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Introduction to the papers of TWG06: Applications and modelling

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THE OVERARCHING THEMES OF TWG06 PRESENTATIONS

The contributions that formed the working basis of the Thematic Working Group on Applications and modelling were characterized by a strong diversity in the topics and issues that were addressed. The group's research field has thus shown to be both active and fruitful whilst maintaining its distinctive facet of being inclusive in terms of the different theoretical, methodological and philosophical perspectives taken by its researchers.

One of the overarching themes illustrates just how important it is to debate and theorize the very notion of mathematical modelling and the concept of mathematical application, namely the question of *perspectives and conceptualisations on modelling* as an important issue addressed by the group. Although it may be useful to emphasise differences and distinguish between modelling problems and mathematical application situations, there are also proposals to blend modelling and applications. The concept of model becomes in both cases a keyword and in general the distinction refers to the need to create a model not available at the outset as opposed to using a model that is previously known. However, there are perspectives for which a common conceptualisation of modelling requires assuming that there are no completely independent mathematical models nor totally disconnected models and that modelling means not only create models, but also integrate and coordinate models somehow contradicting the idea that applications are simply a limited portion of the modelling cycle.

Another emphasis in the discussion refers to areas that might be considered as neighbouring mathematical modelling and potential connections that eventually can be found between mathematical modelling, problem solving, project work and Ethnomathematics. One way to link these different areas can be found in the fact that all these fields are associated to certain types of teaching practices with common characteristics, namely, discovery teaching, inquiry based learning and generally views that put the individual learner actively involved in seeking solutions to real world situations based on mathematics.

One open question stemming from the work that was presented in the group's discussions is whether it will be possible to move towards a comprehensive theory about the teaching and learning of modelling and applications and if such an aim is desirable. Indeed, one other important issue that has much impact in relation to this argument is the growing emphasis on mathematical modelling in the implicit and explicit rhetoric across countries, as portrayed by the most recent frameworks from the OECD's PISA study. Some reluctance towards a pseudo-modelling reflected in certain problems and the need to account for the cyclical nature of the modelling process as a distinctive characteristic, stress the importance of keeping in mind the contrast between mathematical modelling as a pedagogic activity and its professional counterpart.

This topic leads to another overarching theme concerning *the nature of modelling tasks* for school mathematics. The need to converge in a vision on what to consider as good modelling tasks has often been raised. A seemingly relevant item is directly associated with the degree of difficulty of modelling tasks and problems.

Results of research studies indicate that much rests on the students' previous experience, background and pre-knowledge when it comes to modelling tasks; however, it is considered important that modelling tasks reflect authenticity and bring the opportunity to seek, investigate and explore. It is also relatively clear that modelling tasks are still rare in daily school lessons, in part due to the fact that teachers have a restrained attitude towards implementing modelling tasks, sometimes based on the perception that they are too difficult for many students. One of the suggested and analysed difficulties lies on the student's need to picture or imagine a particular real situation, which can be described as creating a situation model. Ideas on the wording of the problems and on how this variable may be of significance were offered and may induce further thinking on the study of task variables in modelling problems.

Modelling contexts and environments was also a developed theme in the working group. On the one hand, the importance of using specially tailored problems for specific areas of knowledge was advocated, as in the case of engineering studies. Emphasis was given to the fact that students often value the specificity of the problems addressed and their relevance to other disciplines in a particular field. On the other hand, it was endorsed the educational wealth of multidisciplinary approaches in allowing integrating tools from different disciplines and subjects, namely mathematical modelling, especially when developed within inquiry teams that are more able to generate questions of real interest.

On the theme *didactic issues in mathematical modelling*, one of the queries was the transposition of the concept of mathematical modelling, as it is usually described in academic literature, to textbooks. This transposition seems to be marked by a poor representation of a holistic view on the modelling process and by leaving aside the critical sense that is inherent to the modelling process. Fragmentation of the model development into a step-by-step model construction tends to prevail and there seems to be a tendency to divide the model into mathematical and non-mathematical parts. Apparently, the widely disseminated design of the modelling process largely supported by studies and research contributions suffers considerable distortions on the route to the textbook and ultimately to the teacher.

Along with this question, the role of mathematical knowledge followed the examination of the differences between experts' and novices' modelling approaches. For some presenters, the differences can be traced by the kind of representations and strategies used by each of them, in close liaison with the mathematical knowledge that they differently dominate. But for others, those differences in fact set the need to clearly understand how mathematical modelling is related to mathematics as a science, and to the many mathematical practices appearing in society outside school. And this implies considering variable features of the modelling activities for the class, namely the design of the activity, its goals, organization, autonomy of the students and adaptation to the local constraints.

One of the more prevalent themes within the participants' contributions – *students' modelling activity* – was investigated in several directions and with different foci. Although a review of this diversity is not easy, it is possible to highlight the importance given to the idea of mathematisation in several papers. For example, this strand appeared with respect to the importance of making assumptions when tackling a mathematical modelling problem. This interpretive flavour of the mathematical modelling activity is also linked to the need for interpretation of the mathematical model back into the original real context. Students' contextual approaches to mathematical notions, concepts and results were widely illustrated at various times, including situations involving experimentation with daily objects and artefacts. To a large extent, the viewpoint of contextual modelling came up strongly represented in a number of studies conducted with students of lower secondary school. In what concerns studies involving upper secondary and tertiary levels, the students' modelling activity was mainly analysed in terms of its relationship to cognitive structures and competing models, formal and non-formal concepts, understanding of scientific concepts and everyday interpretations, and more generally to the mathematical framing of the real world situation.

In the sphere of teacher education and professional development, two themes were discussed: *issues in learning to teach modelling* and *teaching practices and beliefs*. For these themes, investigations have emerged based on different training models, such as the 'lesson study' and the 'study and research path for teacher education'. In both cases, a particular attention has

been placed on the planning of the lesson and on the design of the modelling tasks. The planning of the activities to be carried out in classes of mathematical modelling seems to be a central factor in the shaping of teaching and learning and has a great influence on questioning the usual ways of teaching, namely content-centred practices, and the official curriculum. On the other hand, teaching mathematical modelling in school requires the teacher to realise that many of the steps of the modelling process, such as the simplification of the real situation, are not simple matters and cannot be undervalued.

In regard to teachers' beliefs on mathematical modelling, methodological approaches to obtain data in international comparison studies were presented and examined. As for the teachers' practices, it was stressed the strong influence that beliefs have on practices but it was also highlighted the dilemmas that can be quite evident in mathematical modelling lessons. For example, the demands the teacher faces when getting substantially different models from students and also the need to find appropriate ways of dealing with possibly inadequate models that may emerge during the course of a class.

CONCLUDING IDEAS

The conclusions that emerge from the group's work point to three broad categories: various signs of diversity and plurality of views; some elements of uniformity; and major elicited questions.

The diversity

The diversity is easily detectable in the foci and research questions pursued by the group members in their studies. For example, a quick list illustrates this variety of interests and research aims: to deepen and clarify the meaning of modelling and model; to learn more about the design of modelling tasks; to scrutinize the pedagogical resources in the teaching of mathematical modelling; to see how modelling is translated to learning and to competencies development; to analyse forms of teachers' professional development around the implementation of modelling tasks and to better realise the teachers' beliefs about modelling in teaching practices across countries.

There is much diversity in the theoretical frameworks used by researchers in the field: the range covers many theories and perspectives from the more cognitive

oriented to the more epistemological/anthropological approaches.

With regard to the school levels represented in empirical studies, there was also some diversity, although it should be noted an absence of studies in primary school.

Finally, it is evident that there is plurality in the visions and arguments of researchers from different countries about the purposes of including modelling in the mathematics curriculum and in regular classroom activities.

The uniformity

In contrast with the above mentioned tendency of diversity there are also several signs of uniformity through the studies presented in TWG06. In terms of methodological approaches, for example, there are predominantly qualitative and small-scale studies. It further appears that the modelling cycle and the modelling phases represent the most common conceptual tools in informing the research. There are also shared concerns related to the contexts of mathematical modelling problems and the authenticity of the tasks. Finally, there are prevailing references towards the assessment of mathematical modelling activity, particularly the external and internal assessment of performance, competence, effectiveness, student's involvement, etc.

Major questions

Given the collection of papers and the discussions developed in the working group, we identified a set of big questions that may help us to put in perspective the future development of the TWG and of this area of research.

Some of these big questions immediately capture the diversity of theoretical perspectives represented in the research of the TWG. This diversity, as already pointed out, ensures an enriched agenda and extends the scope of the research but it also has consequences for impact because of diversity in the likely resulting studies and results. Therefore, the following questions and sub-questions point to the importance of reflecting on this particular factor:

- 1) How to cope with diversity within the research community and how is such diversity enabling/

disabling the growth of research on mathematical modelling in education?

- 2) How to induct young researchers into the complexity of the field (theories, terminology, contexts of tasks,...)?
- 3) What is the influence and the tension between the theoretical approach and the nature of the modelling tasks in mathematics teaching and learning?
 - At the level of design/selection;
 - At the level of implementation;
 - At the level of analysis of empirical data.

To conclude, another question emerges from the awareness of the importance of broader and larger scale studies that may systematize or add confidence to the more localized studies grounded on small experiments or particular cases:

- 4) How to facilitate the transformation of local practices with mathematical modelling into large scale integration of modelling at all school levels?

To this respect, ideas were suggested in the contributions offered, namely concerning efforts to be invested in the initial and continuing training of teachers, renewed attention to resources to support teachers and strengthening the interaction between researchers and practitioners.