Supporting quality of learning in university mathematics

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Honored Custos, honored Opponent, dear colleagues, friends, family, members of the audience here on-site and online

'By myself' but not 'all alone'.

In our research group, we have had this motto that somehow describes how we think of learning, and how we think of our work as researchers and educational developers. We think that there is a fundamental difference between doing something 'by myself' and doing something 'all alone'. Personally, today is an important day: I'm defending my dissertation. And I will do it by myself (it is kind of the point), but after this global pandemic and everything that came with it, I'm very happy that I don't have to do this all alone. Thank you so much for showing up today.

The motivation for my dissertation is based on the realisation that the experts in higher education and experts in mathematics have actually quite hard time communicating with each other.

I think we can all agree that higher education researchers have substantial pedagogical expertise on teaching and learning at university. Also, we can see educational research as normative, meaning that based on educational research, we can provide implication for practice, for example, suggest favourable teaching practices and indicate what we should and shouldn't do. In this vein, also higher education research has pointed us towards certain teaching and learning practices. But still, despite of the decades of higher education research, the teaching, especially in the university mathematics context, has remained quite the same.

At university, the lecturers, the teachers of a discipline, are experts of that discipline. However, this subject expertise does not always come along with pedagogical expertise. Still, from the disciplinary perspective, it is not always easy to welcome higher educators – these outsiders, people from another discipline – to tell you what to do and how to teach your very own area of expertise.

It is true that higher education researchers do not always value – or sometimes even consider – the disciplines' perspective. And I think they should because the disciplinary contexts come with disciplinary characteristics. I'll give you one example. Typically, in higher education research, repetition is seen as an unfavourable learning activity. Repetition represents rote learning and memorisation, something that is not directed towards understanding. However, this is not the case for example when reading mathematical texts – an activity that is very central for both expert mathematicians and mathematics students. Research shows that expert mathematicians don't read mathematical proofs in a linear fashion. Instead, they shift their attention back and forth; they start reading, stop, go back to check something, continue, go back again and so forth. The challenge for a beginner mathematician is that they read mathematical proofs as they read any other type of texts – in a linear fashion when they, in fact, should learn to embrace this expert-type repetition.

This does not mean that in the mathematics context, learning would be somehow fundamentally different, as if repetition always had a positive impact on learning. However, it means that in the disciplinary context of mathematics, there are both 'good repetition' and 'bad repetition', repetition that supports understanding and repetition that does not – and when conducting research on university mathematics learning, we should be able to distinguish between the two.

To address these types of disciplinary characteristics, the approach I both promote and demonstrate in my dissertation is discipline-based higher education research. I find it important to distinguish between discipline-specific and discipline-based higher education research. Learning always takes place in a context, and also in general higher education research, students participating in the research are coming from a certain discipline. In discipline-specific higher education research, all the participants are from a single faculty or department. This type of research can address disciplinary characteristics or disciplinary variation – but still only from the higher education perspective. Instead, discipline-based higher education is grounded in the disciplinary practices. It is higher education research that aims to be fully aware of the disciplinary characteristics and takes them as the starting point for further investigations.

By definition, discipline-based higher education combines expert knowledge of the discipline, of the challenges of learning and teaching in that discipline, and of the science of learning and teaching generally. In other words, while I have conducted discipline-based higher education research on university mathematics education, I have operated in the intersection of mathematics, mathematics education, and higher education. This indicates that discipline-based higher education research is interdisciplinary: there are multiple epistemologies present, and there are multiple orthopraxis present. This makes discipline-based higher education a complex endeavour. However, the aim of discipline-based higher education research is to close the gap between higher education and the disciplinary contexts, to bring pedagogical expertise and subject expertise together. This involves interplay of theory and practice, and interplay of research and development. Indeed, discipline-based higher education research is also a collaborative endeavour.

Despite the growing international interest, in Finland, university mathematics education as a research field is at its infancy. However, there is a growing community of mathematics educators engaged in developing new learning environments. A typical, traditional mathematics learning environment constitutes of lectures, tasks, and small-group sessions. Students go to lectures, where the listen to the lecturer explaining the topic, they solve take-home tasks in self-study, and with the tasks solved, come to a small-group session to take turns in writing the solutions to the blackboard.

As mentioned earlier, higher education research has pointed us towards certain teaching practices. In my dissertation, I use ‘student-centred’ as an umbrella term for these various suggested teaching practices. They all emphasise promoting conceptual understanding and quality of learning – and show that this is possible through for example students’ active engagement and responsibility, collaboration, and guidance and feedback practices. Researchers distinguish between first- and second-generation research on university mathematics learning environments. Up today, research has heavily relied on the first-generation research, on the comparisons between the traditional and the student-centred contexts. The results from this type of research are unanimous in favouring the student-centred learning environments. In STEM fields, large meta-analyses show that student-centred learning environments for example increase performance, decrease failure rates, and promote the learning of underrepresented student groups. In fact, the results are so unanimous that this type of research designs are no longer very relevant.

At the same time, the second-generation research, research contrasting two or more student-centred learning environments have remained scarce. Therefore, in my dissertation, I conduct second-generation research and contrast two student-centred learning environments, Course A and Course XA. The courses run parallel, and both of them were mass courses with hundreds of students and were targeted for first-year mathematics students. Course A functioned within the traditional learning environment structure. However, all the elements were student-centred; for example, the lectures promoted students' activity and engagement in mathematical discussions. Course XA included a structural shift away from the traditional learning environment structure as students started learning a new topic with introductory tasks. Course XA was implemented with Extreme Apprenticeship, a form of inquiry-based mathematics with a flipped learning approach.

These two student-centred learning environments were contrasted from the perspective of quality of learning. To conceptualise quality in learning, I built the theoretical framework around three concepts: students' approaches to learning, self-efficacy, and self-regulation of learning. The students' approaches to learning consider the type of aims students have for their learning, and the type of processes students' use to achieve those aims. Self-efficacy refers to students' own beliefs about whether they will make it or not, and student who can self-regulate can set goals for their learning, can monitor and reflect their progress, and if needed, can also adjust the learning processes accordingly.

The main research question of my dissertation is: How can different student-centred learning environments support university mathematics students' quality of learning? With this question in mind, in my dissertation I synthesise four studies investigating the same students in Course A and Course XA as described previously. As the same group of students is investigated in both learning environments, my dissertation can address the role of the context, not only the disciplinary characteristics as in discipline-based higher education research, but also the contextual characteristics on the learning environment level. The results of this doctoral dissertation are based on both quantitative and qualitative data. The quantitative data consists of 91 students who answered a questionnaire in both learning environments, and the qualitative data consists of 16 student interviews, in which the students reflected on their learning in both learning environments.

The findings of my dissertation demonstrate that changes to the teaching structures – or perhaps teaching norms – have the potential to support students' quality of learning in multiple ways. For example, a student reported that in Course XA, because when they had solved tasks prior to the lectures, they were then able to truly engage in the lecture discussions, which then promoted their deep approach to learning. The student said:

> [In the lectures], there were so many different perspectives, and you deepen your learning. [...] [W]e discussed a lot there, [...] you were able to take a stand and reflect. So, I was a very active learner [...] in the lectures. You always left the [lecture hall] with a feeling that something had just opened up in a completely new way.

Another student stated that because there were pre-lecture and post-lecture tasks in Course XA, because of this gradually increasing difficulty of the tasks, and I quote, *I constantly had [these] small experiences of success*. In other words, they describe mastery experiences that promote self-efficacy. Another student also reported that the open learning space was a central structure that supported them to regulate their learning. The student stated:

> I had a strategy that the easy tasks, the ones that felt straightforward, those I could complete at home in the morning. And then I came [to the open learning space] to work on the rest of them. [...] There were friends at the same time working on [the tasks], so it was a lot nicer to work together than to be in agony and all alone.

To conclude, I provide here three different-level theses based on my dissertation:

1. Students need access to meaningful collaboration.

Social interaction is one of the characteristics of student-centred learning environments. So, the challenge is not that student-centred learning environments do not provide opportunities for student collaboration. The challenge is that students do not always have a meaningful contribution to these opportunities.

2. Disrupting the structural teaching norms is beneficial for the quality of students' learning.

My findings show that structural changes can increase the quality of mathematics learning. In fact, quality of learning is quite sensitive to these changes. This means that the mathematics teachers', the mathematicians' pedagogical choices are very relevant, and that – all within the academic freedom and teacher autonomy – the mathematics teachers have a significant opportunity to support students to learn mathematics better.

3. Discipline-based higher education is essential to bring pedagogical and subject expertise together.

So, we know that it is good to move from traditional to student-centred learning environments, and we know that it is good not only to include student-centred elements to the traditional structure but also to disrupt the structure. So, I call upon us in the mathematics community to disrupt the teaching norms. I acknowledge that the aim is high. Developing education is hard, because first you need to look for problems and only after that you can try to solve them. For this, for identifying and solving the problems, we need both pedagogical and subject expertise. In this sense, I call for interdisciplinarity and I call for collaboration. Still, to develop mathematics teaching, we need to involve the mathematicians who teach it. In the end, no higher education researcher can do it for us. We in the mathematics community must do it by ourselves. But the good thing is we don't need to do it all alone.

Honored Opponent, I now call upon you to present your critical comments on my dissertation.