DG 20: Current problems and challenges in upper secondary mathematics education

Team Chairs: ***Olive Chapman***, University of Calgary, Canada
Ornella Robutti, University of Torino, Italy
Team Members: ***Gloria Stillman***, University of Melbourne, Australia
Carlos E. Vasco, Bogotá, Colombia

Aims and focus

DG 20 provided a forum for participants to discuss current issues in upper secondary mathematics (USM) education. The team leaders proposed sample questions to reflect such issues, which were approved by other members of the organizing team (OT). These questions were grouped into four themes as follows:

A) *Research to practice and vice versa*: How do/can we make theoretical principles real in teaching USM? How can practice inform and develop theory? How can new theoretical trends influence practice? Are there any trends in preservice and inservice teacher education that can influence USM education research?

B) *Teachers and learners*: How does teachers' knowledge influence teaching and learning? What are valuable mathematical and pedagogical competencies of USM teachers? How do the different beliefs, values and cultural backgrounds of teachers or students affect teaching and learning? What are appropriate models of instruction and perspectives of learning?

C) Tools and technology: What are appropriate/meaningful uses of technology for USM? What can be the different roles of tools and technologies in the mediation of learning? How can the use of tools and technologies influence students' cognitive processes?

D) *Curriculum*: What are appropriate contents for students with different post-secondary goals? Can new theoretical trends influence school curricula? What are the new curricular trends recently developed in different countries?

Based on these themes, a call was made for papers. Four papers were received, reviewed, accepted and identified with the theme it best reflected. Each member of the OT was given the responsibility for further organizing and leading one of the themes. The activities of the group were structured as follows:

Session 1: The first hour was devoted to opening and overview of the DG. A panel of the OT of the DG addressed the themes. The DG was then divided on a voluntary basis into smaller groups according to the themes. About 60 participants representing a wide range of countries attended the DG – most choosing theme B or theme C. In the second hour, the smaller groups began discussion of their themes.

Session 2: In the first hour, the smaller groups continued discussion of their themes. In the second hour, representatives of the smaller groups highlighted the main points of their discussions in a large-group sharing, i.e., to the whole DG.

Session 3: This session was aimed at synthesizing the discussions and formulating statements about the possible common threads of issues in USM education.

There was no paper presentation in the DG. Papers accepted were posted on the DG website and participants were encouraged to read them prior to attending the DG.

Group activities by themes

Theme leaders were free to conduct their sub-groups in their own way and to determine issues for discussion. Thus each sub-group was unique in its activities as reflected in the following summaries prepared by each team leader as identified.

Theme A: From research to practice and vice versa (Gloria Stillman)

Making theoretical principles real in teaching USM: The teacher is the door to the students so teacher beliefs about the importance and relevance of theory are critical. Teacher-researcher projects may be a way to get started. These are highly practice based initially but then theoretical ideas and concepts mediate understanding of evolved changes in practice and the learning environment. Even when teachers are willing to incorporate theoretical principles into their practice there are obstacles such as high stakes assessment, which is externally controlled and set regionally or nationally. One view is that teachers *can do* when they *will it.* Alternatively, even if change is desired, the obstacles loom large. Student success in tests is uppermost in teachers' minds and this often drives practice. Researcher-driven projects need to be based in a genuinely collaborative environment where both theory and practice inform the research process and design. Teacher voices must be genuinely respected and supported in the research process. Possible solutions are: (a) school-based projects inspiring change instigated by outside research and curriculum experts or (b) formation of research-orientated teacher networks.

Practice informing and developing theory: Again, design research could be the answer here. This question gives rise to a further question that needs investigation: What methodological tools or research designs are necessary to *allow* this to happen?

Influence of new theoretical trends on practice: There are wonderful ideas about teaching in research and theory that might help teachers *see things differently* and allow them to think with these ideas; to see more insightfully; to acquire different tools for thinking and organizing their own experience and their own work than can be acquired from everyday life. However, there are lots of problems such as: (a) relevance of theory is not seen by many teachers, especially those with entrenched practices; (b) some theoretical ideas are not practical in classrooms; (c) teachers need to be in a place where they want to hear (i.e., where they have the desire to develop continually but also have a certain amount of current professional satisfaction); (d) teachers who take up research and are interested in applying theory in the classroom are seen as pioneers and allowed to go alone rather than find a ready source of collaboration amongst colleagues; (e) organizational structures maintain the status quo (e.g., no time to implement or money for ICT infrastructure).

Trends in preservice/inservice teacher education influencing mathematics research: (1) Opportunity to become teacher researchers, e.g., in Finland, where experienced teachers are given opportunity to research their own practice. These teachers are considered part of one research school but are doing degrees at several universities across Finland. (2) Postgraduate subjects where teachers read mathematics education research as consumers. (3) Researchers and lecturers from teacher education courses go to schools and cooperate closely with teachers bringing together researchers', lecturers' and teachers' viewpoints.

Theme B: Teachers and learners (Olive Chapman)

Participants of this sub-group were given the opportunity to determine issues of their own for this theme. In the first session, the sub-group formed three smaller groups and brainstormed responses to: "What are the most important issues/challenges pertaining to the teaching and learning of mathematics at the USM level?" Each small group identified key questions to share and to further discuss. In the second session participants worked in two groups and addressed: "How should these issues and challenges be dealt with?"

The group identified a unique set of issues that reflected the different professional contexts of the participants. These issues included:

- The conflict between covering content versus helping students to achieve true learning. There is a lot of curriculum content for the students to go through at too short a time.
- Teachers covering content based on textbooks and curriculum, and teaching for a test instead of considering what is mathematics and teaching for students' understanding.
- Teachers are not confident to take risks. They do not always feel sufficiently secure to allow students to take responsibility for their own learning. What kind of training do teachers need to take those risks?
- What are teachers to do with all the knowledge the students already have?
- Why should students learn "this" if a computer can do it? Do students need all of the mathematics they learn?
- How can we turn multi-cultural classrooms to our advantage, both mathematically and socially? How do we make it a positive learning environment for everybody?
- Encouraging/influencing students to take up mathematics at a higher level.
- Some teachers do not want to change teaching methods.
- Assessing for understanding.

Catherine Sackur's paper (DG 20 website) raised the issue of the challenge of making students responsible for the mathematics they learn.

There were no definitive answers to the above issues. However, some suggestions evolving from the discussions of actions that ought to be considered to address some of the issues are: More importance should be placed on process rather than product and on students' understanding of the mathematics rather than just learning a method. There should be increased emphasis on open-ended learning. Learning should be to promote active citizenship, i.e., to be able to form a coherent argument, to be critical. It is important to establish contact between teachers of all school levels. We should emphasise highlighting the usefulness of mathematics and not just passing exams as motivation of students; get students to write their solution process; and focus on quality not quantity.

Theme C: Tools and technology (Ornella Robutti)

Introduction to the theme focused on research results involving: (1) *Instrumental analysis* in which a device is considered with two interpretations: an artefact, i.e. an object constructed according to a specific knowledge, and an instrument, i.e. the artefact together with the schemes of use introduced by the user. (2) The distinction between

the *symbolic-reconstructive* and the *perception-motor* ways of learning – the first based on mental reconstructions and decoding of symbolic messages, the second on activities in which doing, touching and perceiving are involved. (3) The notion of *mathematics laboratory*, not intended as opposed to a classroom, but rather a methodology. "In the laboratory activities, the construction of meanings is strictly bound, on one hand, to the use of tools, and on the other, to the interactions between people working together." (Robutti et al., DG 20 website).

The discussion of the subgroup, based on themes introduced by the participants, was very rich. During this discussion, the coordinator aimed only at supporting the participation of people and not at introducing new themes. The discussion centered on questions such as:

- How is it possible to help teachers not only to teach technological commands such as "push that button", "press a key", "write this number", but to teach also at a meta-level, transferring consciousness, awareness of the calculation, sequences, processes, …?
- Does the use of technology really change the mathematics we do at school?
- Does the use of technology promote curricular changes?
- What are the boundaries within which students can believe what they see with tools?
- Do teachers really change their ways of teaching with the use of technological tools?

For the first question, participants noted that what is important to construct is mathematical meaning, not command sequence. Students have to be aware of the fact that they are doing mathematics with the help of technology, and not vice-versa (see Nolli & Reggiani, DG 20 website). For the second and third questions, the crucial point is not the technology used or the algorithms implemented in it, but the way these are used at school. This implies the need for reconsidering methodologies, activities, instructional sequences and assessment. In fact, technology promotes educational and curricular change, for example, to diminish exercises based on rote manipulation, substituting them with problem-solving activities, or directing the attention towards graphs and representations, to a larger extent than what was done in the past. In this perspective, an important challenge for teachers enters the scene: every technology has its potentials and pitfalls. So, for the fourth question, students must be aware of those pitfalls, and learn how to manage them, mathematically checking the results given by technology. This involves new topics, e.g., estimation, discrete solution of equations, graphical representations. Therefore, technology may not only change the mathematics done at school, but also the way of thinking. It can call for discussion, conjectures, different feedback, and also theoretical knowledge, including proof. For the last question, maybe in some cases technology does not influence the *way of teaching*. There are teachers who use technology but teach in the same traditional way as they did without it. A possibility to improve the use of technology aimed at constructing theoretical thinking can be found in both preservice and inservice teacher courses.

Theme D: Curriculum (Carlos Vasco)

The USM curriculum seems to be very *homogeneous* in the countries known to the members of theme D-subgroup: algebra, geometry, trigonometry, analytic geometry,

pre-calculus, and, for a few countries, calculus. Known variations seem to occur in five aspects of the curriculum: (a) amount of geometry (e.g., much in Japan, China, Russia and very little in most Latin-American countries); (b) fusion or separation of algebra and pre-calculus: more or less emphasis on functions in the second or third year of algebra or in the course on analytic geometry; (c) required status of calculus (for all students, apparently only in Colombia; for many students, as in the German "Gymnasium" and in the French "Lycée"; for few students, where only college-bound students take calculus as an elective subject); (d) in the introduction of descriptive statistics, and (e) in the substitution of something called "business mathematics" or "consumer mathematics" for those students who do not show potential for a solid pre-calculus or calculus course.

The USM curriculum seems very *stable*. It is very similar to what was found 50 years ago, except for the variations listed above and the widespread use of set-theoretic language during the last 30 years. Set theory as curricular content went in and then out in most countries, but the language stayed. In fact, the perceived stability seems so strong that it seems not to change much even by government curriculum reforms. Teachers' traditions, college-entrance examinations and textbook publishers manage to bring the taught curriculum back into place after a few oscillations. The only visible changes seem to be initiated not by academic or governmental decisions, but by the gradual introduction of ICT and pressure from television, fashion, parents, students, business, and journalists. The introduction of ICT does not change the content substantially, only the teaching strategies.

Finally, the low attendance of the curriculum subgroup raises questions about the conference participants' interest in this topic as a separate theme.

Conclusion

Given the uniqueness of each sub-group's discussions, it was difficult to synthesize and formulate statements about the possible common threads of issues in USM education during the one hour of the last session. Thus no overarching conclusions were reached outside of those drawn within each theme.

This report was written by Olive Chapman and Ornella Robutti with valuable support by the team members. They are happy to be contacted at chapman@ucalgary.ca and ornella.robutti@unito.it, respectively, for further information on the work of this DG.