The examination of technology use in university-level mathematics teaching

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Abstract

Technology is becoming increasingly used in university mathematics teaching but there are only a small number of studies that have examined technology-assisted teaching at the university level. This is despite the fact that university mathematics teaching has been changing rapidly during the past two decades. To offer an overview of technology use in university teaching I carried out a study examining the extent of technology used by mathematicians, particularly their use of Computer Algebra Systems (CAS), their views on the role of CAS in the mathematics curriculum, and the factors influencing CAS integration into university mathematics teaching. In this study, I interviewed 22 mathematicians and collected questionnaire responses from 1103 mathematicians working in Hungary, the United Kingdom, and the United States. Results of the study suggest that 1) mathematicians use technology for teaching more extensively than school teachers; 2) overall, mathematicians view the role of technology in mathematics curriculum and mathematical literacy in a positive light; and, 3) numerous mathematicians are open to enhancing their teaching practices with technology and to experimenting with innovations in mathematics teaching. In this paper, I will argue that educational researchers should pay more attention to the technology-related teaching practices of mathematicians to better understand and enhance innovations in mathematics teaching at all levels

Introduction

During the past two decades university level mathematics teaching has encountered new challenges which are contributing to the changes in teaching practices in higher education. On the one hand, the increased enrolment in universities, the lower student interest in STEM[1] subjects, and difficulties in school-level education resulted in a decline in mathematical preparedness of students entering universities. On the other hand, the emergence of new technologies available for teaching opened new perspectives and intensified demands for the changes in teaching practices. The observed weaknesses in students' mathematical preparedness and the availability of technology prompted numerous mathematicians to experiment with innovative teaching and a number of them have turned their attention to pedagogical issues. Moreover, in many cases the integration of technology into undergraduate teaching is seen as way to revitalize teaching and assist students to raise their level of mathematical understanding. Although university-level mathematics teaching is undergoing considerable changes and is in need of assistance, little attention has been paid to teaching issues at this level by the educational research community. In particular, little is known about the current extent of technology use and mathematicians' practices in university teaching (Lavicza, 2007).

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[1] STEM = Science, Technology, Engineering, and Mathematics

The majority of research studies on educational use of technology has been conducted at the school level. Results of these studies may be applicable at universities, but because of the substantial differences between the characteristics of school and university level teaching, studies must be conducted at the tertiary level as well. There are certainly studies reporting on technology use at universities, but the majority of research either describes innovative practices, application of software packages, and case studies of student learning; or, outlines results of experimental studies comparing technology-enhanced environments with control groups of traditional teaching methods (Lavicza, 2006). These kinds of studies are valuable, but offer limited overview of the state of technology use at the university level. In contrast, at the school level, large scale research projects are periodically carried out to review the scope of technology integration either nationally (e.g., Ofsted, 2004) or internationally (e.g., OECD, 2004) providing benchmarks for other studies.

To offer an overview of the current state of technology use and the factors influencing technology integration at the university level, I designed and carried out a two-phase international study. In this paper, I report some results of this study and highlight the importance of paying more attention to mathematicians and innovations at the university level.

Research on technology use at the university level

Aims and research design

The study aimed to examine the current extent of technology use in universities; to uncover mathematicians' views on the role of technology in mathematics literacy and curricula; and to explore the factors influencing technology integration into mathematics teaching and learning at universities. The design of the study followed a two-phase mixed methods approach. The first, qualitative phase of the study comprised interviews, class observations, and the review of curriculum materials of 22 mathematicians in Hungary (HU), the United Kingdom (UK), and the United States (US). Based on the findings of this phase, I developed an on-line questionnaire which was sent to 4,500 mathematicians in the participating countries. This phase of the study concentrated solely on a particular technology application, Computer Algebra Systems (CAS)[2], because CAS is one the most widely used mathematical software packages in university mathematics. Furthermore, the review of all kinds of technology would have been unfeasible for such a questionnaire study.

Results

High response rate

Ultimately, 1103 mathematicians responded to the questionnaire, which constitutes as an unexpectedly high 24.62% response rate[3]. In addition to responses to closed questionnaire items, mathematicians wrote an approximate total of 150 pages for the optional open questions and sent approximately 600 e-mails many of which included relevant comments.

[2] CAS = Any software package that is capable to perform numeric and symbolic computations and visualize mathematical expressions. Examples: Derive, GeoGebra, Maple, Mathematica, MuPad, Matlab (included), etc

[3] Response rates by country: 521 US (20%), 347 UK (25.2%), and 235 HU (46.35%)

Furthermore, 297 mathematicians volunteered to participate in future technology-related studies.

The high response rate and the generally positive feedback suggest that mathematicians are interested in learning about technology applications in mathematics teaching and many of them are open to discuss educational issues. However, it is still commonly perceived that mathematicians are difficult to approach with educational issues and often unsympathetic to educational research(ers). Nonetheless, it is encouraging to note that a large number of mathematicians were receptive to participate and collaborate in educational research.

Extensive use of CAS in research

The analysis of the data revealed that 67% of participants reported at least occasional use of CAS in their own mathematical research. This percentage is considerably high even when considering that mathematicians who have some kind of connection to CAS were likely among those responding to the questionnaire. After accounting for this possible bias it can be suggested that every third, or more likely, every second mathematician uses CAS in their own research. Thus, there is a large number of mathematicians who have acquired strong working knowledge of at least one mathematical software and this knowledge can be readily utilized for CAS-assisted teaching. In fact, the Structural Equation models developed for modeling the influences of CAS integration into teaching *CAS-use-in-research* valuable is the strongest predictor of *CAS-use-in-teaching*. Proficiency in the use of a software package offers an advantage to mathematicians over teachers as they often don't require initial training for software before beginning to use it in their teaching.

Extensive use of CAS in teaching

Fifty-five percent of the participating mathematicians reported that they utilize CAS for their teaching at least on an occasional basis. Similar to the research use of CAS, a possible bias should be considered in the sample, which might lower the percentage of CAS use in teaching in the overall population. However, there are other kinds of technologies used in university-level mathematics teaching other than CAS. Therefore it is not unreasonable to assume that more than one third, or even one half of mathematicians use technology in their teaching. Comparing this result to school level studies it can be implied that technology use at universities is substantially higher than those measured (5-10%) at the school level (Gonzales et al., 2004). This result also indicates that mathematicians have already accumulated an immense expertise and knowledge in technology-assisted teaching, although it is only sparsely documented.

The role of CAS in mathematical literacy and curriculum

Responses indicate that mathematicians view the role of technology, particularly CAS, positively in mathematical literacy and in university curricula. They agree that proficiency in CAS use is beneficial for students' future studies and career, and they suggest that CAS will eventually become an integral part of the undergraduate mathematics curricula. The comparison of results between countries indicated little difference in mathematicians' perspectives on the role of CAS in mathematical literacy and curricula. However, mathematicians who use CAS in teaching value the role of CAS in mathematics teaching considerably higher than their colleagues who do not use CAS in teaching. Due to this result, it can be suggested that enthusiasts are more likely to employ CAS in teaching or the use of CAS causes them to think more positively about the usefulness of CAS in education.

Discussion

Results of this study indicate that mathematicians use technology for teaching more extensively than school teachers. Numerous mathematicians have accumulated extensive knowledge about mathematical software packages through their own research. Coupling this knowledge with their expertise in mathematics as well as with the freedom of developing their own curriculum materials provides a rich opportunity for innovations in technology-assisted teaching. In addition, mathematicians view positively the role of technology in mathematical literacy and curricula. Therefore, it is likely that there are already remarkable innovations and successful teaching practices already existing at the university level. Consequently, it would be advisable to pay closer attention to mathematicians' technology-assisted teaching such as documenting and researching these practices and innovations. This could significantly contribute to not only advancement in research and practice at universities, but also at the school level.

It is interesting to observe the evolution of ICMI studies on technology with respect to educational levels over the years. The First ICMI study in 1985 was almost exclusively concerned with the integration of technology into university-level mathematics (Churchhouse et al., 1986) and despite difficulties articulated by several of its authors, the study presented an optimistic future for technology integration into mathematics education. Fifteen years later, the ICMI-11 study reported on the use of technology in a variety of mathematics courses taught in universities (Holton, 2001) and other papers described the ways in which technology could be used to enhance students' learning and the impact of technology on classroom communication (King, Hillel, & Artigue, 2001). Overall, ICMI-11 suggests that technology use is only 'cosmetic' (Hillel, 2001), but the study does not provide a systematic overview of the extent of technology use in universities. Subsequently, further studies have confirmed that in spite of the initial optimism for rapid integration of technology into education, technology is only marginally used in school-level teaching and learning (i.e. Ruthven & Hennessy, 2001). In addition, the Lagrange et al. (2003) review of technology studies highlighted that studies pay little attention to teachers, and that research has been dominated by school-level studies. This trend can be detected in the submissions of the ICMI-17 study, *Technology Revisited*, where only a small fraction of the studies were concerned with technology integration at the university level. Specifically, only Buteau and Miller (2006) document an extensive and sustained undergraduate technology programme besides the report of my own study (Lavicza, 2006).

It can be observed that during the past two decades technology-related studies almost entirely turned their focus from the university to the school level. Certainly, there are new research groups and SIGs[4] founded to deal with issues in higher education and technology is part of their research scope. However, I believe that the present time offers a good opportunity to partially refocus educational researchers' attention on university level research. Particularly, mathematicians are becoming more open and attentive to educational research so that opportunities are becoming increasingly available for research at this level. Also, mathematicians and educational researchers could learn many things from each other which would ultimately enhance research and students' learning at all levels of education.

[4] SIG = Special Interest Group

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