWG23 focus on identifying factors that influence innovation enactment. One of them was developed by Rikke Maagaard Gregersen, Sine Duedahl Lauridsen, and Uffe Thomas Jankvist, who focus on identifying the enablers and barriers for the implementation of the so-called *Swedish Boost for Mathematics*, which is one of the largest initiatives on improving mathematics teaching and learning in the Nordic countries in recent times.

The paper presented by Johan Prytz also analyzes the implementation of the Boost for Mathematics initiative, but this paper adopts a historical and comparative approaches. Through this perspective, the author shows the role that research and models of governance played in the New Math project in the 1960s and 1970s, and later in the Boost for Mathematics project.

Finally, the paper by Dorte Moeskær Larsen, Mette Hjelmborg, Bent Lindhart, Jonas Dreyøe, Claus Michelsen, and Morten Misfeldt describes a recent attempt to implement on a large-scale an inquiry-based mathematics teaching in Danish compulsory school. In their analysis, they identify critical factors for this large-scale implementation.

Improve innovation design, use, and support in practice settings

Most of the works presented fall into this category. For instance, Tomas Højgaard and Jan Sølberg refer to a longitudinal project called KOMPIS (a Danish acronym that stands for "Competency Goals in Practice"). In particular, they present a two-dimensional content model derived from the KOMPIS project that aims at supporting competence-based curriculum development and teacher planning.

In turn, Morten Elkjær discusses the design of a dynamic online diagnostic tool aimed at assessing students' mathematical misconceptions in lower secondary school. The design of such online tool is based on the application of research findings on mathematical misconceptions in algebra and numeracy when working with equations.

The implementation of notions from the inquiry-based mathematics teaching perspective (IBMT) is the focus of the work presented by Per Øystein Haavold and Morten Blomhøj. In particular, they discuss how the design of a four-year professional development project called SUM (A Norwegian acronym that stands for "Coherence through inquiry based mathematics teaching"), can support the implementation of research findings related to the IBMT approach.

The large-scale implementation of alternative models for multiplication is the focus the paper by Anna Ida Säfström, Ola Helenius, and Linda Marie Ahl. They make use of Vergnaud's theory of conceptual fields to produce a teaching design where models in the form of iconic representations serve as a means for creating patterns that make multiplicative invariants and structures visible.

The work by Nina Ullsten Granlund reports on a professional development project where preschool teachers are offered theoretical tools – in particular Bishop's theory of mathematical activity – so that they can think about their teaching in a structured and explicit way, but respecting the play-based tradition on which Swedish preschool education is based.

The last article located in this category is the one presented by Boris Koichu and Alon Pinto. They report on the TRAIL project (Teacher-Researcher Alliance for Investigating Learning), which is a co-learning project between mathematics teachers and mathematics education researchers. They illustrate how this project favors teachers' adaptation of research procedures and ideas in their classrooms as part of participation in community educational research.

Develop theory

The main emphasis of the works included in this category is in the conceptualization of the implementation of research findings. This focus is clearly reflected in the work of Uffe Thomas Jankvist, Mario Sánchez Aguilar, Jonas Dreyøe, and Morten Misfeldt. Taking as a reference implementation research frameworks from outside the field of mathematics education, they try to outline what an implementation research framework in mathematics education could encompass.

Finally, Andreas Lindenskov Tamborg argues in his paper that in order to synthesize the research results in implementation research as an independent sub-field in mathematics education research, there is a need for a consistent vocabulary. He then proposes to combine Century and Cassata's (2016) definition of implementation research with theoretical notions developed in the realm of the documentational approach to didactics.

Results of the thematic group discussions

During our sessions, we organized two thematic discussions. The first thematic discussion focused on the topic of "*Methodology in implementation research*", while the second one concentrated on "*Replication studies*". Below we mention the main ideas that were addressed during those group discussions.

Methodology in implementation research

As of 2017, we as a community of mathematics educators interested in implementation research, got a forum to talk about and publish our "implementation" research, while analyzing our data from multiple perspectives. Here, different dependent variables can be considered: climate variables, learning variables, system variables or independent variables. Yet, in the wider community this type of research does not necessarily fall under the usual paradigm of "research in mathematics education". As a consequence, it is not highly-recognized and often is not considered for publishing in high ranking peer-reviewed articles, due to different factors. That said, the following question naturally arises: "*What would count as a high-quality implementation research (recognized by the community and having impact in high-ranked journals)?*" In order to answer this question, we had small group discussions organized around the following questions:

1. What perspective of implementation research does each project follow? Ones identified, what is the purpose of one's perspective?
2. How is innovation within each project measured and analyzed? What are methodological challenges faced by each "implementation" project?
3. Which of perspectives and purposes from (1) are closely aligned with the usual paradigm of "research in mathematics education"?
4. Which of these perspectives would count as high-quality implementation research? If so, why? If not, why not?
5. What implications would the decision from (4) have with respect to our methodology (e.g., instruments, units of analysis, such as products, processes, evaluation of particular factors, analysis)?
6. What challenges do arise in implementation research (e.g., related to data analysis, to ethical issues) and how could one go about them?

The discussions have shown that TWG23 is at its early stage where many fundamental issues are not yet completely clear. Both thematic discussions as well as the paper discussions made us enter a pathway towards formulating a more precise collective definition of the construct "implementation research in mathematics education" (see last section of this paper). Another issue identified was the complexity of implementation research, which consequently implies the variety of theories needed in order to inform it. Given the length limitation of publications in most of the high-ranked journals, it makes is extremely difficult to report on implementation research in its full complexity – although this is also the case for other types of research. Lastly, in our community implementation of research findings is still not highly recognized by many colleagues. Hence, we discussed the need of a community building and raising awareness with respect to potential of implementation research for the field mathematics education.

Replication studies

The interest in replicating didactic designs and empirical studies has been present in the community of mathematics educators for several years. In the 1970s Phillip M. Eastman (1975) wondered why there were no more studies of replication in our field, while arguing for relevance of such studies. During the 1980s several reproducibility studies were carried out – mainly in the French teaching community – focused on understanding the conditions that allowed a didactic design to be implemented with enough fidelity in different scenarios, preserving the effects in student learning.

Simply put, a replication study can be seen as the attempted repetition of a study or an experiment that has been published in a peer-reviewed journal or book. However, since in the social sciences there cannot be two identical qualitative studies (i.e., there is no duplication), the development of qualitative replication studies involves maintaining certain variables similar to the original design, such as investigating a similar population, using the same didactic design, or applying the same modes and categories of analysis or coding. This kind of replication is known as *conceptual replication* (Hüffmeier, Mazei, & Schultze, 2016). Yet, this characterization does not exclude the possibility of developing quantitative approaches to replication studies.

Lately, replication studies are gaining the attention of the mathematics education community (and beyond). An example of this is the working group on replication in mathematics education, which met for the first time at the PME 42 conference in Umeå, Sweden. Another indicator is that some specialized journals are beginning to receive and publish replication studies, for example the *Journal for Research in Mathematics Education* (JRME). However, despite its apparent importance, replication studies have found some obstacles to establishing themselves as an "accepted" type of study in our field. As expressed by Hugh Burkhardt (2013) "Replication, a key element in scientific research, is simply not sexy" (p. 225).

There are several arguments for this lack of "sexiness". One is that the academic system privileges the publication of original and innovative works, and devalues works that are not perceived as novel. Additionally, some published research does not provide sufficient methodological and empirical details that allow them to be replicated (Schoenfeld, 2018).

With these ideas in mind, the second thematic group discussions revolved around the following questions:

1. Can replication studies be useful for the development of implementation research in mathematics education? If yes, in what way? If not, why not?
2. What characteristics should a replication study have in order to be useful for the development of implementation research in mathematics education?

Although there was no definitive answer to these questions, it did appear a feeling in the group that replication studies could help us identify conditions that allow (or prevent) certain innovations to be reproducible in different scenarios, or even help us investigate the effects of a particular treatment under different conditions or populations, which in turn would allow us to advance the implementation of research results. However, it was also acknowledged that for this type of development to happen in the field of educational mathematics different conditions must be in place. For example, it would be necessary to promote a culture of data sharing where the research protocols, data sets, and other elements on which the research is based are not only public, but also shared among researchers through data repositories.

Toward a new definition of implementation research in mathematics education

In TSG23, we feel that we are witnessing the emergence of a new and vibrant research area within the field of mathematics education. In plan to continue looking for a common ground on what do we understand as implementation research in our future work, because once we have a more precise understanding of what implementation research is, we be able to think more precisely about what its methodological implications and challenges are. A first collective attempt to formulate a chain of definitions of the key concepts of "implementation" and "implementation research in mathematics education" was led by Boris Koichu at the last meeting of the group. At the end of this discussion, the group formulated the following proposal.

> *Implementation* is a change-oriented process of adapting and enacting a particular resource (e.g., an idea, a tool, an innovation, a framework, a theory, an action plan, a curriculum, a policy) that occurs in partnership of two communities, *a community of the resource proponents* (CRP) and a *community of the resource adapters* (CRA). These communities differ but can intersect. At the beginning of the process, the CRP has the ultimate agency over the resource. The process of adapting a resource by CRA includes some of the following: (1) constructing an agency over the resource, (2) changes in ways of communicating, and (3) changes in practice. Accordingly, *implementation research in mathematics education* is research that focuses on aspects of implementation, as specified above, in the context of mathematics education.

As we progress in our work, we will certainly refine our working definition. However, we feel that the above proposal adequately captures many ideas and concerns discussed in the group at CERME 11 and that the journey aimed at further theorizing and characterizing implementation research in our field is worth taking.

References

Burkhardt, H. (2013). Methodological issues in research and development. In Y. Li & J. N. Moschkovich (Eds.), *Proficiency and beliefs in learning and teaching mathematics: Learning from Alan Schoenfeld and Günter Törner* (pp. 203–236). Rotterdam, The Netherlands: Sense.

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.

Eastman, P. M. (1975). Replication studies: Why so few? *Journal for Research in Mathematics Education*, *6*(2), 67–68.

Jankvist, U. T., Aguilar, M. S., Ärlebäck, J. B., & Wæge, K. (2017). Introduction to the papers of TWG23: Implementation of research findings in mathematics education. In T. Dooley & G. Gueudet (Eds.), *Proceedings of the tenth congress of the European society for research in mathematics education* (pp. 3769–3775). Dublin, Ireland: DCU Institute of Education and ERME.

Nilsen, P. (2015). Making sense of implementation theories, models and frameworks. *Implementation Science*, *10*(53), 1–13.

Rogers, E. M. (1962). *Diffusion of innovations*. New York, NY: Free Press of Glencoe.

Schoenfeld, A. H. (2018). On replications. *Journal for Research in Mathematics Education*, *49*(1), 91–97.

Stein, M. K., Remillard, J., & Smith, M. S. (2007). How curriculum influences student learning. In F. Lester (Ed.), *Second handbook of research on mathematics teaching and learning* (pp. 319–369). Reston, VA: National Council of Teachers of Mathematics.