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TWG2 report: Mathematics for engineers, Mathematical Modelling, Mathematics and other disciplines

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INTRODUCTION TO TWG2

The purpose of this report is to give an account of the work conducted within TWG2 during the [INDRUM2020](#) conference, which was held virtually from Bizerte (Tunisia), in September 2020. Initially, the group was composed of 43 registered participants from 16 different countries, with up to 28 participants simultaneously connected during the sessions. We had a total of 13 presentations, 11 papers and 2 posters, all of them addressing essential issues related to the teaching of mathematics for engineers, mathematical modelling or mathematics and other disciplines. In the three sessions of TWG2, the discussions were organised around three main topics covering five leading themes (Table 1). The three main topics delimited were about: (a) students and/or teachers-researchers' practices (Theme 1 and 2); (b) the prevailing way to teach and learn university mathematics for engineers and for non-specialists (Theme 3 and 4); and, (c) looking for a change of paradigm in maths university teaching and learning (Theme 5 and 6).

<i>Topics</i>	<i>Leading themes</i>	<i>Papers</i>
(a)	T1. Teaching and learning strategies for engineering students	2
	T2. Teaching practices of teachers-researchers at the university	2
(b)	T3. Analysing the prevailing conditions for the teaching and learning of Calculus for engineers	2
	T4. Institutional analysis of mathematical modelling for non-specialists	2
(c)	T5. New perspectives for a renewed teaching and learning of mathematics: problem-posing activities and interdisciplinary projects	3
	T6. Instructional proposals to move towards the paradigm of 'questioning the world'	2

Table 1: Overview of the leading themes related to the main topics in TWG2

This delimitation of the leading themes facilitated to group papers with similar aims and to make researchers interaction easier. The thematic group sessions were organised in five phases in order to make the discussions as fruitful as possible: presentation of the session, work in small parallel groups to discuss the themes and formulate questions, report of the groups, authors' answers and general discussion. In light of the

quality of submissions, the substance and relevance of exchanges during the sessions, we can point important contributions to the development of research in the different topics and themes. The next sections summaries the contribution we had concerning each main topic and wants to report on the main issues and questions raised and discussed within TWG2. We conclude the report by highlighting some of the main open questions for future research that deserve more attention in the years to come.

Focus on students or teachers-researchers

The two first papers *Liebendörfer et al.* and *Zakariya et al.*, in Theme 1, focus on teaching and learning strategies for engineering students. Several common issues have emerged from the corresponding presentations and discussions. They are both concerned with the specificities of studying the teaching and learning of mathematics for engineering students, and consequently, with the design of appropriate interventions to support these students. Both investigations propose relevant tools in order to differentiate engineering students' learning strategies or attitudes in relation to their approaches to learn mathematics. Some are statistical tools used to interpret the quantitative and qualitative analyses and to locate correlational patterns among the data.

Concerning Theme 2 about the teaching practices of teachers-researchers at the university level, we discuss two connected papers from *Bridoux et al.*, *Bridoux, de Hosson* and *Nihoul*. Because their authors are involved in the same research project, they share several common aspects. Both investigations address theoretical and methodological issues to analyse teachers-researchers' teaching practices, for ideal or declared practices (first paper) or *in situ* practices (second paper). In both cases, the purpose is to compare the practices of teachers-researchers from different disciplines (mathematics and others) in order to measure the influence of the disciplines involved, their epistemology or their didactics upon these practices. The second research also addresses the issue of detecting the possible effects of these practices on students' learning during courses or tutorial sessions.

Among other issues, the following questions give a pertinent account of the discussions that took place in relation to Theme 1 and Theme 2:

- What are the specific mathematical needs of engineering students? In which way mathematics teaching for future engineers is adapted to their future professions? What balance between proof-based teaching and applications in mathematics?
- Are there differences between applied and theoretical mathematicians' teaching practices? How can we compare the practices of teachers from different disciplines? What is the influence of the discipline and its epistemology?
- What can theoretical and methodological tools help give an account of the restrictions experienced by teachers-researchers concerning their teaching? What are the conditions and constraints to use statistical tools to interpret quantitative and qualitative results in didactics research properly?

Focus on the prevailing way to teach and learn university mathematics for engineers and for non-specialists

The second topic focuses on analysing the prevailing way of how mathematics is taught and learnt at the university for engineers and non-specialists. Different empirical data is here considered, from textbook analysis, course content analysis, students' attitudes, among others, to analyse how some particular mathematical topics are taught and learnt for mathematics undergraduate courses. About the papers here discussed we have, on the one hand, two papers that analyse the specific conditions and constraints for the teaching and learning of Calculus for engineers, in particular, of integration. The paper from *Nilsen* analyses a group of first-year university engineering students and their sensemaking of integration and its symbolism. Through a semiotic approach, special attention is made on how students use and interpret symbols for integration. By their side, *González-Martín* and *Hernandes-Gomes* focus on developing a praxeological analysis, in the sense of the ATD, for analysing a course's reference book, of a Strength of Materials course, to show the role that integrals have in *logos* block. This analysis is complemented by interviews with an engineering teacher to understand the dominant way how integrals are planned to be taught and learnt in a Calculus course for engineers.

On the other hand, the other two papers are more specifically focused on the role of mathematical modelling for university mathematics teaching and learning for non-specialists. In particular, the paper from *Doukhan* focuses on probabilistic modelling in the transition between secondary and tertiary education with first-year biology students. Through the analysis of students' responses to a test, the paper shows the diversity of difficulties in the secondary-tertiary transition concerning probability and probabilistic modelling. *Job* discusses the prevalence of "applicationism" as the dominant way to understand mathematical modelling for economics. In particular, the paper describes a peculiar epistemological standpoint about the relationship between mathematics and economics, namely that of subordinating economics as an application of mathematics, may impact students' views about the interplay between mathematics and economics.

In the general discussion about this topic, we address relevant questions about the aims, contents' selection and lack of specificity of the mathematical knowledge to be taught in the different specialities. In particular about:

- What is the main goal with the first-year Calculus courses? What kind of conceptual understanding is needed in different engineering specialities?
- What is important about calculus (integrals, sums, derivatives, ...) for engineers, mathematicians, other university degrees? Could we find different rationales for their teaching and learning, depending on the university context?
- What elements of calculus, probability, mathematical modelling, etc., does each profession need? What elements have to be included in each undergraduate programme?

Focus on looking for a change of paradigm in maths university teaching

Contributions related to the last topic refer to some instructional proposals for university mathematics to move towards a change of paradigm, such as problem-posing activities, interdisciplinary projects or study and research paths. The pursued aims are varied, but when looking at their complementarities, we found some common aspects. They all refer to the detection of conditions and necessities concerning the change of paradigm through the analysis of the student's attitudes and competencies; the impact of alternative teaching proposals; and the viability of their implementation and long-term dissemination.

Radmehr et al. explore engineering students' mathematical problem posing competencies in relation to integral calculus, and their attitudes towards mathematical problem posing. Answers from students to some tasks related to the Fundamental Theorem of Calculus and the notions of integral and area are explored, complemented by a questionnaire that explores students' attitudes towards problem posing. The poster from *Gaspar Martins* presents an interdisciplinary project for computing engineering students about a car race, where Python appears as a means for programming language. The paper from *Cumino, Pavignano and Zich* presents an interdisciplinary project for first-year students in Architecture about the visualisation of mathematical objects through physical and digital models. The authors explore the appearance of varied models to improve the accessibility of interdisciplinary elements, building a common language for students with different backgrounds.

About the proposal of study and research paths (SRPs) within the ATD, *Barquero et al.* focus on the analysis of several implementations of SRPs as an inquiry-oriented instructional proposal at the university level. This paper focuses on the different modalities of integration of SRPs into current university teaching, by linking inquiry to the study of knowledge organisations, without considering it only as a means to better learn the curricular content. The poster presented by *Quéré* presents a particular SPR guided by a chemistry lecturer about how we can be sure that a medical product meets the dosage as it is described on the package. The implemented SPR is discussed in terms of the usefulness of the developed praxeologies for the engineer's professional context.

Some critical questions discussed refer to the inherent assumptions in the design and implementation of the different teaching proposals, in particular:

- About problem posing: What do we consider a “good problem”? What does it mean to pose a problem for teachers-lecturers? For the students?
- About interdisciplinarity: What epistemological limitations appear when working in co-disciplinary or interdisciplinary contexts?
- About SRPs: How to find a “good” generating question for an SRP? Can the design and implementation of SRPs help us to rethink the contents of the course? Does the context of engineers' university training offer better conditions to implement SRPs than others, due to their proximity to the profession?

CONCLUDING REMARKS AND FUTURE PERSPECTIVE FOR TWG 2

The topics and leading themes addressed in TWG2 show the variety of research approaches and questions addressed. Since all those papers that are more focused on making the different “agents” (students and lecturers) react, to the ones working on the proposal of alternative teaching proposals to investigate about a change of the dominant pedagogical paradigm for the teaching of mathematics at university. Furthermore, the variety of theoretical frameworks provide a fruitful interaction to collectively understand phenomena related to the teaching and learning of mathematics for engineers, for other disciplines, and about the role that mathematical modelling can play to build bridges between disciplines. We want to finish this presentation by sharing some questions that were discussed in TWG2 about the future lines of development of our working group:

Mathematics for engineers and other disciplines

- Is “mathematics for engineers” a too general term? How do we approach the specificities of each engineers’ context?
- What mathematics do university students need for their future professions? What communities may participate in the discussion of this crucial question?
- How has the use of technology (at university and in the workplace) accelerated the distancing between what is actually taught from actual professional needs?
- What are the theoretical and methodological possibilities to study teacher-researchers’ practices and detect their possible effects on students’ learning?

Need to rethink university mathematics curriculum

- How to make such a significant change in curriculum design at university (where we have a very “stable” curricula)?
- How to look at university mathematics curricula from an interdisciplinary approach? How can the perspective of mathematical modelling contribute to it?
- How to consider professional and workplace needs when designing mathematics curricula and defining its role in the different undergraduate programmes?

Last but not least, a crucial issue is a necessary collaboration between different communities (mathematicians, didacticians, engineers, among other) to rethink university curricula, not only in terms of contents, but also thinking about the new needs, competencies and abilities that may be integrated. Who may participate in this discussion and what is the role of didactics research are also questions that may be addressed. And a more complicated and yet essential one can be the long-term collaboration of didacticians with researchers-lecturers from different disciplines to make this curriculum questioning evolve productively.