Conference summary report

Mathematics Education: the next decade and beyond

11-12 April 2019, Utrecht, The Netherlands

In April 2019, a conference on Mathematics Education took place in Utrecht. The conference brought together mathematicians, lectures of Mathematics in higher education and educational experts. New trends and innovations in Mathematics education have been explored and discussed. Over 60 participants attended the conference. The first day of the conference focused on Digital Testing of Mathematics, Learning Analytics and Blended and Online Learning of Mathematics. **Hans Cuypers** (TU/e) opened the 4TU.AMI workshop officially by welcoming the participants. He soon gave the floor to **Annoesjka Cabo** (TUD). She stressed the challenges of increasing number of students at the universities, whereas funding remains behind. How to teach this growing group of students and simultaneously increase learning outcomes are high on the agenda. A lot of topics on mathematical education will come by at this conference. It is important to think what the goals are and then how to achieve them: collaboration is crucial. Conferences provide an opportunity for people to meet each other and to share information. Support in all universities and from companies is required to implement innovations in a sustainable and a scalable way. Finally, she mentioned to not forget to stay connected with other fields. She ended with the note that passion about teaching, and the related development, is definitely there!

The conference started off with topic **1: "Digital Testing of Mathematics"**. **André Heck** (UvA, *Automatic Computer Aided Assessment of Mathematics in Practice*) stressed that assessment is key in teaching and learning. In his work he focuses on feedback facilities, using the SOWISO environment. Formative and summative assessments, depending on the purpose, are very helpful in providing qualitative feedback for students. The many requirements for digital exams and the main objections of lecturers were briefly discussed. Then, main principles of digital practice were gone through. It became clear that SOWISO is not just an assessment tool: it is an online environment for learning, practicing and testing Mathematics. André showed with a few examples that the methods and techniques parts of mathematics courses can be automated, but that this is more difficult or simply requires more creativity for conceptual tasks. Anyway, it is hard work for authors. To conclude, the benefits of digital assessments have become clear during this presentation. However, scaling up creates challenges, because of the need for proctored environments for tests. **Alisa Lochner** (UT, *What works in digital testing: the math case study)* underlined the potential of digital testing. It is not the question if digital testing will happen, but rather when and how. Alisa pointed out that, at the moment, high difficulty and high thinking skills, which are typically multi-line math questions, could not yet be digitally tested using current multiple choice and short answer question types. However, there is potential for questions of either high thinking skills, or high difficulty. To test that issue, participants explored questions of various difficulty levels and thinking skills in groups during this workshop. The discussion grew: would a change in learning goals of Mathematics for engineers be needed? A variety of responses followed, including scepticism for digital answers: are zero points unfair when the line of thinking is correct? Does it depend the study, such as Physics or Mechanical Engineering?

After the break, **2: "Learning Analytics"** were on the agenda. **Dirk Tempelaar** (UM, *Learning analytics: where digital testing, blended learning and individual learning paths come together*) took the floor. Every year, he faces 1200 freshmen with a huge diversity in prior knowledge and prior education. Individual learning paths, with the focus on feedback, is needed to get all students at the same level. It is remarkable that 2 lecturers and about 70 teaching assistants (2nd year students) can do the first course in Mathematics. In Maastricht, blended learning with a "flipped classroom" approach is supported by SOWISO and MyStatLab. Unlike André, Dirk uses content which has been provided by SOWISO. Applying learning analytics at micro level (course level), learning activities of students are closely followed using logs in Sowiso, as well as measuring survey data. Frequent learning feedback is provided both directly to students and their tutors. As an example of such learning analytics application, Dirk notes that there are differences in how students make use of worked examples in different learning phases. Students who use worked examples at the start of the learning cycle make adequate use of this tool, in contrast to students who call lots of worked examples shortly before quizzes or exams. These different patterns can be made visible by cluster analysis of traces of log data, to create different profiles of learning patterns. This can help in discovering which students are at risk of failing or even of dropping out. **Jan-Paul van Staalduinen** (TUD,

Using learning analytics to improve education: practical experiences) emphasized the use of learning analytics to improve education. Online education, through Massive Open Online Courses (MOOC's), are being developed at TUD. Learning analytics are being collected from 2 million+ learners. These data are being used to make improvements. Patterns were discovered. Interesting was that the larger group quits the course at 60%, after passing. This is an issue that calls for an improvement because people miss out the most important part of the course. Jan-Paul told the attendees about the STELA-project. This project supports the transition from secondary to higher education using learning analytics, in close cooperation with KU Leuven. Progress of learning skills will become transparent after students do a self-assessment. Useful feedback could be used to improve skills. With a few conclusions and recommendations, he ended the presentation:

- pay attention to ethics
- wording and context matters
- take time to prepare and organize data
- use small data
- impact is difficult to measure

In the afternoon, topic **3: "Blended and Online Learning of Mathematics"** was next in line. **Theresia van Essen** (TUD, *Hands-on Linear Optimisation*) came onto the stage. She is developing an online course Hands-on Linear Optimisation. The course will be available on the Open Edx platform, hosted by TU Delft. The content has been divided in three parts: linear programming, integer linear programming and heuristics for integer optimization problems. The 3 ECTS course will be closed with a project: a competition on the best solution found. Theresia then showed the public what's behind the methods used. For the future: the idea is to go online in September 2019, for use in modelling practical first-year Mathematic students, to add an ID-verified track and create a MOOC for professionals. **Hans Cuypers** (TU/e, *feedback to students in very large courses*) took the baton from Theresia on this topic. Eindhoven has to deal with a growing amount of students. How to give feedback to students, the most powerful influence on students learning, is a challenge. As an example, Hans showed how the Calculus course for freshmen deals with providing relevant feedback. Up to 3000 students, 10 lecturers and 160 teaching assistants are being involved, using a blended format for the course. To guide students in an optimal way, feed up, feedback and feed forward is provided on four levels: task, process, self-regulation and personal. The tutor groups take care of the latter two levels. The organisation of the course is huge: there is weekly (written) homework. The several tests must ensure that weekly feedback is given to the students.

The closing **keynote** speaker was **Peter Grünwald** (UL/CWI, *safe testing*). He is worried about irreproducible published research. He informed the public all about the reasons for the reproducibility crisis. Publication bias and problems with hypothesis testing methodology are the culprits. Peter illustrated limitations: "results are not always true" and "keep in mind that p-value-based testing could mean trouble". He proposed, through examples, an alternative hypothesis testing methodology, which has a gambling interpretation. With his proposed method, it is much easier and safer to draw conclusion based on data from different experiments. He concluded that safe tests are based on "reverse information projection". He wondered if there is a good excuse to not use his safe T-test.

The first day of the conference ended in Court (also known as restaurant De Rechtbank), a perfect place for an informal closing.

The second and final day of the conference was all about: **4 "Didactics of Mathematics teaching" and Programming in Mathematics Education**. Paul Drijvers (UU, *Trends and topics in next decade's mathematics education*) started the day by informing the audience of the current trends and topics in Math Education in primary and secondary education. An ongoing development in the curriculum of Math for "students" between the age of 4-18 is secured by teachers. This development has high impact on future students. Also, Mathematical thinking in high-order is world-wide high on the agenda. Core points are: problem solving, modelling and abstraction. Another trend is the use of digital technology in Math education: "combining the old way with intelligence". The digital tools and intelligent feedback were discussed by **Sietske Tacoma** (UU). The challenge is all in the design of the program: "which topics will be included and how to categorize them?" She made it clear by using examples. Student data and learning curves showed that it helped students more to create a learning plan. Also, the difference between general and specific feedback was mentioned. Sietske concluded the session with these words: "Feedback matters and steps matter as well". Subsequently, **Zeger-Jan Kock** (TU/e, *Selection and use of resources by first year students to study mathematics*) took the floor. He did a study on the use of resources by first year Calculus and Linear Algebra students. An example showed that a particular student used different resources (lecturers,

googling, Wikipedia, book, ask a friend, etc.) to solve a task. Students used resources according to their needs and constructed their own study paths. However, for many first year students a starting point formed the study paths they knew from high school, in which the textbook played a very important role. Also, "resources used differ between Calculus and Linear Algebra students" was one of the findings, and this could be understood to a large extent from the different nature and organization of these courses. Zeger-Jan explained the difference between curriculum resources (offered by the university), general resources and social resources. The research brought up some patterns in the importance of resources at university, according to the students: three clusters were found, with lecture explanation, textbook, and teaching/blended considered the most important resource. The first and the second cluster corresponded to high school habits. Zeger-Jan wondered if 6 weekly hours of Calculus lectures a course were really effective. Considerations he put forward were: a) consider the alignment of the mix of curriculum resources with learning goals and the assessment practices , b) consider the role of different resources during the course design, and c) consider if students new to university need guidance with respect to the use of resources. He concluded his talk with the remark "more resources is not necessarily better".

The last topic of the conference was **5: "Programming in Mathematics education". Knut Mørken** (University of Oslo, *Computing in STEM Education*) noticed that, 15 years ago, computing in Mathematics and Science Education was put back in the curriculum. Math topics are solvable by pencil and paper, but why this constraint? It makes it hard to include practical and realistic examples. Additionally, students think they need programming skills for the future. The question is: how to integrate programming in standard courses in Analysis and Linear Algebra to strengthen both disciplines? In Oslo, broad collaboration is needed as all bachelor programmes consist of basic Mathematics, Physics, Chemistry, Bioscience and Geoscience. It is important for students that they understand that computers have limitations. Also, it takes time to learn the syntax of a programming language. Programming is basically Mathematics: a) learning how a computer handles numbers, b) structuring a problem, developing an algorithm, c) estimating and understanding errors and d) debugging, opportunity to develop logical thinking. Knut also finds programming a way to activate and engage students. He mentioned one new pedagogical opportunity: explaining math to a stupid "person"; the computer. Knut uses Python, but whether this is the best languages is like "a discussion on religion". Knut finished his performance by facing the greatest challenge: overcoming disciplinary. **Jan-Fredrik Olsen** (Lund University, *Why use Python in introductory Calculus?*) made a strong call for using Python in the introductory Calculus course. Numbers showed an increasing amount of successful students after integrating Python to this course in 2015. He was wondering: what would Newton think about it? Activating students enables them to do more Math. In Lund, there is a growing conviction of the effect of integrating a Python component in courses. Students see the main point of the theory and they are getting feedback by using Python. Feedback from students showed that the course stimulated interest in Math and made them understand Math. Additionally, the lecture attendance increased. **Felienne Hermans** (UL, *How to teach programming and other things?*) paid special attention to the didactics of teaching programming. Not much research has been done on the best way to teach programming; the field is relatively new. Felienne describes how most programmers her age taught themselves programming, without an instructor around. It is tempting to use the same approach in teaching programming; letting the students explore themselves. Her experience in teaching programming to kids is that it does not work. This is supported by researches in teaching in other fields, where it turns out that in general direct instruction works better than letting students explore themselves. To automate things by practicing and offering many basic skills is the way to go, according to Felienne. She found that Vocalising syntax, by reading code aloud, helps children. Teaching children strategies for learning code and making assessments is all part of direct instruction. In the end, Felienne pointed a misconception that motivation leads to skill. Rather, it is the other way around.

Finally, Hans Cuypers (TU/e) summarized that the conference, featuring many topics, reflected on what is happening in Math Education. Opinions were shared, trends were discussed and thoughts and suggestions were brought up for consideration. New ways of thinking and learning should always be embraced to prepare for the future!

The organizing committee on behalf of the 4TU.AMI project "Blended Learning" thanks all for contributing to or participating in the conference!

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Joost van Opheusden (WUR)
Jan Willem Polderman (UT)
Bart van den Dries (TUD)
Caroline de Wit (TUD)