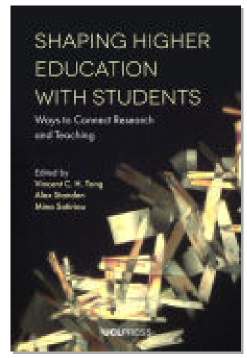
3.5. Digital tools for bridging the knowledge gap to university mathematics



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3.5
Digital tools for bridging the knowledge gap to university mathematics

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1. Introduction

According to the Organisation for Economic Cooperation and Development (OECD), England has three times more low-skilled people among sixteen- to nineteen-year-olds than the best-performing countries (Kuczera et al. 2016). Anecdotally, researchers and university teaching staff seem more concerned than ever with the evident problem of the growing deficiency in mathematical skills among undergraduate students in science, engineering and other applied sciences. While most of these problems have their origins at school, universities have to cope with several challenges, such as students' diverse backgrounds and levels, and that students often fail to recognise the importance of mathematics for their main degree. All these problems make additional support (tutorials, formative assessment and feedback, etc.) difficult and, in conjunction with the increased intake of students, time-consuming. Additionally, most undergraduate courses require a higher foundation in mathematics than that provided by GCSE (UK school examinations taken at the age of around 16). And so it often falls to universities to deal with this poor level of prior knowledge that can have a negative impact on students' progress.

We advocate that to help students to transition from school to university mathematics, higher education should look into the vast research of digital education. It should consider innovative technologies and associated pedagogies that can help students bridge the gap to university mathematics and achieve their full potential on their degrees.

Without endorsing specific tools, we provide below a brief description of some digital technologies that could transform higher education pedagogy. We also make a call to arms to the teaching community to: consider such technologies; engage with research in mathematics education that aims to understand better how learners interact with emerging technologies; identify ways to support the learners; and provide meaningful information about their interaction to instructors.

2. Digital technologies supporting university mathematics learning

There are a huge variety of systems for learning and teaching that can be used at undergraduate level. Comprehensive reviews include Engelbrecht and Harding (2005), Lavicza (2006) and, more recently, Kissane et al. (2015). Readers may also be interested in a broader review on the impact of technological change on science, technology, engineering and mathematics education (Davies et al. 2013) that, despite its focus on schools, can inform undergraduate teaching practice as well. In brief, such systems include: computer algebra systems (CAS), graph plotters, automatic assessment, and adaptive and intelligent systems. The above-mentioned reviews also show that the different functions of these systems are often combined. Going beyond the direct use of CAS, which is well reviewed (e.g. Marshall et al. 2012), we highlight two key types of digital technologies on which we and colleagues have undertaken research, and which we have noticed are underutilised despite their potential.

2.1 Computer-aided assessment

Automatic formative and summative assessment has important teaching and learning implications. Readers may be interested in a comprehensive review of the field and the practical suggestions discussed in Sangwin (2013). Among successful examples in mathematics is the STACK project (www.stack.bham.ac.uk/) that has evolved over years of research (see Sangwin and Grove (2006) and previous related work in Mavrikis and Maciocia (2003) and Mavrikis and González-Palomo (2004)). This work recognises that mathematically rich assessment requires the use of CAS in the background to automate the assessment of pedagogically valid questions. Unlike the traditional use of CAS, systems like STACK utilise the power of CAS to accurately compare mathematical expressions, automate graphical representations and perform rapid re-calculation to facilitate assessment (Sangwin and Grove 2006).

2.2 Adaptive and intelligent systems

Adaptive systems equipped with artificial intelligence can provide students with individualised learning based on their abilities, knowledge and skills. This is possible through recommendation algorithms underpinned by pedagogical models that can adapt task selection, taking into account difficulty and previous performance of students in a previous cohort (see a short review in Davies et al. 2013). Similarly, intelligent tutoring systems provide a degree of intelligent support during problem-solving. An actively maintained research-oriented example is the ActiveMath project (now MathBridge – see www.math-bridge.org/). A variety of commercial tools are also beginning to emerge from well-known educational publishers in the field.

3. Pedagogical considerations

Although today's students are technologically literate – many students entering university in 2017 will have never known a life without the internet and will have experience of social networking technologies – using technology for learning requires 'learning how to learn' with the new medium. Research in mathematics education has long demonstrated the potential challenges – in, for example, exposing students' limited understanding of computer algebra systems (Lavicza 2007). In our research, we have noticed that the design of a system can have an impact on students' approach to learning, including triggering curiosity and interest (Margeti and Mavrikis 2015).

There are still several questions about the pedagogy of digital technologies for university mathematics that need addressing. For example, the transition from school to university requires a shift from an external locus of control to an internal one. Even though interacting with digital tools can be engaging, how can we promote engagement with the actual mathematics? How can we support students' interactions with the tool in hand and ensure the focus is on the mathematics by addressing any technical difficulties that could potentially lead to disengagement? How do students collaborate and support each other through digital tools, online communities or collaborative digital platforms? How can we promote resilience, mathematical 'habits of mind' and inquiry-based learning that equip students to tackle the 'harder' mathematics and apply them where needed? Considering the wide range of digital literacy skills of today's university students, there needs to be a clear distinction between technical competence and mathematical competence. We need to identify strategies to facilitate the appropriate use of digital tools for teaching and learning mathematics at university.

4. Join the community

We are seeking to form a 'community of interest' (Henri and Pudelko 2003) to host a close collaboration between researchers, university lecturers of mathematics and students, with the aim of utilising our expertise and plethora of research prototypes to produce supporting material and integrate digital tools in mathematics teaching across UCL.

The inclusion of researchers, lecturers and students in the design of supporting materials is critical, with respect to both lecturers' development processes and for supporting students' transition to higher education. In another area of educational digital technology, namely learning analytics, we are beginning to observe how the availability of data showing learners' engagement with digital environments can be used for both real-time monitoring and post-interaction reflection (Mavrikis et al. 2016). This requires bringing together the expertise of different stakeholders, including computer scientists, developers, educators and students.

Our aspiration is to harness teaching expertise in mathematics across our university, which, combined with research in computer science and digital education, can act as a springboard for spreading excellent practice even more widely. This won't just help the study of mathematics, but will benefit all students and teaching staff from different departments, at both UCL and other universities.

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