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TWG4: Teaching and learning of mathematics for engineers, and other disciplines

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THE CONTRIBUTIONS IN TWG4

These proceedings evidence the rich content of the presentations in TWG4. Several “other disciplines” were considered by the authors: engineering, physics, chemistry, life sciences, with different foci that we briefly evoke here.

Some studies concern interventions, from their design to their implementation and the evaluation of their impact for students. Pollani and Branchetti designed and implemented a course for future mathematics teachers about mathematics-physics interdisciplinarity, where the students investigate the characteristic features of the two disciplines and their boundaries (Akkerman & Bakker, 2011). Cabrera, Vivier, Montoya and Vandebrouck, referring to the Mathematical Working Spaces theory (Kuzniak et al., 2022), explore student learning in an experimental course where trigonometric polynomials and Fourier series are used for modelling sounds. Rizzo introduces an active teaching approach, where Natural Science students collectively work on modelling tasks. Hernández-Méndez, Cuevas-Vallejo and Orozco-Santiago also implement a modelling-based course about differential equations and the harmonic motion. Rønning investigates the impact, in terms of students’ perceived relevance, of a contextual learning approach to mathematics teaching, where students use mathematics to solve engineering problems. In these studies, concerning modelling-based courses, different kinds of technological tools play a significant role, providing in particular access to specific representations (e.g. Audacity representing the sounds as sinusoidal curves).

Several intervention studies in TWG4 concern Study and Research Paths (SRPs, Bosch et al., 2020) and refer to the Anthropological Theory of the Didactics (ATD, Chevallard, 2015). Lombard presents an epistemological analysis grounding the design of an SRP at the interface between mathematics and quantum mechanics. Markulin, Jessen and Florensa focus on the cross-disciplinary collaboration needed for managing an SRP in statistics for business administration (including the active participation of the client). Freixanet, Alsina and Bosch also implemented an SRP about statistics. In their study, the questions were proposed by the students (first-year future engineers) themselves, about the proposed topic of water as an indispensable resource.

While the researchers were involved in the design of the courses in the above-mentioned studies, some institutions also propose innovative courses. Salinas-Hernández, Kiliç, Kock and Pepin consider a challenge-based course for future

engineers. Referring to the instrumental approach (Trouche, 2004), they investigate the use of resources by students in such courses, and how they perceive their learning both professional and in mathematics. The issue of “authenticity” is also important in the study by Hilger, Schmitz, and Ostsieker, which concerns the views of engineering students about application examples (provided in ‘usual’ courses), and how these views are linked to students’ beliefs (Rooch et al., 2014) about mathematics.

‘Ordinary’ mathematics courses for non-specialists are also studied by other authors. Rogovchenko and Rogovchenko analyse Calculus and differential equation courses in terms of potential conflicts for student learning, in particular in terms of concept image (Tall & Vinner, 1981). Burr studies the teaching and learning of Numerical Analysis. Gueudet, Doukhan and Quéré focus on teachers’ practices in mathematics courses for non-specialists, using ATD (Chevallard, 2015) and the concept of didactical praxeologies to identify specificities of these teaching practices.

Cuenca, Barquero and Florensa also refer to ATD, and analyse a reform of the engineering mathematics curricula in Ecuador. They evidence the stability of the contents of the courses, in spite of changes in their titles.

We note that, whatever their focus is, all these studies took into account the specific features of teaching mathematics to non-specialists. In what follow we briefly summarize the thematic discussions in TWG4.

INTERVENTIONS

One of the main discussions of the group, accordingly to the number of proposals including them addressed interventions in different programs and courses. The first aspect regarded the need to establish *collaborating groups* in order to reflect and to design the interventions. Secondly, the group addressed the need to systematize *the dissemination* of mathematics education research results in order to ensure an impact on the actual teaching practice.

The need for collaborations between researchers in mathematics education, mathematics teachers and teachers of the “domain” where the mathematics courses are taught (engineering, business administration, etc.) was considered as a necessity emerging from the analysis of the different contributions to the TWG4. Specifically, one of the proposals was to consider the members of the mathematic education research community as the brokers between the teachers of the domain and mathematics teachers to facilitate the design and implementation of new teaching proposals considering the need of each domain. This idea of networks of mathematic researchers and teachers was seen as a way to study and modify the conditions affecting the research-based proposals avoiding the fragility of the implementations led by a single person doing at the same time the role of researcher-teacher.

However, the development of these collaborations needs to consider several factors explicitly. For example, it is important to define the inputs considered and the outputs expected of these collaborating groups. Another aspect to be considered is the need to

fix the institutional settings to ensure the ecological viability of interventions: as long as this activity is not considered as a part of the institutional activity, and that might involve different departments, their viability might be very fragile. The discussion also addressed the importance to reflect on the level for implementing interventions: lesson, course, or even full program.

Regarding the dissemination of the research results, the discussion considered two main proposals. Firstly, the participants considered that there is a need to develop resources around the teaching of mathematics to non-mathematicians addressed to mathematics teachers. One of the points that were considered is the need that these resources should be developed by mathematicians, mathematics educators and non-mathematicians working together. A second aspect that was considered to facilitate the dissemination of research results is the need to develop professional development proposals further from pedagogical courses. One of the specificities of undergraduate mathematic teachers is often the need to hold a doctorate in mathematics and some pedagogical course while the courses on didactics are often seen as complementary.

MODELLING

A second aspect that was addressed during the discussions of TWG4 was the consideration of modelling as one of the proposals that should be incorporated to the mathematics courses for non-mathematicians. However, the discussion revolved around the need to consider “authentic modelling tasks” coming from the workplace of engineers, biologists, etc. and avoiding giving a ready-to-use model to students. In other words, activities such as developing the model, validating and proving its accuracy that often do not exist in mathematics courses were considered by the participants as crucial as other activities such as using the model to obtain results which are very common in school settings.

A second aspect, related to the theories used to analyse modelling processes concerns the need to overcome the classical dichotomy between “non-mathematical” and “mathematical” contents proposed by diverse models. The discussion also considered important to enrich the different theories emerging from mathematics education with the theory of models in philosophy or the analysis of modelling in other disciplines such as engineering.

EPISTEMOLOGY

Finally, the need to develop appropriate tools to explicitly describe knowledge was considered as a priority by the participants. There was a clear consensus on the need to question of what is conceived as mathematics when addressing problematic phenomena in the teaching and learning of mathematics. In other words, the “classical knowledge labels” (such as derivatives, differential calculus, or statistics) are not a precise enough way to describe knowledge: the activity developed under these labels can be significantly different depending on the teaching proposal.

The role of proof also was addressed during the TWG4 discussions. Often, the mathematical activity of non-specialists does not explicitly include proofs: however, the models used are founded and considered valid because they had already been validated. A clear open question is how to deal with this “hidden” role of proof in the mathematics taught to non-mathematicians.

FUTURE DIRECTIONS

The future directions discussed in TWG4 were linked with the different issues discussed above. They concern both research and development, which are closely linked in these issues. Developing groups associating mathematics education researchers, mathematicians, specialists of other disciplines is a need for the design of productive interventions. Nevertheless, the conditions allowing the existence of such groups in various institutional contexts are complex and deserve a specific study. Similarly, understanding the conditions for a productive design of resources for university teachers – mathematics teachers teaching to non-specialists, or teachers of disciplines using mathematics – grounded in research results, and contributing to the dissemination of these results is a complex issue requiring further research. Would it be possible, for the “UME for non-specialists” research community, to write a ‘white paper’ presenting recommendations for stakeholders and policy-makers? Would it be possible for this young community to identify a list of “solid findings” that could support recommendations for practice, and/or professional development programs? The successful interventions designed are often very local; further research could work in the direction of interinstitutional projects, to evaluate the generalizability of these interventions.

Other research directions concern the epistemological basis of the studies, and the need to deepen our understanding of the links between mathematics and other disciplines. Including historical sources in our studies, which enlighten the historical genesis of the contents at stake, their *raison d’être*, appears as a promising mean for investigating this direction.

Finally, while ATD (Chevallard, 2015) seems to be increasingly used in TWG4, other frameworks were also present in the group (e.g. boundary crossing, the instrumental approach). The question of the theoretical frameworks relevant to identify and study research questions specific to mathematics for students following physics, chemistry, biology, engineering, economics or other subjects remains open.

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