DIGITAL LEARNING GRAPHS WITH ASYMPTOTE – STUDENTS FEEDBACK

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Abstract. The success of digital technology in mathematics education includes the design of digital tools. The ASYMPTOTE system has been developed and improved since March 2021 an effective, powerful, and user-friendly digital tool for online mathematics education. This article aims to present an exploratory study of the use of the ASYMPTOTE system in the classroom. The participants of this exploratory study are engineering students of different degrees of the School of Engineering of the Polytechnic of Porto (ISEP) and in different subjects. In some subjects, the ASYMPTOTE was used in an evaluation context and in others in a training context.

Key words: ASYMPTOTE, digital tools, mobile learning.

INTRODUCTION

The pandemic, caused by COVID-19, affected the lives of millions of people and the closure of teaching activities, forced universities and polytechnics to reorganize and move from face-to-face teaching to online teaching. However, this reorganization was not thought about calmly, it was motivated by the need of the moment, which is why this teaching was called emergency remote teaching because it is a solution for the moment of confinement (Viamonte & Pinto, 2022; Barlovits et al., 2022). However, this teaching resulted in many gaps in the students' learning process and one of the most principal issues that appeared during the confinement was the guarantee of equal opportunities for access to digital education. Netta Iivari and colleagues address the digital transformation started in education due to the COVID-19 pandemic (Iivari et al., 2020). They mention that some problems with access to technology meant that not all students were in an equal position to take part in digital education. The United Nations (United Nations, 2020) recommends as a top priority the right to higher education for all, within a framework of equal opportunities and non-discrimination.

Technology is fully embedded in society, being part of people's lives in many ways and being increasingly implemented in our daily lives. Students and teachers must adapt to this evolution and, therefore, it is necessary to implement new methodologies, with the use of technological tools such as mobile phones and the internet, which are directed to the needs of students (Esteve-González et al., 2015; Haleem et al., 2022). The idea of adding digital resources such as the use of specific applications in the classroom as an auxiliary teaching method brings flexibility for both students and teachers. In this way, using the students' own mobile phones, it is possible to help in the assimilation of knowledge, and information and to facilitate learning, since the student can study at any place and time, being able to provide the teaching-learning process becomes more pleasant and stimulant. When the mobile phone is used with an adequate methodology in the educational environment, it is possible

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for the student to see that it can be used for purposes that bring benefits to their knowledge and that this is also a means of communication, which is essential in the teaching-learning process and makes this process simpler and easier. However, the use of these technological tools must be directed in an adequate and well-defined way, to promote inclusion efficiently (Iivari et al., 2020; Mehdi et al.., 2020).

Since March 2021, the ASYMPTOTE system has been developed and improved. ASYMPTOTE stands for Adaptive Synchronous Mathematics Learning Paths for Online Teaching in Europe (https://www.asymptote-system.eu/en/portal-en/#!/), and the project aims to develop an effective, powerful and user-friendly digital tool for online mathematics education. This system consists of two components, a web portal for teachers and a smartphone application for students (Barlovits et al., 2022).

In this article we will present an exploratory study of the use of the ASYMPTOTE system in the classroom. The participants of this exploratory study are engineering students of different degrees of the School of Engineering of the Polytechnic of Porto (ISEP) and in different subjects. After this introduction, we will describe the ASYMPTOTE system. We begin by presenting and describing the system and, then we will describe the scenario in which this exploratory study was carried out: the several courses, the different subjects and, if the ASYMPTOTE was used in class as a training or as an evaluation tool. Next, we will investigate the impact of the ASYMPTOTE on students, an anonymous survey was conducted to assess the students' opinions about this experience. The goal is to present the results obtained in the survey and we end with some considerations and conclusions.

APPROACH

The integration of digital technology into the teaching and learning process has been fundamental, resulting in significant changes in education. The use of digital technologies gives teachers the opportunity to design engaging learning opportunities in the courses they teach. In this article we will use the ASYMPTOTE system in the classroom in a school of engineering and in different subjects.

The tool

The aim of ASYMPTOTE project is to develop a system for synchronous and adaptive online learning. The ASYMPTOTE system has two components: a web portal and an App.

- A web portal where teachers can create tasks and learning graphs, or even, search and choose tasks and learning graphs that are available in the system. Teachers can cluster some tasks in a sequence with multiple levels of difficulty, for a specific or general topic of mathematics.
- An App for smartphones where students can complete assignments and browse the learning graphs. In the App it is possible to visualize the tasks and the learning graphs. Students, strolling the learning graph, solve the tasks and get synchronous and systematic feedback. The applications run on Android and iOS mobile devices.

The web portal also provides teachers the Digital Classroom, where, the teacher can monitor their students' work in real time. A chat is also implemented, is for one-to-one synchronous communication between instructor and student (Larmann et al., 2021).

Tasks and learning graphs

Tasks in ASYMPTOTE are divided into three broad categories regarding their focus:

- training - includes mathematics and/or mathematical techniques;
- reasoning - requires the use a mathematical argument, interpretation, or explanation;
- modelling - real world modelling and problem solving.

The tasks must include some basic information, such as, the title and description and the author's information; core components, such as, the answer types, task type, sample solution, some hints, the assigned grade and tags. The answer type can be: exact value, interval, multiple choice, fill in the blanks, vector (exact value), vector (interval), set, fractions and matrices.

A learning path is defined as a sequence of tasks which are designated to assist the student in improving their knowledge or skill in a particular subject area (Brusilovsky, 1992). In ASYMPTOTE, task sequences are presented in the form of a learning graph, which is defined in (Barlovits et al., 2022) as follows:

A learning graph is defined as a directed graph, where each vertex represents a learning activity (or task), based on a learning trajectory as the intended and expected way of learning.

The structure of ASYMPTOTE learning graphs ensures that the entire learning process is self-guided and autonomous and, it also aims gamification, where students receive points for a successful task-solving process, motivating and stimulating them for learning (Lieberoth, 2015). In the ASYMPTOTE, the learning graph consists in a sequence of tasks (see Figure 1):

- the main tasks (yellow), they are mandatory tasks and they in the center;
- support tasks (green), they are easier related tasks that can help to solve the main task afterward and they are on the right side;
- the challenge tasks (purple), with higher difficulty, challenging those students who want to dive even deeper into the topic, and they are on the left side.

As the tasks are carried out, those that were answered correctly will be marked. Students have four attempts per task, if they make a mistake on the first attempt, they don't lose points, and when they make a mistake, they are motivated to use the hints that are available in the task. When students respond to the task, they immediately receive feedback and a task resolution suggestion. Feedback, combined with effective instruction in the teaching and learning process, it can be very powerful in enhancing learning (Hattie & Timperley, 2007).

The learning graph in Figure 1 is named "Gauss Elimination Method and Applications" and can be downloaded in the ASYMPTOTE App by entering the corresponding code.

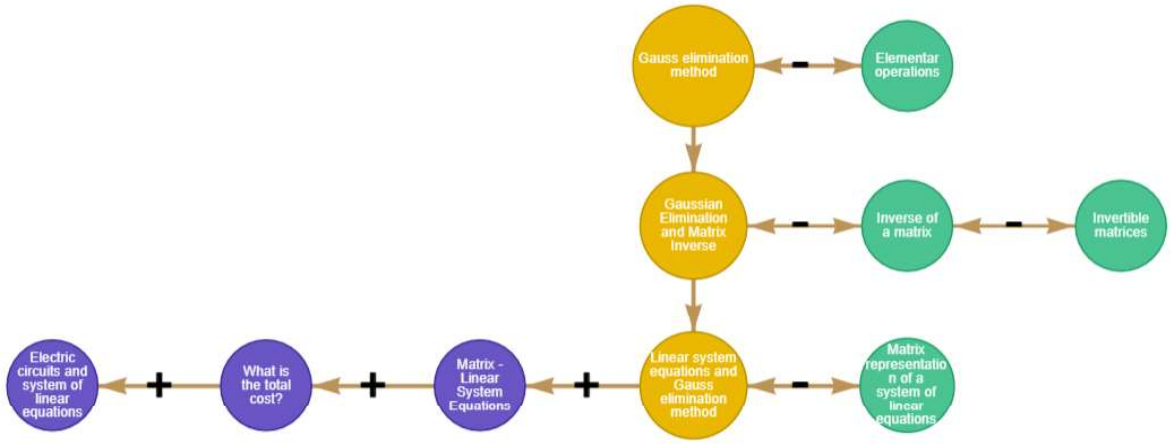


Figure 1: Example of a learning graph (CODE: g17203).

The setting

Our scenario is an engineering school, ISEP, and the participants involved were mathematics professors and engineering students. They are students of five different types of engineering degrees:

1 Biomedical Engineering (LEBIOM);
2 Civil Engineering (LEC);
3 Electrical Engineering – Power Systems (LEESEE);
4 Systems Engineering (LES);
5 Telecommunications and Informatics Engineering (LETI).

and three different subjects of the scientific area of Mathematics:

1 Calculus I;
2 Calculus II;
3 Linear Algebra.

The students of Biomedical Engineering attend the 2nd degree year and the rest attend the 1st degree year, totaling 409 possible students for the exploratory study.

It was proposed to the students of these engineering degrees courses that they solve a learning graph in class, in the context of an evaluation or in the context of preparation for an evaluation test.

Table 1 shows the relationship between the various engineering degrees, the subjects, the number of students enrolled in the discipline and the codes of the proposed learning graphs. It should be noted that not all students enrolled in the subjects took the proposed learning graph. There are students who, despite being enrolled in the discipline, do not attend classes for unknown reasons.

Engineering degrees	Subject	Number of students	Purpose	Codes
LEBIOM	Calculus II	61	training	G01337
LEC	Linear Algebra	119	training	G19364
LEESEE	Linear Algebra	91	evaluation	G49502
LES	Calculus I	71	training	G07299
LETI	Linear Algebra	67	evaluation	G69513

Table 1: Engineering degree - Subject - Number of students – Purpose and LG Codes.

RESULTS AND DISCUSSION

A questionnaire to understand the App's applicability as a tool for learning, training and assessment was given to students. The students' questionnaire contained eight questions of mixed nature, closed-ended and one question open-ended. In the closed-ended questions it was intended to evaluate the use and applicability of the App and the last one is an open-ended question where the students were asked to indicate the weaknesses and the strengths of the App. Of the student population (409) enrolled in courses that used the App, 176 participated in the questionnaire.

Two variables were defined to characterize the participants in this survey by questionnaire: gender and number of enrollments in the course. Figure 2(a) reveals that male participants were remarkably higher than females and Figure 2(b) shows that most students are attending the course for the 1st time.

(a) (b)

Figure 2: (a) Participation according to gender; (b) Number of attends in the course.

Regarding the use of the application, the two questions were made to students:

- Should the ASYMPTOTE App be a tool to use in learning and training during theorical an practical classis?
- Should the ASYMPTOTE App be a tool for evaluation?

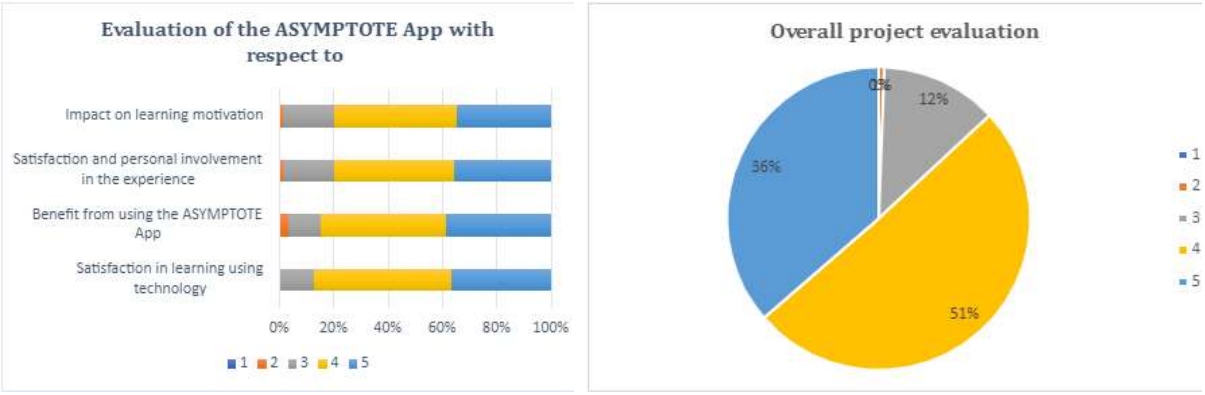
About the use of the App as a tool to be used in classes, most of the students (79%) agree with its use, but different answers were given about the use of the App as a tool for evaluation. Only half of the students (54%) agree with its use for evaluation. Note that 25% disagree with its use. Table 2 shows the results.

	Should the ASYMPTOTE App be a tool to use in learning and training during theorical an practical classis?	Should the ASYMPTOTE App be a tool for evaluation?
Strongly disagree	1%	8%
Disagree	5%	17%
Neither agree nor disagree	15%	21%
Agree	46%	33%
Strongly agree	33%	21%

Table 2: Use of ASYMPTOTE App application.

The students were asked to evaluate the ASYMPTOTE App with respect to five items: impact on learning motivation, satisfaction and personal involvement in this experience, benefit from using the App, satisfaction in learning using technology and overall project evaluation. A Likert-type scale on satisfaction was used to specify students' levels of satisfaction, where 1 means that students are very dissatisfied with ASYMPTOTE App and 5 means that they are very satisfied. As can be seen in Figure 3(a), the "overall project evaluation" is very good. The fact that a student can study (or be assessed) using an app, which allows suggestions, immediate feedback and access to task resolution, makes the project very appealing.

In the first four items a great percentage of students (more than 80%) are somewhat/very satisfied with the App, only a residual percentage (less than 3%) states that they are somewhat/very dissatisfied. Most students (87%) are overall satisfied with the App, see Figure 4(b).



(a) (b)

Figure 3: (a) Evaluation of ASYMPTOTE App; (b) Overall project evaluation.

Weaknesses and the strengths

Students were asked to justify their answer by giving their opinion about the project relative to weaknesses and strengths. Some students considered that the project was very interesting, and it was an opportunity to gain new skills. Others point out existing bugs on App and internet network failures as points to improve. Some of the answers are expressed in Table 3.

Weaknesses	Strengths
"Existing bugs"	"Having the resolutions and the large amount of exercises"
"Some internet failures can harm the student"	"Using technology to learn revealed greater interest on my part"
"For a global assessment of the subject, I don't think it's a fair way of evaluating the discipline, mainly because I personally think that mathematics has to be expressed on paper, with calculations"	"I think the implementation of ASYMPTOTE was a very creative idea, which in a way captivated the students' interest as it was a different platform than usual. The level system transforms learning into a fun and more relaxed challenge, the possibility of having "clues" in the exercises helps to clarify possible doubts in solving them and the demonstration of the exercise solution and its calculations at the end make these activities like a "mini-lesson"".
"Too bad it doesn't have computer support"	"The App is easy to use and well organized, in terms of learning it is a good teaching tool"

Table 3: Students' opinions about the App.

CONCLUSIONS

The present study is based on the student's responses to a survey about the use of ASYMPTOTE in the classroom and intends to assess the advantage for students' motivation and learning. The survey had several questions on a 5-point Likert scale and at the end had an open-ended question where students were asked to point out the main negative and positive points of their experience with ASYMPTOTE. Although no conclusions can be drawn as there was no control group, based on the data it seems that students believe that using ASYMPTOTE is efficient for their learning and motivation.

Some responses suggested that the use of ASYMPTOTE as a teaching tool brings several benefits to the educational process, such as increasing individual participation in the teaching-learning process and the possibility for students to manage and plan their own learning process. As can be deduced from the data, in terms of ease of use and usefulness, the average score of participants is above average. These dimensions illustrate the benefits of using ASYMPTOTE and these results are also in line with other research (Gan & Balakrishnan, 2014; Mehdi et al., 2020), claiming that the adoption of mobile technology in learning can improve teacher-student interaction and factors such as ease of use, self-efficacy, and engagement an important role in the uptake of mobile digital learning.

The results show that, in general, the App was well accepted by the students. Most of them agree that the App should be used as a tool to be used in classes and most of them are overall satisfied with the App. While mobile learning can never fully replace traditional learning, it appears that it can increase motivation and contribute to more effective student learning. Mobile phones have come a long way from being seen as distractions in the classroom to now

being seen as tools that can help students. There are several benefits to using mobile phones as a teaching aid, including better learning outcomes, greater student engagement, and an easier ability to keep students up to date on assignments. However, as with all tools, teachers need to plan to ensure these devices are used properly in the classroom.

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