RESEARCH ON STEM EDUCATION IN THE DIGITAL AGE: EDITORIAL

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In spring 2020, the Covid-19 pandemic caused strict lockdowns of public life all around the world. Also teaching and learning changed massively. Instead of learning in a common place, namely the classroom, the pandemic situation led to a spatial and temporal separation of students and teachers. Hardly surprisingly, this entirely new distance learning situation was perceived as a major challenge by both students and teachers (Hodges et al., 2020).

The need to reorganize the realization of education "shocked teachers at all levels and at the same time inspired them to find solutions to problems they have not encountered before" (Flores & Swennen, 2020, p. 456). Mostly with the help of digital media and the internet (Crompton et al., 2021), educational institutions have developed new teaching methods and found creative solutions for distance learning (Flores & Swennen, 2020).

THE ASYMPTOTE PROJECT

Among other approaches, the ASYMPTOTE project was developed in the context of these distance learning issues (cf. Barlovits et al., 2022). It aimed at creating an adaptive, synchronous and mobile system for online mathematics lessons.

In order to do so, the ASYMPTOTE project (**A**daptive **Sy**nchronous **M**athematics Learning **Pa**t**h**s for **O**nline **T**eaching in **E**urope) was carried from March 2021 to February 2023. Within the framework of an Erasmus+ Strategic Partnership, seven institutions from five countries contributed to the project, namely:

- Goethe University Frankfurt, Germany
- Autentek GmbH, Germany
- School of Engineering, Polytechnic of Porto, Portugal
- University of Bielefeld, Germany
- University of Catania, Italy
- University of the Aegean, Greece
- Spanish Federation of Mathematics Teacher Societies, Spain

From a technical point of view, ASYMPTOTE offers two components. In a *web portal* (www.asymptote-project.eu/), teachers can select task examples, so-called learning graphs. It also offers an authoring tool that teachers can use to create learning content themselves. Students work on this content through a *mobile app* which is available for iOS and Android devices. Their progress can be monitored by teachers in the web portal's Digital Classroom feature. The ASYMPTOTE system can be used free of costs and advertisement.

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In addition to the technical development, the ASYMPTOTE project also aimed at creating best practice examples for digital tasks and learning graphs. As part of the project, we developed a comprehensive *open database* of learning content for secondary schools and universities. To enable teachers to create their own content to meet the needs of their students, ASYMPTOTE provides detailed video tutorials and an extensive step-by-step user guide.

Pre-service and in-service teachers were trained in the use of ASYMPTOTE in various events: A university course for pre-service teachers was developed and delivered at the Universities of Bielefeld, Catania, Frankfurt and Rhodes (*long-term curriculum*). Furthermore, a *massive open online course* (MOOC) on ASYMPTOTE was conducted in 2022. Other dissemination activities included an intensive study program for university students (Frankfurt, Germany) and an international teacher training (Granada, Spain).

Lastly, the ASYMPTOTE project was continuously monitored from a scientific perspective. Besides an ongoing evaluation of all technical developments, a pedagogical model for ASMYPTOTE was set up in view of relevant literature on teaching and learning mathematics online (cf. Fesakis et al., 2022). Moreover, a *scientific evaluation* of users' perception of ASYMPTOTE was embedded in all project-related dissemination events. First results were presented at the ROSEDA conference and can be found in these proceedings.

THE ROSEDA CONFERENCE

How can STEM education be enriched by means of digital technology? This key question was addressed by the "**R**esearch **O**n **S**TEM **E**ducation in the **D**igital **A**ge" conference (ROSEDA)**.** It took place in Porto from February 23 to 25, 2023, and focused on teaching and learning of science, technology, engineering, and mathematics with digital technology.

Given the great importance of digital technologies in STEM education (cf. Tytler, 2020) and in dealing with the pandemic situation (cf. Crompton et al., 2021) the ROSEDA conference dealt with the following three topics:

- ideas and experiences for the design, conduct, and assessment of online courses;
- innovative approaches of using digital technology in education;
- research on teaching and learning during the Covid-19 pandemic.

During the conference, various approaches to digitized STEM education were presented, shared, and discussed. For all conference contributions, a short outlook is given below. Thereby, we start for all three topics with a short introduction of the invited contributions. All other contributions are grouped in view of their topics.

Ideas and experiences for the design, conduct, and assessment of online courses

In their invited paper, Corlu et al. explore key elements for effective online professional development in STEM education. In doing so, the authors investigate in a case study the implementation of STEM lessons by a teacher after participation in a PD programme.

The conduct and assessment of university is addressed by two papers. Geisen and Zender present ideas for formative assessment of online higher education seminars through a

balanced mix of instructor and peer feedback. Läufer and Ludwig show an approach to incorporate 3D printing into university courses for student teachers.

Kleine and Anhalt emphasize the need for building adequate cognitive structures, so-called "Grundvorstellungen", for students' ability to work on mathematical modeling tasks. An approach how mathematics can be learned enactively in distance education is presented by Kleine and van Randenborgh.

Innovative approaches of using digital technology in education

Vaz de Carvalho presents different approaches for technology-enhanced active learning in his invited paper. He shows best practice examples from different STEM disciplines with a special focus on serious games.

Several papers address the development of new tools. Barbosa and Pereira present a mapping tool for teaching and learning descriptive geometry or, more specifically, the Monge method. Stäter et al. present the <colette/> project, which aims to enhance students' computational thinking skills. The Erasmus project LEARN+ is presented by Carvalho and Lázaro. Here, the authors pay special attention to the training of teachers in the use of the MILAGE LEARN+ tool.

The math trail idea is addressed by three papers. Benito et al. discuss the possibilities of combining outdoor mathematics and augmented reality elements for initial teacher education. Cahyono describes how virtual reality can be used to conduct math trails including real-world STEM problems despite of the pandemic situation. Using the MathCityMap system, Jablonski evaluates the role of hints and feedback for outdoor mathematics in a case study.

Two papers present and discuss the ASYMPTOTE project. Caldeira et al. describe how the ASYMPTOTE was used in higher education and how university students experienced the usage of the system. Dos Santos dos Santos et al. compare the automated feedback of ASYMPTOTE and GeoGebra and present an approach to take full advantage of both systems.

Research on teaching and learning during the Covid-19 pandemic

Whether it exists a "positive side" of the pandemic, is discussed by Swidan in view of Covid-19-induced distance. In the invited paper, he presents several technical approaches to help teachers deal with this particular situation.

The papers on teaching and learning during Covid-19 pandemic addressed different educational levels. Caldeira et al. present an approach to dealing with the Covid-19 pandemic in which university students developed short videos on linear algebra. In their paper, Oehler et al. focus on secondary students and discuss ways to enhance computer science projects with distance learning elements.

Two papers evaluate the ASYMPTOTE system in the educational praxis: In a case study with elementary school students, Fesakis et al. evaluate the use of the ASYMPTOTE system in school practice. University courses on ASYMPTOTE in Germany, Greece, and Italy are evaluated by Taranto et al.

Workshops and posters

As a poster, Caldeira et al. present an approach for teaching mathematics with robotics as part of a STEM project. Oehler et al. give an overview of the ASYMPTOTE project and its technical development.

The ASYMPTOTE project is also presented by Barlovits et al. in the form of a workshop. Other workshops by Jablonski et al. and Stäter deal with the MathCityMap and the <colette/> system, respectively.

ROSEDA conference and proceedings

During the ROSEDA conference, researchers from across Europe were able to share experiences from research practices in science, technology, engineering, and mathematics education. They discussed innovative approaches to teaching and learning in the digital age and received numerous suggestions from the STEM community.

We are convinced that, with the conference and these proceedings, we can contribute to the manifold discourse on how STEM education can be enriched with the help of digital technologies. We would like to thank all participants of the ROSEDA conference for the rich and fruitful discussions and wish all readers a lot of pleasure with the multifaceted contributions in this conference proceedings.

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