Topic Study Group 31

In-Service Mathematical Teacher Education and Mathematical Teacher Professional Development at Secondary Level

Konrad Krainer[1], Betina Duarte[2], Talli Nachlieli[3], Craig Pournara[4], and Youchu Huang[5]

ABSTRACT The focus of TSG-31 for ICME14 was the study of in-service and/or professional development initiatives aimed at improving secondary mathematics teaching on a *large scale*. We adopted the definition of *scaling up* as reaching many classrooms, and potentially whole schools, districts, cities, or even a whole state or nation. We also encouraged submissions dealing with the adaptation and implementation of an initiative from another country. TSG-31 covered a wide range of secondary in-service courses and professional development programs, as well as school development projects, and collaborative networks of practitioners and researchers.

Keywords: Scaling up; Professional development; Large scale programs.

1. Topic under Study: General Description

At ICME-14, the Topic Study Group "In-Service Mathematical Teacher Education and Mathematical Teacher Professional Development at Secondary Level" (TSG-31) focused on the study of in-service and/or professional development initiatives aimed at improving secondary mathematics teaching on a large scale. *Scaling up* means to reach many classrooms ($n \geq 10$), and potentially whole schools, districts, cities, or even a whole state or nation. The TSG team expressed openeness for a broad range of initiatives, including in-service courses, professional development programs, school development projects, and collaborative networks of practitioners and researchers. Each initiative was asked to be research-based and to provide new insights into the challenge of improving mathematics teaching on a large scale. Some of the research questions considered were: What does it take to up-scale a professional-development

[1] Institut für Unterrichts- und Schulentwicklung, Alpen-Adria-Univerität Klagenfurt, 9020 Klagenfurt, Austria. E-mail: Konrad.Krainer@aau.at
[2] Departamento de Ciencias y Tecnología, Universidad Pedagógica Nacional, Ciudad Autónoma de Buenos Aires, C1070AAV, Argentina. E-mail: betina.duarte@unipe.edu.ar
[3] Department of Mathematics Education, Levinsky College, Tel Aviv-Yafo, 6937808, Israel. E-mail: tallin@levinsky.ac.il
[4] Wits School of Education, University of the Witwatersrand, Johannesburg, 2193 Gauteng, South Africa. E-mail: Craig.Pournara@wits.ac.za
[5] School of Education, Shanghai Normal University, 100 Guilin road, Xuhui District, Shanghai, China. E-mail: hyc@shnu.edu.cn

program? What are the factors that need to be considered when adapting a certain program to new cultural settings? Which aspects of the intervention could be scaled up and which couldn't? How could the impact of large-scale approaches be evaluated? What types of diagnostics about students' mathematics learning can be applied and why? To what extent can a steady collaboration between research and practice be achieved on a systemic level? What are the key factors in sustaining such collaboration? What challenges arise during such collaborations?

In order to facilitate the organization of activities, the TSG-31 team carried out a voluntary online-meeting one day before the first session. Among others, we explained our chat & notes system which helped us to record questions, answers and comments by onsite and online participants as well as by us during the week.

2. Contributions

Overall, 40 papers and posters had been submitted to TSG-31. Due to several reasons (review process, pandemic etc.), we finally had 20 paper presentations and one invited talk (IT) (18 online and 3 onsite), representing countries on six continents (Tab. 1 on the next page). In addition, five posters were presented in an extra session outside the topic study groups.

2.1. Core ideas about scaling up

Paul Cobb[1], the invited speaker, pointed out the significant progress reached by research on the teaching and learning of mathematics in recent years. However, these findings have limited impact on classroom instruction in many countries, including the USA.

On a recent investigation, Cobb collaborated with mathematics teachers, school leaders, and the leaders in several large urban school systems for eight years to investigate what it takes to support improvements in the quality of instruction and thus students' learning on a large scale. Their findings from this work take the form of an empirically-grounded theory of action (ToA) for instructional improvement at scale that spans from the classroom to system instructional leadership and encompasses: curriculum materials and assessments; pull-out teacher professional development; school-based teacher collaborative meetings; coaches' practices in providing job-embedded support for teachers' learning; school leaders' practices as instructional leaders in mathematics; and system leaders' practices in supporting the development of school-level capacity for instructional improvement.

Scaling up is a special case of implementation which can be understood as "a change-oriented process of endorsing an action plan" (Koichu et al. 2021). Implementation, that aims at scaling up (e.g., to thousands of mathematics classes or schools) has much more complex issues to deal with than a smaller project (e.g., working with some mathematics classes or schools). When reaching a larger regional or national level, a sound interaction between research, practice and policy is needed. Regarding the balance between research, practice and policy, two contrasting approaches — Technical rationality and Reflective rationality (Schön, 1983; Altrichter et al. 2008) — have been described so far. In order to combine the strengths of both approaches and to avoid weaknesses, a third approach — Societal rationality — is introduced (Krainer, 2021) and discussed.

Tab. 1. List of presentations and invited talk (IT) in TSG-31

	Paper and author(s)
[1]	Investigating what it takes to improve the quality of mathematics teaching and learning on a large scale. ***Paul Cobb*** (USA). (IT)
[2]	How Chinese mathematics teachers prepare for teaching competition in community? ***Chenfei Zhu*** *and Hongbing Wang* (China).
[3]	Linking theories and practices: understanding teachers' learning in Chinese lesson study through activity theory perspecitve. ***Wenjun Zhao***, *Rui Ning, Xiaoxia Zhang, Chuan Zeng, Xianjia He, and Jun Wen* (China).
[4]	Shifting cultural contexts: a professional development program towards congnitively demanding instruction. ***Talli Nachlieli*** *and Einat Heyd-Metzuyanim* (Israel).
[5]	Scaling up a mathematics professional development course in South Africa and its impact on students. ***Craig Pournara*** (South Africa).
[6]	Action learning: a tool to help teachers promote self-regulation (SR) in students. ***Tamsyn Margaret Terry*** (Australia)
[7]	Collaboration between mathematics and special education teachers to promote argumentation as an inclusive practice. *Pilar Peña*, ***Horacio Solar***, *Constanza San Martín, and Florencia Gómez* (Chile)
[8]	Developing and supporting exemplary mathematics educators in high need schools. *Lillie R. Albert, Chi-Keung Cheung, and* ***Solomon Friedberg*** (USA).
[9]	An investigation on mathematics teachers' professional development in rural China. ***Limin Chen*** (China), *Caroline Williams-Pierce* (USA), *and Min Jing and Lieven Verschaffe*l (Belgium).
[10]	Sustainablity and scaling up of school-based teacher professional development programme. ***Zhen Feng Eric Koh***, *Leng Low, and Ngan Hoe Lee* (Singapore).
[11]	Effective design of massive open online courses to support mathematics teachers' professional learning. ***Karen Hollebrands*** *and Hollylynne S. Lee* (USA).
[12]	Using videos to foster facilitators' noticing in the field of language-responsive mathematics teaching. ***Christoph Look***, *Christin Laschke, Bettina Roesken-Winter, and Rebekka Stahnke* (Germany).
[13]	Investigation on the identification and group differences of professional development approaches of mathematics teachers. ***Luyishou Ma*** (China)
[14]	Developing an e-mentoring professional development program in supporting pedagogical content knowledge of novice mathematics teachers: A design-based study. ***Derya Çelik***, *Mustafa Güler, Rukiye Didem Taylan, Müjgan Baki, Esra Bukova Güzel, Fatma Aslan Tutak, Damla Kutlu, and Aytuğ Özaltun Çelik* (Turkey)
[15]	Enhancing students' mathematical reasoning through a professional development experiment. *Joana Mata-Pereira and* ***João Pedro da Ponte*** (Portugal).
[16]	Exploring online learning environments in professional development for scaling-up educational innovations. *Robert Weinhandl and* ***Stefanie Schallert*** (Austria).
[17]	Professional development facilitators and their learning goals towards a PD course on teaching probability and inferential statistics. ***Ralf Nieszporek***, *Birgit Griese, and Rolf Biehler* (Germany).
[18]	Out-of-field teachers' acquisition of school-related content knowledge during a professional development course. ***Steffen Lünne*** *and Rolf Biehler* (Germany).
[19]	Survey and analysis of confusion of the implementation of the new curriculum for high school mathematics teachers in Henan Province, China. ***Deming Yan*** *and Hongwei Wang* (China).
[20]	In-service mathematical teacher education in Morocco: impediments and challenges. ***Nouzha EI Yacoubi*** (Morocco).

2.2. Professional development issues at large scale

China has a level-by-level teaching competition system. Every selected contestant teacher from a lower-level competition, together with their community, prepares for a higher-level competition through iterative and incremental preparing sessions. These preparing sessions all start with a mock-teaching lesson with randomly selected students and are followed by discussions within the community. As a part of an ongoing research, Zhu and Wang[2] reported findings from these preparing sessions through an analysis of 28 interviews. These sessions share similar features in objectives, procedures, participants, resources, and effects; as they mature, there are changes and trends; all participants improve their knowledge, abilities and beliefs related to mathematics teaching. The process of the preparing sessions is constructive, resourceful, inspirational, and problem-solving-like. Moreover, the influence of this type of work is progressive, productive, transferrable and pointed to all participants' long-term professional development.

Chinese lesson study is powerful in linking theories and practices in the reform context. However, the mechanism behind such effectiveness is still under-researched. Zhao et al.[3] contributed to this issue exploring how teachers learn to use theories to guide their teaching in a Chinese lesson study. Taking activity theory as the theoretical lens, their research identified contradictions between activity systems of research and teaching, and how they were dealt with through the lesson study activities. This can shed light on how teachers learn in lesson study and necessary conditions that support their learning.

Nachlieli and Heyd-Metzuyanim[4] provided another contribution to the understanding of the processes of teachers change through professional development programme. The study explored processes of change in teachers' practice as a result of participating in a professional development (PD) for cognitively demanding, discourse-rich, instruction, titled TEAMS (Teaching Exploratively for All Mathematics Students). The TEAMS PD was "imported" from the USA to Israel, relying on two programmes: "The 5 Practices for Orchestrating Productive Discussions" and "Accountable Talk". Participants included 50 middle- and elementary-school teachers who participated in PD meetings during one school year and videotaped themselves teaching cognitively demanding tasks. Lessons were coded using a lesson-observation protocol. Individual Growth-Curve Model analysis indicated statistically significant growth in several parameters. Their findings contributed to shed light to the challenges of transferring a PD programme between two cultural contexts. As an example, it is pointed out that the "travel" of observational measures for studying the cognitively demanding instruction across cultures, is limited.

Schallertn and Schallert[16] agreed in her presentation with Cobb on the difficulty of getting educational innovations beyond the pilot phases. To scale up educational innovations, they combined professional mathematics teacher development and online learning environments (OLE). By applying a grounded theory approach and design-based research, they have investigated how OLE should be designed to support scaling-up. Analyzing written and oral research data indicated that (a) teachers make their own decisions concerning online learning, (b) OLE highlights benefits and practical relevance of an approach/technologies, (c) OLE does not lead to additional work, and (d) security and privacy of OLE could be crucial for teachers.

Related to online environments, Hollebrands and Lee[11] investigated the use of MOOCs for professional development. The design of three MOOCs for mathematics and statistics teachers based on principles of effective online professional development were guided by design principles and describe characteristics and engagement of 5,767 registrants with these designed features. Through this experience, the researchers claim that design principles provided opportunities for educators to develop their pedagogical skills.

Coming back to sustainability issues, the paper[10] of Koh and colleagues discussed the factors that influence the sustainability and scale-up of a school-based professional development programme for mathematics teachers in the Singapore context. In particular, this study considered factors such as shared vision and mutual accountability, influencing the scale-up and sustainability of a school-based professional development programme's impact on mathematics teachers' knowledge or practice.

Special characteristics of professional development are to be considered in the case of novice teacher as it was pointed out by Çelik et al.[14]. Although many studies have determined the professional needs of novice teachers, there are limited articles that have introduced interventions to address these needs. As part of a large-scale project, this paper presented two cycles of a design-based study aimed to develop the pedagogical content knowledge (PCK) of novice mathematics teachers. The study was conducted with the participation of twelve novice mathematics teachers in total and the change between two cycles is described. The analyses of the data show that teachers in the cycle which was enriched with additional video content presenting student thinking made better progress in knowledge of students, particularly related to misconceptions and learning difficulties compared to other teachers. Overall, both cycles appeared to support novice teachers' PCK. Finally, some suggestions are made for further research and practices for teacher learning.

The challenge of improving students' mathematical reasoning is addressed by a study aimed at improving the professional development of secondary teachers in charge. Mata-Pereira and Ponte [15] identified the main characteristics of a professional development experiment (PDE) centered on developing secondary teachers' mathematical and didactical knowledge to enhance students' mathematical reasoning. This design-based research is one of the strands of project REASON and concerns a PDE with secondary teachers that begins in October 2019. One of the main features of this PDE is the close link between research-based knowledge about enhancing students' mathematical reasoning and participant teachers' practice, thus providing innovative PD strategies and materials to enact such link.

Linked to the intention to consider the PD's specific characteristics are needed to improve school performance of students from lower secondary schools in the South African context, Pournara[5] showed some evidence to promote mathematics teachers' interventions. The Transition Maths 1 course was designed for teachers many of whom were under-prepared for this task. Following the initial pilots, a quasi-experimental study revealed conditions to impact student attainment. The intervention was scaled up and has now been completed by more than 150 teachers from approximately 80 schools. A recent quasi-experimental study provides further evidence of impact at student-level although this impact is not necessarily evident in the year immediately following course completion, suggesting a delayed impact of PD on students.

In a different context, the shortage of mathematics teachers in secondary schools of many German Federal States have promoted professional development courses in mathematics for teachers who already teach or want to teach mathematics out-of-field, which means teaching mathematics without official qualification. Since 2014 the German Centre for Mathematics Teacher Education and the regional government in Detmold (North Rhine-Westphalia) have conducted three of these professional development courses for out-of-field teachers in mathematics (secondary schools). Lünne and Biehler[18] presented an experience with the research aim to improve the knowledge about the group of the participating teachers and about aspects of success in the design of the courses as well as with the goal to develop curriculum material for such courses, which can be put to broader use all over Germany. During the second and the third course they investigated participants' development of school-level content knowledge in elementary algebra. The results show that participants with little prior knowledge can build up content knowledge in the PDC, while participants with a high level of prior knowledge are probably under-challenged by the test.

2.3. Collaborations between researchers and teachers

Some presentations showed the complexity of working with in-service teachers and their great potential. Terry[6] explored how action learning processes contribute to teachers' understanding and practice of self-regulation (SR) in secondary mathematics classrooms. Three constructs of SR, cognitive, metacognitive and motivational informed this study. Ten secondary teachers who participated in this study during 2019 reported that action learning was key in building teacher understanding of SR and improved pedagogical approaches that enhance student SR. Observations of their classroom behavior confirmed the targeted impact on the classes.

Peña et al.[7] presented preliminary results of a qualitative study with the purpose to analyze the collaboration processes between teachers' dyads of special education and mathematics that favor the development of argumentation in the mathematics classroom. Using case studies methodology, they conducted interviews and classroom video recordings. From a sample including 24 pairs of 7th-grade math and special education teachers, three pairs of cases were selected because they showed high levels of argumentation and had worked collaboratively. Through analyses of interviews, they identified facilitators and obstacles of collaboration to promote argumentation. They supported that, in order to promote argumentation, teacher dyads need to have common goals and shared workspaces for planning and decision making, but time devoted to shared work is still insufficient.

Albert et al.[8] addressed the collaboration with educators in high need schools. As students in high need school districts of United States generally do not do as well in mathematics as students in other districts, they are ultimately less likely to become part of the STEM workforce. Addressing this gap requires both the development and the retention of high-quality math teachers in high need districts. They reported on a project, now in its seventh year, to do so. The project features university level math educators and mathematicians working together, allowing for foci on content knowledge, pedagogical content knowledge and expertise in pedagogy as well as the development of a professional community concerned with supporting secondary math teachers. The project has been broadly successful, and the experience provides lessons that may be taken for other programmes with similar concerns.

In a similar way, students showing low language proficiency struggle with learning mathematics, especially in comprehending conceptually. Thus, teachers challenged with the language-responsive mathematics teaching needed, engage in Professional Development (PD). Look et al.[12] presented a design research approach to prepare PD facilitators who provide support teachers' learning. To prepare facilitators for their challenging role, and to foster their noticing of teacher learning they opted for using videos, taken from PD. Their approach was twofold: by an expert rating, involving five experienced facilitators, they confirmed that the videos address PD-PCK aspects, and yielded noticing prompts to be added to the videos. In the implementing study they showed that 60% of the discussion was related to PD-PCK, the remaining 40% on general PK. When facilitators reflected on content-specific aspects, 31% of the time was dedicated to describing, 44% on interpreting the situation, and 25% on making suggestions for alternative actions. On a re-design they will concentrate to further push discussions towards PD-PCK.

The need of qualified facilitators is found in different scenarios and Nieszporek et al.[17] presented the case of professional development for the teaching of probability and statistics. Although facilitators and their competencies play an important role for the success of PD courses, there is only little research on their orientation towards central learning goals. The need of providing facilitators a strong development including material for their work justifies this study as a scaling-up context. This case study casts a light on facilitators' decision-making, using an expertise model for the PD level. Preliminary results on the choice of learning goals by facilitator Mike (the study case) and his justifications enable a better understanding of his practices and thinking.

2.4. Constructing Professional Development Maps

Chen et al.[9] presented a research base on a questionnaire administered to 61 rural middle school mathematics teachers from China to investigate their professional development and their views of its influencing factors on their professional development. The questionnaire was designed in four dimensions: teachers' personal information; teachers' professional development (i.e., identity as rural teachers, self-development consciousness); impact of other influencing factors (i.e., rural students and their parents, school atmosphere); and their training requirements. Firstly, results revealed that rural teachers held slightly positive beliefs in their professional development, as well as the impact of influencing factors on their professional development. Secondly, results revealed a significant positive relationship between teachers' points of view in their identities, self-development consciousness, the impact of rural students and parents, and the impact of school atmosphere.

Ma[13] presented a qualitative survey designed to document on 110 primary and secondary mathematics teachers' independent development, teaching and research activities, routine training practices, induction culture and exceptional professional development approaches. The study seeks to determine the basis for the selection of the methods of mathematics teacher education.

2.5. Constructing Professional Development Maps

The development of a new curriculum is a starting point for a professional development process insofar this kind of changes arouses Yan and Wang[19] used an open questionnaire and statistical methods to investigate the confusion for high school mathematics teachers in Henan Province. The researchers found that the core literacy of high school mathematics is the most conspicuous, the new curriculum structure and content related issues need to be solved, teaching quality evaluation needs to be operated, and in consequence new curriculum training needs to be expanded and upgraded. Based on these findings, suggestions from four aspects are established: strengthening the implementation of new mathematics curriculum standards of high school mathematics, giving play to the leading and radiating role of the experimental area, giving full play to the leading role of the college entrance examination, and training the new high school mathematics curriculum well.

Several reports reveal that the Moroccan Educational System, despite some registered progress, is still facing some dysfunctions, in particular the In-service Mathematical Teacher Education and Mathematical Teacher Professional Development has not yet been placed in a strategic position to respond to teachers' real needs. El Yacoubi[20] presented the priorities of the system reform, one of them aiming to enable teachers to complete and perfect their training.

3. Summary

In the following, we sketch some important assumptions and questions that emerged from our discussions in TSG-31:

- The starting point for many scaling up initiatives is the wish to take an instructional innovation that has proved effective in supporting students' learning in a small number of classrooms and reproducing that success in a large number of classrooms (Cobb and Smith, 2008). Clearly we could replace *classrooms* with *schools, districts* or *regions* etc.
- Scaling up initiatives must take into consideration a wide range of contextual constraints. This is particularly important when importing from or exporting to vastly different cultural settings. For example, different countries have

different general conditions for their education systems (centralized versus decentralized, public or private sector, relatively well resourced versus relatively poorly resourced, urban areas versus rural areas, top-down versus bottom-up steering, voluntary versus compulsory professional development etc.).

- Also, it makes a difference whether an initiative focuses on a specific mathematical content or theme (e.g., algebra or proving), on a reform that aims at improving mathematics teaching, or a larger reform focusing on STEM teaching (where mathematics is only one subject).
- Scaling up an initative might change the character of the initiative: For example, will it lose its focus on the micro-level (e.g., students' learning, student-teacher interaction etc.)? Does it get more policy-driven? What does this mean for research and teaching practice?
- Scaling up of initiatives poses new challenges for researching the initiative. For example, what kind of data become more important? What kind of knowledge is aimed at: for the scientific community (publications, presentations etc.), for practice (suggestions, materials etc.), and for policy (steering information, policy advice etc.)? Which knowledge regarding teachers gets specific focus (content knowledge, pedagogical content knowledge, pedagogical knowledge etc.)? Are larger projects more under pressure than the initial interventions to produce "success stories"?
- Studies of scaling up do not necessarily involve only quantitative methods. A good mixture of quantitative and qualitative methods helps to generate "numbers and stories".
- Scaling up involves working with stakeholders who may be less relevant in smaller initiatives (e.g., from mathematics teachers to district lead teachers, from single mathematics education researchers to research institutions, from superintendents to a country's policy makers).
- What can we expect from school-based interventions on a large scale? How can we respect/consider the particularities of a school in a large-scale education intervention project? (e.g., the existence of teachers with specific qualifications in mathematics education)? Which financial implications need to be taken into consideration?
- Collaboration among mathematics teachers and collaboration between teachers and researchers in mathematics education are both important means to make initiatives successful (Borko and Potari, 2020). How can the benefits of such collaborations be drawn into the scaling up of initiatives where such collaborations may not easily occur?
- What can we learn from lesson and learning studies as collaborative approaches in mathematics education? And how might these learnings inform the scaling up of lesson and learning studies?

References

H. Altrichter, A. Feldman, P. Posch and B. Somekh (2008). *Teachers investigate their work: An introduction to action research across the professions* (2nd Ed.). Routledge.

H. Borko and D. Potari (2020). *ICMI Study 25 Conference Proceedings. Teachers of mathematics working and learning in collaborative groups*. ICMI.

P. Cobb and Th. Smith (2008). District development as a means of improving mathematics teaching and learning at scale. In K. Krainer & T. Wood (Eds.), *Participants in mathematics teacher education: Individuals, teams, communities and networks*. Volume 3 of the International handbook of mathematics teacher education (pp. 231–254). Sense Publishers.

B. Koichu, M. S. Aguilar and M. Misfeldt (2021). Implementation-related research in mathematics education: The search for identity. *ZDM Mathematics Education*, 53, 975–989. https://doi.org/10.1007/s11858-021-01302-w

K. Krainer (2021). Implementation as interaction of research, practice, and policy. Considerations from the Austrian initiative IMST. *ZDM Mathematics Education*, 53, 1175–1187. https://doi.org/10.1007/s11858-021-01300-y

D. A. Schön (1983). *The reflective practitioner. How professionals think in action*. Basic Books. http://www.loc.gov/catdir/enhancements/fy0832/82070855-d.html