# Mathematical competencies and blended education

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**Publication date**
2021

**Document Version**
Final published version

**Published in**
Proceedings - SEFI 49th Annual Conference

# Imprint

**Blended Learning in Engineering Education: challenging, enlightening – and lasting?**
SEFI 49th Annual Conference
Technische Universität Berlin (online)
13 – 16 September 2021

ISBN: 978-2-87352-023-6

**Editors:**
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*The manuscript was closed on 30 November 2021.*

# MATHEMATICAL COMPETENCIES AND BLENDED EDUCATION: HOW TO BUILD A RESILIENT COURSE?

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***Conference Key Areas***: *Resilient curricula and teaching methodology, Competence development for engineering professions, Sustainable changes beyond COVID-19*

***Keywords***: *service mathematics, mathematical competencies, blended learning, student success, instructional design, educational technology*

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## ABSTRACT

## 1 INTRODUCTION

### 1.1 Background

To educate future competent engineers, it is crucial to adopt teaching and learning approaches that support students in dealing with highly complex problems [1]. One strategy is to enhance service mathematics in higher engineering education by shifting from outcome-centered to competence-centered approaches [2]. This strategy is examined and adopted in a large-scale innovation programme of mathematics education (PRIME) at TU Delft to design effective service mathematics courses in higher engineering education.

As mathematics is at the core of engineering education, we will, in this workshop, explore how to create a viable and resilient educational model for developing mathematical competencies, described in the Framework of Mathematics Curricula in Engineering Education [2, 3]. Additionally, we will discuss how the development of mathematical competencies can be facilitated by leveraging technology in blended and remote learning environments. The aim of this workshop is to start a process via a living document which serves to share and create material and expertise in teaching, learning and assessing the mathematical competencies.

### 1.2 PRogramme of Innovation in Mathematics Education (PRIME)

In 2014, TU Delft piloted PRIME with the aim of redesigning service mathematics education for engineers by employing the blended learning cycle principle: Prepare, Participate, Practice. The main goals of PRIME are academic success, transfer, and student engagement [4]. Over 20.000 engineering students in 45 courses are being taught in PRIME each year.

### 1.3 Framework of Mathematics Curricula in Engineering Education

The report of the SEFI mathematics working group on the Framework of Mathematics Curricula in Engineering Education advocates the acquisition of mathematical knowledge in engineering education through consideration from the broader perspective of acquiring mathematical competencies at desired levels. [2]. Niss [5] (p. 6/7) defined mathematical competencies as “the ability to understand, judge, do, and use mathematics in a variety of intra- and extra-mathematical contexts and situations in which mathematics plays or could play a role”. Alpers et al. [2] argued that mathematical competencies can only be obtained by their application in engineering contexts and courses, and by stimulating active student involvement. Examples of how learning activities in PRIME support the development of mathematical competencies as a part of the Engineering curricula have been shared in the workshop.

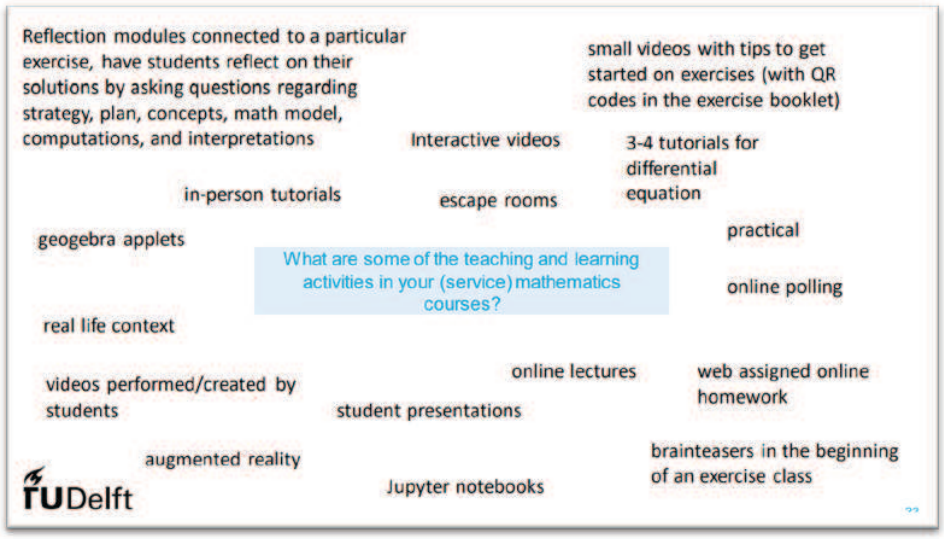
## 2 WORKSHOP METHODOLOGY

Prior to the workshop, a small survey study assessing mathematical competencies was conducted with 22 (73%) math lecturers teaching in PRIME. The survey was adapted and made available for participants after the workshop. Reading materials and links were also provided in advance, but no preparation was required from workshop participants.

During the workshop, the presenters provided an overview of the blended approach in PRIME and invited the participants to share some of their course activities (see Figure 1).

Figure 1

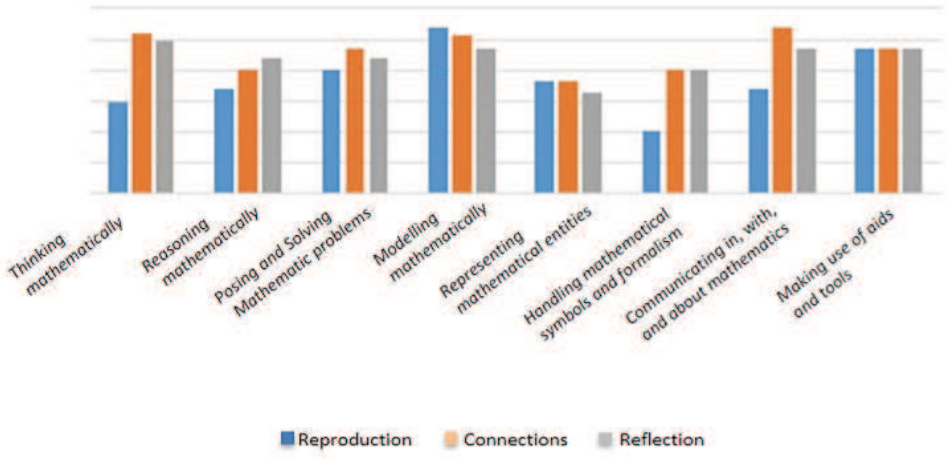
*Ideas Shared in Brainstorming Session*




In addition, the mathematical competencies theoretical framework [2] was introduced and key conclusions from the small survey study in PRIME were shared with workshop participants (for an example, see Figure 2).

Figure 2

*Math Lecturers' Relative Assessment of "Application Examples in Lectures" as a function of Mathematical Competencies across three levels of transfer: Reproduction, Connections, and Reflection*




Lastly, a description of the RULES_MATH project (https://rulesmath.usal.es/) was presented. In the final workshop session, participants shared experiences on fostering mathematical competencies, first in breakout rooms and then in a plenary session. The discussion was prompted by two questions: "How do the activities in your courses support the development of mathematical competencies?" and "How do these activities align with the three levels of transfer?". During the discussion, a living document with examples, thoughts, and ideas on effective teaching and learning materials was initiated.

At the end of the workshop, participants were expected to experience the following outcomes:

- Reflect on how their math courses support engineering students in developing mathematical competencies
- Share how course activities in different universities support students in developing mathematical competencies
- Discuss how service mathematics courses and activities can be designed to optimize learning outcomes associated with mathematical competencies

## 3 WORKSHOP RESULTS

The brief presentation at the beginning of the workshop provided participants with insights into the activities developed in the context of PRIME and the study that was conducted to assess how different activities may support students in developing the eight mathematical competencies with regards to varying extent of transfer (i.e., reproduction, connections, reflection). Using the zoom annotation tools, participants shared the teaching and learning activities that they use in their service mathematics courses. Figure 1 shows participants' ideas from the brainstorming session. The

ideas were used as a starting point for the discussion in the breakout rooms. During the breakout session, participants elaborated on the activities that were shared and discussed how these different activities contributed to the development of mathematical competencies for engineering students. Based on the discussion, participants gained an understanding of the various teaching practices at other universities and reflected on their own course designs. A few important themes surfaced from the small group discussions:

- Students need opportunities for reflection and mathematical thinking. This can be facilitated by providing students with better forms of feedback so that they can learn from mistakes.
- Problem-driven activities can serve as a starting point for students to think about how to better apply what they have learned and enhance mathematical modelling.
- There is a need to support students in critical reflection and to stimulate metacognition.

The discussions in the workshop led to a collaborative living document where we envision that teaching and learning ideas and best practices carried out in the universities can be compiled and shared across universities. (For more information on the living document, please contact the corresponding author.)

## 4 FUTURE DIRECTIONS

Ideas from the workshop led to two initiatives.
Firstly, the survey study assessing mathematical competencies conducted with math lecturers teaching in PRIME will be extended to math lecturers at other universities. The study aims to examine how math activities in different universities support the development of mathematical competencies and whether there are differences in lecturers' perceptions of mathematical competencies.
Secondly, a living document is created to facilitate sharing of resources and ideas across universities. This document serves as a dynamic and collaborative working space for practitioners in service mathematics to contribute, inspire, and connect.

Having concluded the workshop with deep reflections and generous sharing of activities and ideas for service mathematics courses by participants from different universities, the general sentiment is that ongoing discussions and sharing are needed to build a community of knowledge and practice around mathematical competencies. Furthermore, the strategic shift from outcome-centered to competence-centered approaches in higher engineering education is necessary for ensuring that students are equipped with relevant competencies to become competent future engineers.

### Acknowledgement

The authors thank D. M. L. Dias Rasteiro for presenting and sharing her results on the RULES_MATH project during the workshop.

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