A CASE STUDY FOR THE PEDAGOGICAL EVALUATION OF THE ASYMPTOTE SYSTEM

Georgios Fesakis, Stylianos Triantafyllou, Nikolaos Tzioufas, Despoina Koutsomanoli-Filippaki and Stamatia Volika
University of the Aegean, Greece

Abstract. *This paper examines how primary students use the ASYMPTOTE system and whether it helps them overcome their misconceptions about fractions. Therefore, a case study was conducted for 6th grade students (Primary School) during their regular school schedule. The results proved that some of the students who engaged systematically with ASYMPTOTE's affordances managed to overcome, to a considerable extent, their misconceptions with the support of their teacher.*

Key words: ASYMPTOTE, mathematics teaching, primary education.

INTRODUCTION

The challenges that the covid-19 pandemic brought to the educational system (Barlovits et al., 2021; Mishra et al., 2020; Zhang et al., 2020) arose the need for the development of new learning environments that can guide the learner remotely (Flores & Swennen, 2020; Hall et al., 2020), particularly in Mathematics education, where the integration of technological means in the teaching process had been more conservative in previous years (Chronaki, & Matos, 2013). In this research, the ASYMPTOTE system (www.asymptote-project.eu), which is a modern tool for teaching and learning Mathematics remotely from primary education to university level, was studied to identify its pedagogical validation. The ASYMPTOTE system's development started on 2021 as part of the ASYMPTOTE project (Adaptive Synchronous Mathematics Learning Paths for Online Teaching in Europe), funded by ERASMUS+ KA2, with the participation of seven institutions from five European countries (Germany, Greece, Italy, Portugal, and Spain).

THE ASYMPTOTE SYSTEM

The ASYMPTOTE system consists of two components, a web portal and a mobile app (Barlovits, et al., 2022). In the web portal teachers can create their own tasks or use already existing ones from a rich task repository. The main goal for the teacher is to design organized collections of tasks, i.e., a *Learning Graph* (LG) with multiple levels of difficulty, for a specific topic of Mathematics. The web portal also contains a Digital Classroom functionality (DC) that provides the opportunity of direct communication between the teacher and the students and personalized support (Barlovits, et al., 2022). In parallel, through the app the students can browse and interact with a specific LG that the teacher assigned them on, having systematic, synchronous feedback on their entered solutions (Barlovits, et al., 2022). The mobile application is established upon gameplay elements such as a reward-based system that increases students' engagement (gamification). In this research emphasis is given on the use of the system's affordances, as described in Barlovits, et al. (2022), by the students.

Fesakis, G., Triantafyllou, S., Tzioufas, N., Koutsomanoli-Filippaki, D., & Volika, S. (2023). A Case Study for the Pedagogical Evaluation of the ASYMPTOTE System. In M. Ludwig, S. Barlovits, A. Caldeira, & A. Moura (Eds.), *Research On STEM Education in the Digital Age. Proceedings of the ROSEDA Conference* (pp. 153–160). WTM. https://doi.org/10.37626/GA9783959872522.0.18

RATIONAL AND RESEARCH QUESTIONS

The mathematics topic that was selected for this case study is fractions, mainly because it is an important part of Mathematics (Bailey et al., 2012) and a conceptual barrier for students (Gabriel et al., 2013; McMullen et al., 2015), relating to a series of common difficulties and misconceptions in Primary Education. Adopting the findings of Aliustaoğlu et al. (2018), we examined the following areas regarding fractions, in which specific misconceptions for students of 6th grade have been identified: part-whole relations, representation on the number line, comparison and operations (addition).

The aim of this research is to examine how students will use the affordances of the ASYMPTOTE system to overcome their misconceptions. In parallel, this research glances at the teacher's/researcher's difficulties on the use of the DC tool. Thus, the following research questions should be answered through this study:

(1) Which of the affordances of ASYMPTOTE do students use the most and how?
(2) To what extent did the affordances that the students used, helped them overcome their misconceptions about fractions?
(3) Which of these affordances were most useful according to the students' opinion?

METHODOLOGY

For this research, an exploratory case study (Yin, 2009) was developed using a group of students as the unit of analysis in order to study ASYMPTOTE in real classroom conditions. For the data collection, the research followed a mixed quantitative and qualitative approach. More specifically, a Pre-test and a Post-test questionnaire were used to evaluate and estimate the impact of the teaching intervention with ASYMPTOTE and a specifically designed LG on the students' learning of fractions. Also, personal interviews were conducted in combination with a Likert-scale questionnaire for assessment of the usefulness of ASYMPTOTE's affordances. The questionnaire is available here: shorturl.at/ePQ37. Finally, the video recordings of the interaction of students to the system were analyzed.

Research conditions & process

Firstly, for the design of the Pre-test and Post-test questionnaires, the tasks of the data collection tool used in the research of Aliustaoğlu et al. (2018) were implemented with minor adjustments. The test that was used in this study can be found here: shorturl.at/kwxDU.

For the teaching intervention, two LGs were designed in ASYMPTOTE's webportal, in order to support the students' learning, regarding their misconceptions in the specific areas of the fractions mentioned above. The first LG "Fractions 2" (https://www.asymptote-project.eu/de/portal-de/#!/graph/g38312) covers the part-whole relation, the representation of fractions on the number line and the comparison of fractions. The tasks included in it were adapted to the corresponding questions per section of the Pre & Post test. Since there was no previous introductory teaching in fractions, special emphasis was given to the utilization of *Support tasks*, *Hints* and *Sample Solutions*. The first LG was structured in four series of tasks (Figure 1, left) with the criterion of supporting one subject to another in a cognitive continuum. In the beginning of the LG there was an introductory *Main task* on the parts of the fraction followed by a *Main* and a *Support task* regarding the thematic "part-whole". Three tasks -*Main, Support* & *Challenge*- were also created for the comparison of

fractions, focusing on the relationship between the numerator and the denominator. To help students comprehend how the number line is divided into parts in order to place the fraction on it, one *Challenge*, one *Main*, and three *Support* tasks were created for the representation of a fraction on the number line, which was thought to be the most demanding topic.

The second LG was created to teach the topic of addition in fractions. The LG "Fractions 3.2"(https://www.asymptote-project.eu/en/portal-en/#!/graph/g35315) was structured (Figure 1, right) with the same logic of the cognitive continuity of the subjects which in this case were *Equivalent fractions, Comparison* and *Addition of fractions*. The *Comparison of Fractions* and the whole LG in general are focusing on the strategy of creating like fractions.

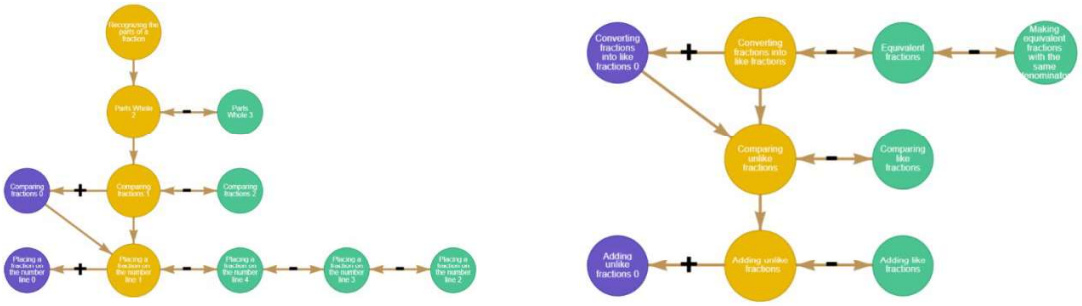

Figure 1: LG Fractions 2 (G38312) and LG Fractions 3.2 (G35315) (from left to right).

After the design of the Pre-test, Post-test, and the development of the two LGs mentioned above, five teaching hours were devoted to familiarizing the students with the ASYMPTOTE system, so that they could use all of ASYMPTOTE's affordances before the start of the teaching intervention. During this stage, three LGs were used (LGs codes: g47109, g05316 and g12319).

Participants and data collection

The case study was carried out face to face in the 6th grade of a Primary School in a suburban area of Rhodes, Greece, in a classroom with 7 students (1 boy, 6 girls). Firstly, the Pre-test was given, and the misconceptions of the students were determined. The next few days, two two-hour sessions with the LG application took place in the classroom, where the teacher/researcher was communicating with the students only through the ASYMPTOTE DC chat. The screen of both the students' devices (tablets and mobile phones) and the teacher's laptop were recorded. Detailed observation of the chat-log and the screen recordings was documented for each student to locate incidents of learning, support provision and the utilization of ASYMPTOTE's features in general. After the teaching intervention, the Post-test was filled by the students. On the same day, through personal interviews, the Likert-scale questionnaire for assessment of the usefulness of ASYMPTOTE affordances was completed.

FINDINGS

Patterns of use

The data collected from these two sessions led to the detection of two main patterns of student use of the system: a) *Using ASYMPTOTE as a learning tool* and b) *Using ASYMPTOTE as a quiz app*.

In the first category that is constituted by the majority of the students, the system is clearly used as a learning tool and the students' patterns of use exhibit signs of a learning orientation. Moreover, in this category we can distinguish two subcategories regarding the use of the learning supporting functions: a) *using Hints as the main helping tool* and b) r*esorting to asking the teacher for help through the Chat*. Students with pseudonyms ES, EA and EX, for example, followed a strategy of carefully reading the content of the tasks and prioritizing the use of *Hints*, either from the beginning, as additional information or in the event of a mistake in order to redefine their solution path. They generally acted autonomously and communicated with the teacher only in cases where the help from the *Hints* was not sufficient. For example, student EA, having completed five tasks, contacted the teacher for the first time after submitting two wrong answers, because she couldn't understand why they were wrong. In the second subcategory we have students who rely more on the help of the teacher through the *Chat* features. The students in this category seem more cautious and insecure and to avoid making mistakes, they contacted the teacher through written or voice recorded messages. EM for example, wasted valuable time on a task waiting for the teacher's response to a procedural issue that she ultimately solved on her own. However, both EM and EB subsequently started using more *Hints*, alongside communicating with the teacher.

On the contrary, in the second category, students do not show much interest in the learning part of the session but focus on using ASYMPTOTE as if it was a common knowledge quiz. For example, students EK and EP rushed through the LG without noticing the details of the tasks and chose their answers almost at random. An indication of this pointless browsing of the LG was that they didn't use the affordances of the application that aim to support the learning process, such as *Sample Solution, Hints* and the *Chat*. EP, for example, did not use any *Hint* and didn't communicate with the teacher, except at the end to declare that she was finished.

The Sample Solution

During "Session 1" of the DC almost no students paid the expected attention to the *Sample Solution* after correct or incorrect answers. An exception was student EB who seemed to carefully read the *Sample Solution* in most of the tasks as opposed to EC who hardly ever opened them. In "Session 2" however, a small increase in the use of Sample Solutions was observed.

The Give up button

During "Session 1" there were only two skipped tasks and 1 Not completed, while in "Session 2" there were 6 Skipped tasks and 10 tasks Not completed. The majority of the Not completed tasks were *Challenge tasks* (1 in "Session 1" and 8 in "Session 2"). This is due to the fact that "Session 2" was perceived as a more difficult session and because, after "Session 1", the students realized that the *Challenge tasks* were optional. In addition, we could tentatively say that the gamification function of the application didn't have the expected effect on the students of this research, who did not seem to care whether they would lose points by not completing the *Challenge tasks*.

Learning incidents

Worth noting learning incidents were identified during the analysis of the users' activity (screen recording & event logs of the system) and in some cases they indicate a shift in students' initial misconceptions. More specifically on the group of tasks included in LG Fractions 2, EA, who initially completed the first two tasks (recognizing the parts of the fraction, Parts Whole 3) without opening Hints, in the third task (Parts Whole 2) she started with an incorrect answer which forced her to open Hint 1. This led her to choose the correct answer but before clicking on the "check" button she opened and studied Hint 2, to make sure of her answer. This specific incident of learning through *Hints* was also reflected positively in EA's performance in the Post-test, where she corrected the relevant question 1c and by extension her initial misunderstanding (Figure 2). The *Hints* feature of ASYMPTOTE seems to be able to play a role of formative assessment in online learning of mathematics.

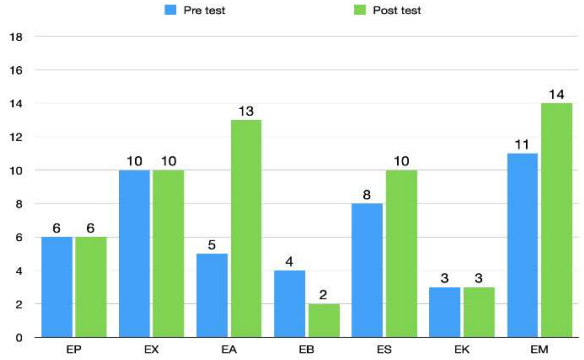

Figure 2: Pre & Post test results of each student.

Another interesting incident of learning was recorded in the task "Comparing fractions 1", where student EA gave the same wrong answer twice and as a next step, she texted the teacher for help. This dialogue followed:

EA: Mr, it tells me it's wrong but it's right, why?

TEACHER: Where, in what exercise? Tell me exactly.

EA: The third yellow.

TEACHER: You will put a letter as the answer (A or B or C or D). Pay attention, it says from the smallest to the largest.

The help from the teacher seems to have influenced the reasoning of EA, who immediately gave the correct answer. In this case EA did not use *Hints*, changing her usual practice probably because she was sure of her answer.

In "Session 2" there were noted two incidents of learning that led to an improvement in the performance of two students in the Post-test. In the first, ES, following his favorite Hints-focused usage pattern, opened the *Main task* "Adding like fractions" and gave three wrong answers. Between them he opened and studied the *Hints* again and again and then proceeded to the *Support task* "Adding like fractions". There he easily gave the correct answer and studied the *Hints* again to go back to the previous task where he opened Hint 3 once more. It seems that he was not getting sufficient help, so he gave another wrong answer. It is noteworthy that ES was intently searching for the information that would help him understand how to solve the *Main task* in the *Hints*, then turned in the *Support task* and finally again in the *Hints*. The fact that he repeatedly studied the same *Hints* and opened some of

them even after his final answer, further emphasizes this finding. Even though he failed to solve the "Adding unlike fractions" task, the information he got from this search helped him give the correct answer to question 5 of the Post-test.

In a corresponding incident, EA started with two incorrect answers from the *Support task* "Adding like fractions". The *Hint* that she then studied helped her not only to give the correct answer but also to improve her Post-test performance in questions 4a and 4b. In the *Main task* she gave four wrong answers. Between these answers, EA, as ES did, opened and studied the *Hints* many times and communicated with the teacher. The interesting fact in this incident is that EA, after the last wrong answer, in addition to the three *Hints*, studied the *Sample solution* as well. Thus, despite the incorrect answer, the learning process that followed helped EA, similarly as ES, to improve her performance in task 5 of the Post-test.

Difficulties

The usage recordings showed that the teacher/researcher encountered some difficulties while using the system. An indicative example is when student EB asked for clarification about the task "Comparing fractions 2" and the teacher mistakenly thought that EB was in the task "Placing a fraction on a number line 3" and replied accordingly. This mix-up caused confusion to the student who, after finally receiving the correct clarifications from the teacher, spent a lot of time re-reading their dialogue before understanding the information provided to her and finally giving the correct answer.

This incident highlights the difficulty for the teacher in monitoring the usage activity of all participants in a session. It is a process that obviously requires enough practice and familiarity with the application for the teacher to be able to successfully check and respond immediately to students' messages, while cross-referencing the information in the "participants" menu and the detailed usage activity in the "events-log". Given the fundamental targeting of the ASYMPTOTE project in remote learning, this is a critical feature on which a large part of each session depends. The teacher should be able to intervene easily, when necessary, with general or personal messages, in order to help the students readjust their pattern of use and overcome difficulties. Indicative is the inability of the teacher in this study to check in time the events-log of the user EP, who rushed to complete the tasks without taking into account the sporadic text messages from the teacher, such as "Anyone who needs help or explanations send me a message to help" or "Don't rush".

The usability questionnaire

Some interesting results also emerge from the usability questionnaire analysis. As seen in Figure 3, which presents the sum of all students' choices, the features *Support tasks*, *Hints*, *LG map*, *Recorded messages*, *Interface*, and *Gamification* stand out higher in students' preferences, while the *Challenge tasks*, *Sample solution*, *Written messages*, *Picture messages*, and *Live snapshot*, got a lower grading by the students.

In more detail, it seems that the students in this study consider the *Support tasks* more useful than the *Main* and C*hallenge tasks*, as expected. Regarding the other help functions, *Hints* outperformed the four chat communication options (8a to 8d), but *Recorded messages* were the most popular teacher communication option. The students don't seem to consider the *Sample solution* as a very useful feature as it gained one of the lowest scores. EB and EA users,

however, rated this feature with a 5 on the Likert scale which is consistent with the observations recorded from the usage activity analysis above. On the contrary, it is noteworthy that while no interest was observed in the *Gamification* function from the usage activity, the students' opinion of its usefulness was very positive. Finally, a particularly useful illustration, according to the users of the study, was the *map of the LG*, and the overall *Interface* of the application.

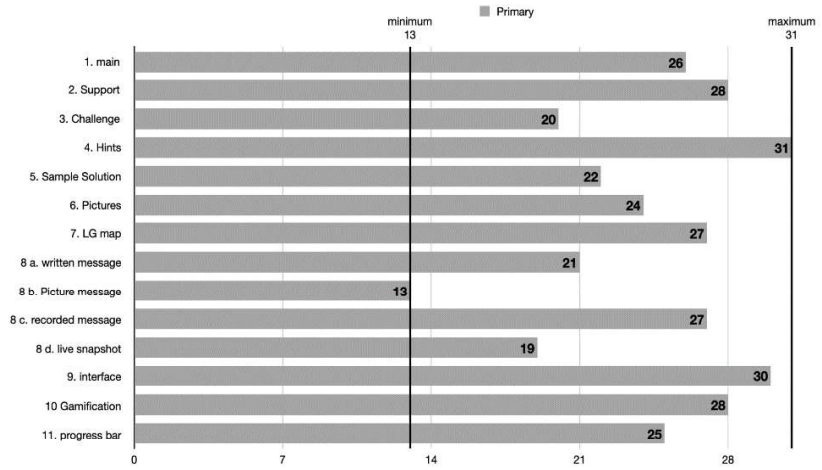

Figure 3: Results of the usability questionnaire.

CONCLUSION

In this research, a case study was developed to examine how students will use the affordances of the ASYMPTOTE system to overcome their misconceptions regarding fractions which is a challenging topic in mathematics education (Aliustaoğlu et al, 2018; Bailey et al., 2012).

As shown by the results of the usage analysis, *the students utilized more the following affordances of the ASYMPTOTE system*: the *Hints*, the *Chat* feature and the *Support tasks.* This finding also corresponds to the higher grade they gave to these features on the usability questionnaire. Regarding *the extent to which the system' affordances helped them overcome their misconceptions about fractions*, it was found from the students' Pre and Post test results that although there was not a significant improvement in overcoming their misconceptions, however, in the cases of students who did better on the Post-test, the LG design and ASYMPTOTE's affordances played a crucial role. Finally, *according to the students' opinions, the most useful affordances were* the *Support tasks*, the *Hints*, the *LG map*, the *Recorded messages*, the overall *Interface of the app* and the *Gamification* aspect of the system. Their preferences were in line with the way they used the app, with the only exception being the *Gamification* aspect, since in both sessions the students didn't pay attention to the grading system and especially in "Session 2" they didn't make an effort to solve the *Challenge tasks*.

To conclude, the data collected from this study indicate that students consider most of ASYMPTOTE's affordances useful. The DC can be used to support fruitful interactions among the teachers, the students and the LGs resulting in quality learning and misconception overcoming even in hard topics such as the fractions in primary education. Regarding the pedagogical validation of the ASYMPTOTE system, the presented case study provides supporting evidence that the system supports the key requirements for effective teaching

and learning during Emergency Remote Teaching that are mentioned in Barlovits et al. (2022) such as Personal interaction and Formative assessment. However, it is important to note that the sample of this study is too small to generalize and, since the system is still under development, further studies need to be conducted.

Acknowledgment

The ASYMPTOTE project is co-funded by the European Union as part of the Erasmus+ Strategic Partnership Programme (DAAD; grant no. 2020-1-DE01-KA226-HE-005738).

References

Aliustaoğlu, F., Tuna, A., & Biber, A. Ç. (2018). The misconceptions of sixth grade secondary school students on fractions. *International Electronic Journal of Elementary Education*, *10*(5), 591–599.

Bailey, D. H., Hoard, M. K., Nugent, L., & Geary, D. C. (2012). Competence with fractions predicts gains in mathematics achievement. *Journal of Experimental Child Psychology*, *113*(3), 447–455.

Barlovits, S., Caldeira, A., Fesakis, G., Jablonski, S., Koutsomanoli Filippaki, D., Lázaro, C., Ludwig, M., Mammana, M. F., Moura, A., Oehler, D.-X. K., Recio, T., Taranto, E. & Volika, S. (2022). Adaptive, Synchronous, and Mobile Online Education: Developing the ASYMPTOTE Learning Environment. *Mathematics, 10*(10), 1628.

Barlovits, S., Jablonski, S., Lázaro, C., Ludwig, M., & Recio, T. (2021). Teaching from a Distance—Math Lessons during COVID-19 in Germany and Spain. *Education Sciences, 11*(8), 406.

Chronaki, A., & Matos, A. (2013). Technology use and mathematics teaching: Teacher change as discursive identity work. *Learning, media and technology*, *39*(1), 107–125.

Flores, M.A., & Swennen, A. (2020). The COVID-19 pandemic and its effects on teacher education. *European Journal of Teacher Education*, *43*(4), 453–456.

Gabriel, F., Coche, F., Szucs, D., Carette, V., Rey, B., & Content, A. (2013). A componential view of children's difficulties in learning fractions. *Frontiers in Psychology, 4*, 715–712.

Hall, T., Connolly, C., Ó Grádaigh, S., Burden, K., Kearney, M., Schuck, S., Bottema, J., Cazemier, G., Hustinx, W., Evens, M., Koenraad, T., Makridou, E., Kosmas, P. (2020). Education in precarious times: a comparative study across six countries to identify design priorities for mobile learning in a pandemic. *Information and Learning Sciences, 121*(5/6), 433–442.

McMullen, J., Laakkonen, E., Hannula-Sormunen, M., & Lehtinen, E. (2015). Modeling the developmental trajectories of rational number concept(s). *Learning and Instruction*, *37*, 14–20.

Mishra, L., Gupta, T., & Shree, A. (2020). Online teaching-learning in higher education during lockdown period of COVID-19 pandemic. *International Journal of Educational Research Open*, *1*, 100012.

Yin, R. K. (2009). *Case study research: Design and methods (Applied Social Research Methods)* (4th ed.). Sage.

Zhang, W., Wang, Y., Yang, L., & Wang, C. (2020). Suspending classes without stopping learning: China's education emergency management policy in the COVID-19 outbreak. *Journal of Risk and Financial Management, 13*(3), 55.