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Introduction to the papers of TWG22:

Curriculum resources and task design in mathematics education

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Introduction

The Thematic Working Group 22 (*Curriculum Resources and Task Design in Mathematics Education*, hereafter TWG22) was launched at CERME10 in recognition of the growing area of research in the field of curriculum resources (Pepin & Gueudet 2018; Stylianides, 2016), their design and use by teachers and students, and the specific design of mathematical tasks, mostly by teachers acting as designers (Laurillard, 2012; Jones & Pepin, 2016) but also their place in textbooks (e.g., Stylianides, 2014). While this field shares approaches, methods and research topics found in other areas in mathematics education research (e.g. TWG15, 16), it has its own distinctiveness. It focusses on the design and use of curriculum materials (digital and non-digital) for various educational purposes, including the design of classroom-based interventions to promote important but hard-to-teach and hard-to-learn learning goals (e.g., Komatsu, 2017; Saxe, Diakow, & Gearhart, 2013; Stylianides & Stylianides, 2009). Moreover, leaning on work by Pepin, Choppin, Ruthven, and Sinclair (2017), we make here a clear distinction between (digital) curriculum resources and educational technology, as research on (digital) curriculum resources (in the area of mathematics) pays particular attention to

- the aims and content of teaching and learning mathematics;
- the teacher's role in the instructional design and task design process (i.e., how teachers select, revise, and appropriate curriculum materials; how teachers design tasks);
- students' interactions with (digital) curriculum resources in terms of how they navigate learning experiences within a digital or non-digital environment;
- the impact of (digital) curriculum resources in terms of how the scope and sequence of mathematical topics (and tasks) are navigated by teachers and students;
- the educative potential of (digital) curriculum resources in terms of how teachers develop capacity to design pedagogic activities and tasks. (amended from Pepin, et al. 2017, p. 647)

We acknowledge that “curriculum resources” is an elastic term: ranging from particular tasks and activities, over one-off worksheets or tests, to a full-blown curriculum program, and all of these notions were addressed in the different sessions at CERME10 and CERME11.

The role and importance assigned to curriculum resources and task design in the last decades has led to an enormous variety of approaches to research in this area. At CERME10, 17 papers and 6

posters were accepted, and at CERME11 the number of papers submitted to TWG22 has increased: 22 papers and 8 posters were accepted. In terms of organization, the paper contributions were presented (by the lead author) and discussed (by an ‘independent’ TWG colleague). The presentation/discussion sessions (see below) were followed by parallel table discussions (colleagues could choose which table to join), and finally a plenary, where amanuenses of each table/paper reported back on the main issues discussed.

The sessions were organized under the following six themes (distributed over six sessions):

1. International textbook studies
2. Teacher thinking and competences
3. Task design
4. Digital curriculum resources and task design
5. Particular task design and theories
6. School and workplace mathematics

Although there was considerable overlap between some of the sessions, for clarity we briefly discuss each theme separately below. During the first part of session 7 the eight posters were presented and discussed in a “poster walk”. The second part of session 7 was devoted to a discussion of the issues raised during the six thematic sessions.

Within CERME, the 22 papers and 8 posters presented in TWG22 at CERME11 drew upon research from 25 countries across 4 continents, and offered a wide spectrum of perspectives. Outside CERME, we saw an increase in handbook chapters, special issues, and whole books focusing on the design and use of curriculum resources (e.g. Pepin, Gueudet, Yerushalmy, Trouche, & Chazan, 2016; Pepin & Choppin, 2017; Stylianides, 2014, 2016). At the same time, the work of TWG22 overlapped with research in the field of, for example, digital technology in mathematics education, or teacher education. New conferences have been initiated (e.g. ICMT; MEDA) with colleagues from TWG22 involved in their set-up and as IPC members.

Themes and paper contributions

In session 1 international and comparative research was presented, predominantly related to textbook studies. In two paper presentations (Memis; Ruwisch & Huang) a particular topic area (e.g. reasoning; length measurement) was compared in two countries’ textbooks (Japanese & Turkish textbooks; German & Taiwanese textbooks). Results showed that, for example, in Taiwanese textbooks the emphasis was on concrete actions, whereas in the German textbooks it was on abstract and mental procedures; and the Japanese textbooks provided more “creative” mathematical reasoning opportunities (in the area of proportions) than the Turkish books. A third textbook study of Malawian primary textbooks (Lisnet) examined grade 1 textbooks with respect to mathematical opportunities (with respect to the number concept), whilst teachers’ pedagogical design capacity with respect to using textbooks was investigated in another (Chowdhuri). A comparison of naming systems (of curriculum resources) by Chinese and Mexican teachers was conducted in Wang et al.’s study, which highlighted the problem of conceptual equivalence in international studies (see permeating themes).

In session 2 issues related to teachers’ use of curriculum resources, their lesson planning and related instruction were discussed. Whilst in the paper by Siedel examined teachers’ knowledge of their

resource options in order to support and further their design of effective instruction, another group of researchers (Allsopp, et al.) explored teachers' use of a curriculum framework (involving mathematical competencies) for teaching activities. The team of Delaney and Gurhy investigated task characteristics and teacher practice that supported differentiated instruction and work on challenging tasks.

In session 3 core issues of task design was addressed. These related to the design of tasks with particular characteristics (e.g. self-explanation prompts - Dyrvold & Bergvall); to task design on particular mathematical topic areas (e.g. slope of a curve - Bos, et al.) or with focus on particular challenges (e.g. conceptual and/or creative challenges - Jaeder); to task design fostering students' engagement (e.g. construction of examples on a particular topic – Cusi & Olsher), and to the design of a task progression framework (e.g. Courtney & Glasnovic Gracin).

In session 4 core issues of task design continued to be addressed, also in relation to digital curriculum resources. Whilst the study by Essonnier et al. addressed collaborative design (in an EU project) of a digital resource and the linked social creativity, the study by Eckert and Nilsson investigated the design of digitally enriched classroom talk. In her research Rafalska focused on the teaching and learning of 'algorithmics' in terms of resource design, whilst Geti and Ding examined the use of variation theory for problem-based task design.

In session 5 task designs related to particular theories were examined. These theories included the Hypothetical Learning Theory for the learning of rules for manipulating integers (Schumacher & Rezat) and for the learning of Calculus (Breen, et al.), and the Theory of Conceptual Fields for the analysis of textbooks on the concept of function (Sureda & Rossi).

In session 6 curriculum resource design related to school and workplace mathematics was explored. Studies included those that investigated the 'building of bridges' between school and workplace mathematics (Herheim & Kacerja), and the integration of inquiry-based learning and workplace mathematics into mathematics teaching (Kalogeria & Psycharis).

In session 7 the eight posters were presented. The issues addressed in the posters ranged from those related to the design of the mathematics curriculum (e.g. Solano, et al.) and tools for such design (e.g. Noehr, et al.; Katona); over those linked to task characteristics (e.g. Misailidou & Keijzer; Martin); to teachers' selection and use of curriculum resources (e.g. Kock & Pepin; Varga; Jukic Matic & Glasnovic Gracin).

Issues raised across the six sessions

The sessions were organized under six themes, and naturally issues related to those themes were discussed in those sessions. However, there were also selected permeating strands/themes that ran across the themed sessions. The following themes permeated all six sessions: (1) terminology; (2) teacher learning and student learning; (3) networking of theories; (4) particular theories: hypothetical and actual learning trajectories; (5) methodologies; (6) theory and practice; and (7) context.

Terminology

Questions such as the following were raised:

1. What constitutes a task? - An activity in a textbook? A lesson? A learning trajectory?
2. Where does task design finish? Should implementation be included in the design?
3. When is a task educative for students?
4. When is a task educative for teachers? E.g. in a teacher guide?

The issue of ‘terminology’ (and ‘naming’) was raised in the first session, initially because several comparative studies were presented (e.g. Memis; Ruwisch & Huang; Wang et al.). In the comparative studies the researcher/s have tried to establish ‘equivalence of concepts’, so that they could establish validity of concepts for the comparisons. This was linked to the translation from one language to another, and the meaning making of particular notions, so that the researchers could actually compare ‘like with like’. It was also questioned what it means to design a ‘task’ (see also session 3 and 4): first, is a task similar, or equivalent, to an activity in a textbook, or do we mean a lesson, or even a whole lesson series, when we speak of a task? Second, what does ‘task design’ mean? Is it linked to task/lesson preparation, or is the enactment part of task design? Third, when is a task educative for students, and when for teachers? The issue of “educative materials” (Davis & Krajcik, 2005; Pepin, 2018) was raised, and educative for whom. Clearly, educative curriculum materials for students (e.g. in textbooks) are likely to be different from those for teachers (e.g. in teacher guides that accompany textbooks).

Teacher learning and student learning

Issues and questions such as the following were raised:

- It is often (naively) assumed that students “automatically” learn when using a particularly designed task
 - How do we investigate that?
- How does teacher learning take place when working with tasks and materials?
 - If tasks are developed in a community, how does this affect teacher learning?
- What kind of teacher learning is required for choosing, designing, interpreting, and implementing tasks?
 - What is the possible role of educative curriculum materials?

The issue of ‘teacher and student learning’ links to the above-mentioned questions raised concerning educative curriculum materials. It was discussed in which ways teachers learn when working with curriculum materials (e.g. textbooks; digital curriculum materials) and mathematics tasks. How does one know that teachers learn when interacting with curriculum materials, and as importantly, what do they learn? And if they work in a collective, do they learn more, or less likely, or otherwise? Indeed, it seems to be necessary to establish under which conditions teachers learn best, and with which kinds of curriculum materials. Effective educative materials (for teachers) must have particular characteristics/heuristics.

Networking of theories

Issues and questions such as the following were raised:

- Abundance of theories
 - Activity Theory
 - Variation Theory

- Theory of Conceptual Fields
- Documental Approach to Didactics
- What are their boundaries/ domains of application/ similarities & differences/ limitations?
- Can they be combined/ networked?
 - Is any combination viable?
- How can they be linked to design principles?

In session 5 particular theories were emphasized as bases for the analysis and design of tasks (e.g. variation theory). Moreover, it was questioned whether particular theories could be combined or networked (e.g. Bikner-Ahsbals & Prediger 2014), and under which circumstances this might be useful. For example, the theory of Hypothetical Learning Theory (HLT, Simon 1995) was seen as a theory supportive of teachers to design a coherent learning trajectory for their students. However, this particular theory might not suffice for defining particular design principles of a learning trajectory; for design principles particular curriculum design tools, or task design principles, would be also be needed (e.g. variation theory). Furthermore, issues related to the use of a theory outside of the context where it was ‘born’ were discussed, and whether a theory might be differently interpreted in different contexts.

Particular theories: Hypothetical and actual learning trajectories

Issues and questions such as the following were raised:

- What do they mean?
 - Issue of singular (trajectory) vs. plural (trajectories)
 - Common/joint/collaborative learning path vs. individual learning path
- What does the comparison of the two tell us?
 - Implications for task design(ers)
- How do they link (or how might they be linked) to design principles?

Linked to the above, it was questioned whether the envisaged hypothetical learning theories would actually develop into actual student learning/study paths (e.g. Pepin & Kock – this conference; Weber, Walkington, & McGalliard 2015), and in which ways the comparison of the two would provide indications of design criteria/principles (for task/curriculum designers) or the efficacy of an intervention (Stylianides & Stylianides, 2009).

Methodologies

Issues and questions such as the following were raised:

- Design (based) research as a methodology tailored to bridging theory and practice.
- How do theories inform methodologies for studying task design, implementation...?
- Are some methodologies better suited to study task design, implementation than others?
- How do we measure effectiveness of the task design, implementation, stability, for example? Is comparison of HLTs and ALTs a viable way to do this?

In terms of empirical research, questions were discussed linked to the ‘measurement’ of the design and implementation of tasks, the design and evaluation of processes expected to help students (and teachers) to develop deeper understandings of the mathematics and its learning (and teaching).

Theory and practice

Issues and questions such as the following were raised:

- Role of users
 - Teachers as designers
- Researchers and teachers working together
 - Collaboration/cooperation?
 - Role of researcher/s and teacher/s
- How can research findings inform practice and how can practice inform research?

Several studies presented in the TWG22 used a design-based research approach. This methodology was seen to bridge theory and practice, as theoretically underpinned designs/interventions are evaluated in practice, and subsequently re-designed and evaluated in iterative cycles to reach the desired results. One of the questions on design-based research links to the role/s of the designer and users: for example, when do teachers act as designers; when are they the ‘implementers’ of commercial designs (e.g. from textbooks), who are expected to appropriate the design/s, or even enact the design/s ‘with fidelity’? What does ‘teacher design’ mean, and does design include creativity and novel design? Or is teacher design when teachers make small amendments to mathematical tasks during their lessons? Perhaps more importantly, it was questioned in which ways research findings can help teachers in their daily practice of ‘task design’, and how teachers’ practice informs and stimulates research that addresses the issues relevant for teachers.

Context

Issues and questions such as the following were raised:

- Researchers are often not explicit about particular contexts, and societal influences are sometimes difficult to determine, so are particular teaching cultures (e.g. textbooks – or lack of them – play different roles in different places).
 - What might we be able to infer from a textbook analysis in terms of student learning opportunities in the classroom?
 - Affordances and limitations of textbook analysis
- Exploratory study – are the systems stable? What has changed and what stays the same, when
 - Curricula change?
 - Resource systems vary?
- Technology, and the changes it brings, can render some tasks redundant or unworkable

One of the permeating strands throughout the six sessions related to the context of the design and enactment of curriculum resources. Mathematics teachers work under very different conditions with different kinds of curriculum resources, inside and outside the classroom. In some contexts, textbooks are crucial/mandatory resources, in others teachers prefer to ‘pick and choose’, or design their own materials. In some contexts, teachers can dedicate half of their time to the design of curriculum resources and learning trajectories, in others they are expected to ‘teach by the book’. It became clear that what we measure as researchers might be valid for one particular school or

region, or true for a particular time, but that parameters change with time and context, and hence research only provides glimpses of particular phenomena.

Possible directions for future research

Whilst there was a clear overlap of research themes (and directions) between CERME10 and CERME11 in TWG22 (e.g. task design, plurality of theoretical frames), at CERME11 issues related to international studies and international comparisons emerged as important points for discussion. This also related to theoretical frames, or those that were developed in one context and used in another. Moreover, teacher professional development practices and their work with curriculum resources were compared from one context to another, and this led the way to question the scalability of particular curricular practices and design activities.

The following directions for future research emerged from the discussions in TWG22:

- Understanding better the appropriation of tasks by practitioners (teachers, lecturers) and the impact on students (and teachers) would be a valuable focus. Teacher design often includes appropriation.
- There is additional potential to look at professional development around particular tasks.
- Students and their learning experiences should be included in considerations for task design. They are typically included in design-based research, where selected aspects of student response (to tasks) are often included.
- There is abundant potential to research the notion of ‘task design’, in particular when researchers or task designers let go of designs and hand them over to practitioners/teachers (e.g. in terms of the fidelity to the intended design of the task). Confrey and her team (Sztajn, Confrey, Wilson, & Edgington, 2012) have developed learning trajectories for the common core standards, which have fidelity to the common core curriculum.
- We discussed fidelity of resources that are passed on to teachers, but we have not sufficiently discussed fidelity of design to research on tasks or to the theory used and this may be addressed in future work.
- Scalability of processes was not a strong focus of the working group. The mathematics education community is still more concerned about small groups of teachers implementing tasks. However, for example, Chinese mathematics education research has moved towards scalability of tasks/materials.

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