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ASYMPTOTE THEORETICAL BACKGROUND

Teaching and learning mathematics online

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ASYMPTOTE Theoretical Background

ASYMPTOTE (Adaptive Synchronous Mathematics Learning Paths for Online Teaching in Europe) is an Erasmus+ KA226 – Strategic Partnerships for Digital Education Readiness project co-funded by the European Union (grant no: 2020-1-DE01-KA226-HE-005738). Institutions from Germany, Greece, Italy, Portugal and Spain work on this project until February 2023. Project website: http://asymptote-project.eu/

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ASYMPTOTE Theoretical Background

SUMMARY: The aim of the Theoretical Framework is to introduce ASYMPTOTE and explore its potential implementations in Mathematics education. In this process: The continuum of educational settings is introduced, the role of the teacher in Technology Enhanced Learning concepts is defined, and ASYMPTOTE's uses in the various educational settings are described. Moreover, online pedagogy theoretical frameworks such as the Community of Inquiry and mobile learning pedagogy are presented as the base to the identification of the pedagogical model specifically designed for ASYMPTOTE. Briefly outlined are also learning design principles and online teaching and feedback strategies. Lastly, the technical characteristics of the system are presented and more specifically the sequencing of tasks, the Learning graph construction and the adaptivity features of ASYMPTOTE.

KEYWORDS: Mathematics education, Technology Enhanced Learning, online pedagogy, Community of Inquiry, mobile learning, task design, learning graph, adaptivity.

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Chapter 1. Teaching and learning with ASYMPTOTE in the continuum from face to face to online education

Aim

The aim of this chapter is to introduce ASYMPTOTE and explore its potential implementations in Mathematics education. In this process:

- educational settings will be elaborated as a continuum from face to face to online teaching and learning
- the concepts of Technology Enhanced Learning will be presented and analysed, while clarifying the definition of mobile learning.
- the role of the teacher in Technology Enhanced Learning concepts will be defined and the case of ecoshock when moving to online teaching will be briefly outlined.

Key Competencies and Skills

In this chapter you will have the opportunity to learn about face to face Technology Enhanced Learning, Blended Learning, and Online Learning concepts.

- You will explore ASYMPTOTE's possibilities and the ways it can be incorporated in the concepts of Technology Enhanced Learning.

Keywords

ASYMPTOTE, Technology Enhanced Learning, Mathematics education

1.1 Introducing ASYMPTOTE

Corona pandemic brought major challenges to the educational system (Barlovits et al., 2021; Mishra et al., 2020; Zhang et al., 2020). Both teachers and students had to adapt to a new reality since teaching and learning were conducted, for a long period of time, mostly remotely, synchronously and/or asynchronously (Barlovits et al., 2021; Mishra et al., 2020; Zhang et al., 2020).

This crisis forced teachers, all around the world, to restructure their teaching processes, basing them mainly on digital media and the Internet (Crompton et al., 2021). They had to adjust and find solutions to overcome rising problems (Aldon, Cusi et al., 2021), maintaining the continuity in education, in its new form (Hall et al., 2020). In parallel, students and parents were also challenged, as many of them didn't have the experience or/and the means to adjust to this sudden technologically driven change (Agostinelli et al., 2020). The new reality required a high degree of students' self-organization and self – management, which for many was not an easy task. The above resulted in an increase in learning gaps and inequality (Agostinelli et al., 2020).

The difficulties mentioned above were also evident in Mathematics education, where the integration of technological means in the teaching process was more conservative, in the previous years (Chronaki, & Matos, 2014). In a recent study that was conducted by Barlovits et al. (2021), Mathematics teachers from Germany and Spain, reported that some of the problems they faced during the shift in educational processes due to Covid-19, were pertaining to the technical equipment, feedback, lack of personal contact and assessment. Especially the lack of personal contact was reported as a main challenge from teachers in Spain.

On the positive side, these new challenges inspired half of the teachers, in the study mentioned above, to integrate more digital tools and media in their teaching process, after returning to the classrooms (Barlovits et al., 2021). Specifically, teachers in Germany, reported an increase in the digitalization of educational materials and the use of learning software and platforms, while more than half of the teachers in Spain, mentioned an increase in the use of digital media in their math lessons, outlining the importance of learning platforms (Barlovits et al., 2021). As it seems, the sudden need of integrating technology in the educational processes, due to Covid-19, formed new patterns and introduced new practices in Mathematics education.

ADDITIONAL READING MATERIAL

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.

This new reality in Mathematics, and the already mentioned problems that the pandemic arose, inspired the formation of the ASYMPTOTE project. ASYMPTOTE stands for "**A**daptive **SY**nchronous **M**athematics learning **P**a**T**hs for **O**nline **T**eaching in **E**urope" and was created in an effort to cover deficiencies of remote learning in Mathematics education (Barlovits et al., 2022), like the lack of personal support and direct feedback and the increased consequential self-organization.

The technical starting point of the ASYMPTOTE project has been the already existing and successfully used MathCityMap (MCM) system. MCM has been developed at Goethe University Frankfurt as a system for experiencing mathematical trails (Ludwig, & Jablonski, 2019). The ASYMPTOTE project adapted the MCM system to meet the new challenges of distance learning. It transformed the concept of straight outdoor learning trails into a concept of branched, adaptive online learning graphs. The ASYMPTOTE system consists of a web portal and an app. Both are available free of charge and are GDPR-compliant. The ASYMPTOTE app runs on Android and iOS mobile devices.

ASYMPTOTE's design aims mainly to enable teachers to conduct synchronous and adaptive online teaching and learning processes in Mathematics. Here, students need only a smartphone or tablet and an internet connection, minimizing participatory barriers. The web portal provides access to a repository of tasks, including task formulation, hints, and sample solution, on different learning topics for primary, secondary and university level Mathematics. Tasks in ASYMPTOTE are divided into 3 broad categories regarding their focus: training, reasoning, modelling (more in chapter 3.5)

Through the web portal teachers can search for, and select existing tasks, or create their own in order to design a task sequence with multiple levels of difficulty, for a specific topic of Mathematics - or a learning graph as it is called in ASYMPTOTE (more in chapter 3.5). Concurrently, the students through the app will be able to see the available tasks that the teacher has set for them and go through them, having systematic, synchronous feedback on their entered solutions. Meanwhile, the reward-based system applied, facilitates students' engagement, and puts the app in the gamification spectrum of education.

Moreover, ASYMPTOTE provides a Digital Classroom mode that offers the possibility of direct communication between the teacher and the students and between groups of students assigned by the teacher. One of the main challenges in self-guided distance learning is the possibility to provide individual feedback as a teacher. Larmann et al. (2021) showed that students using MCM with distance education tasks (MCM@home) used the chat to ask the teacher content questions without prior initiation. This observation highlights the importance and acceptance of this communication channel. Based on these experiences made with the MathCityMap system, ASYMPTOTE offers a teacher-student chat, too. Concerning the different types of feedback, the chat allows teachers to make valuable evaluative and explanatory comments (Hattie, 2007; Larmann, et al., 2021) in a synchronous online environment.

Moreover, in the MathCityMap chat, teachers missed the possibility for communication among the students (Larmann, et al., 2021). This finding is in line with CoI (see Chapter 2.1) and highlights the importance of student collaboration in online environments. Since using a messenger app in school to communicate raises data protection issues and would harm the workflow and concentration, the Digital Classroom chat is developed to a point where it covers all necessary communication among students to work on a LG successfully. This so-called teamwork mode involves setting up a group chat for synchronous and text-based interaction to support collaborative task processing, discussion, and reflection (Barlovits et al., 2022). It includes the support of images/screenshots and voice messages, as well as chatting in predefined teams with the teacher.

The Digital Classroom can also be viewed as an assessment tool for the teacher, because it monitors students' progress through the display of events. The Digital Classroom offers both an individual progress display and a class overview. While the first feature is useful for retracing the student's individual work progress, the second feature can give the teacher insight into which tasks are the most challenging for the learners etc. Consequently, it provides the possibility for the teacher to elicit the student's success in completing the tasks even at a distance. In addition, the Digital Classroom monitoring system helps to prioritize follow-up discussion of tasks, e.g., via videoconferencing, thus assisting teachers in organizing fruitful discussion

These possibilities allow teachers to provide individualized support to the student in the sense of formative assessment (Black & Wiliam, 2003). The system provides user interaction data for an effective monitoring and evaluation of students' progress, rendering the design process easier for the teachers who can design learning graphs, with tasks adopted to each students individual learning progress. Thus, the system further allows assessment and the use of adaptive elements in online learning. Lastly, to facilitate learning for students with disabilities, a read-out-loud mode and a zoom function are available. All the available tasks in the system are translatable in various languages which helps bridge language barriers, by facilitating teachers from around the globe to translate and use tasks into their language, and by enabling foreign students who are still learning the language to solve tasks in their mother tongue.

Note: All tasks and learning graphs created by the project's team will be available in English, German, Greek, Italian, Portuguese and Spanish.

ADDITIONAL READING MATERIAL

Barlovits, S., Kolokytha, A., Ludwig, M., Fessakis, G., (2022). *Designing mobile environments for mathematics distance education: The theory-driven development of the ASYMPTOTE system.* Accepted for publication at the Congress of European Research in Mathematics Education 2-5 FEB 2022-CERME12, https://www.cerme12.it.

ASYMPTOTE's features can be utilized in almost any teaching and learning setting that encompasses technology. From face to face to blended and online learning, ASYMPTOTE can be an asset for both teachers and students. Thus, ASYMPTOTE can be placed in the concepts of Technology Enhanced Learning.

DEFINITION

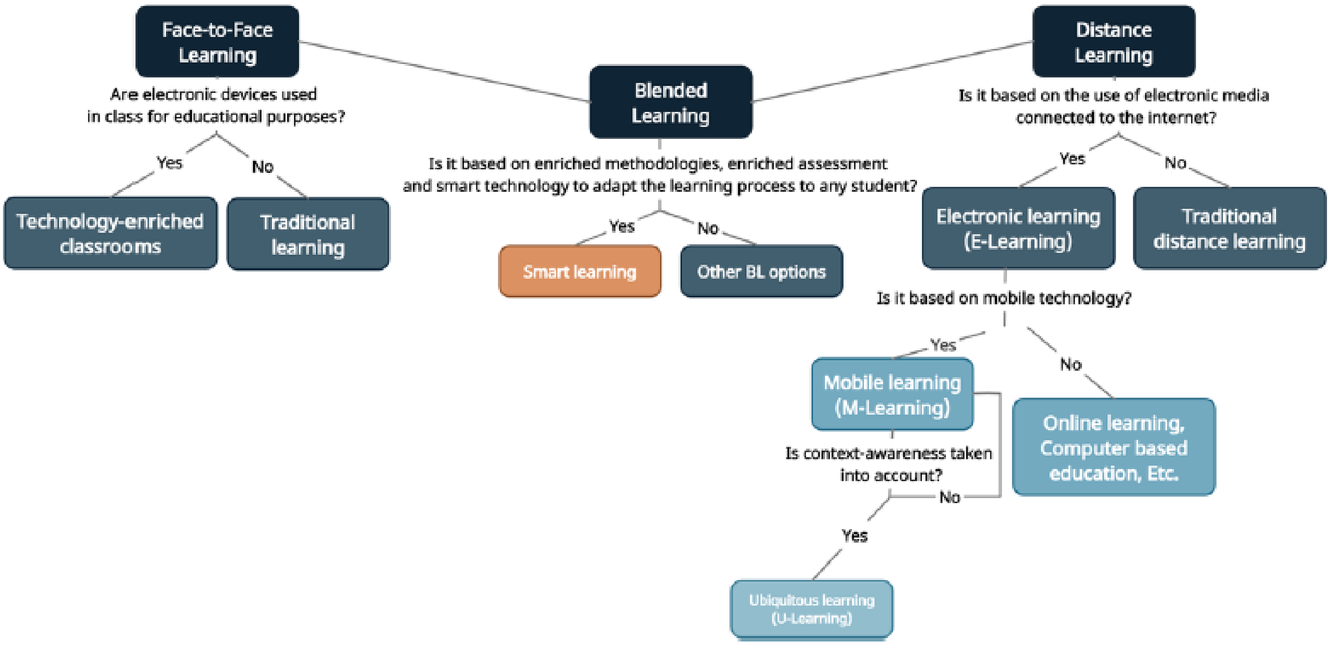
Technology Enhanced Learning – TEL, in the current context, is used to describe the applications of technology in education that aim at improving the processes of teaching and learning.

To fully understand the potentials of using ASYMPTOTE, the concepts of Technology Enhanced Learning need to be analysed, while taking into perspective the role of the teacher and the difficulties that they can face when shifting from a traditional face to face to a Technology Enhanced, blended or fully online instruction. This chapter will attempt to shed light on the different technology supported educational settings as a continuum, where technology can be seen as a medium for an enhanced face to face education; or a complementary tool for blended methodologies; and finally, as the main instrument that can support education by developing the communication and information processes in an online educational concept (García-Tudela et al., 2021; Tikhomirov et al., 2015).

1.2 The continuum of educational settings

In all education processes, technology has been used to enhance teaching and learning in many ways, throughout the years (Cakir et al., 2009). The different uses of technology in education result in a wide range of pedagogical possibilities (Redmond, 2015). García-Tudela et al. (2021), in their paper, present the following conceptual map (Figure 1.1) that describes the key existing concepts of Technology Enhanced Learning. This map can facilitate the understanding of the theoretical exposition around key concepts related to the educational use of technology.

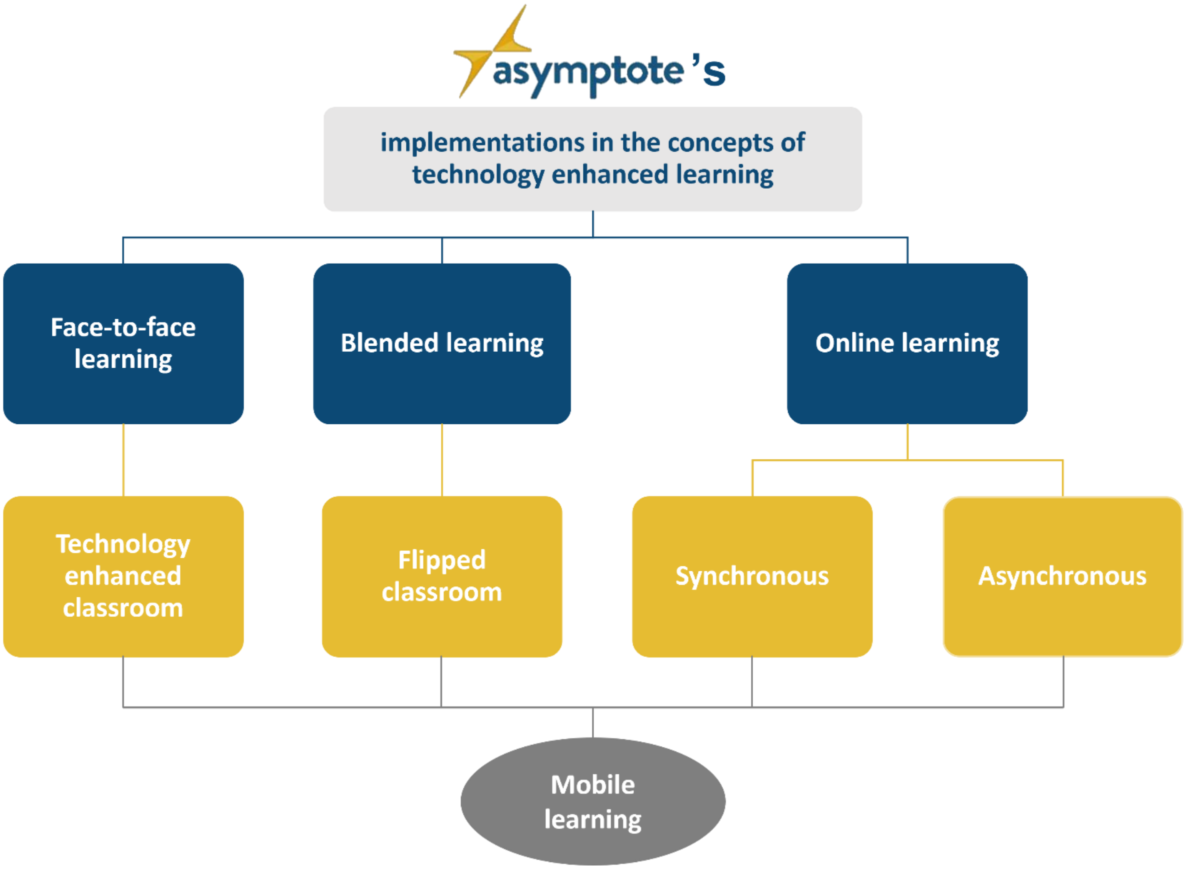
Figure 1.1. Key concepts of Technology Enhanced Learning García-Tudela et al. (2021)



As it's shown in Figure 1.1, the concepts of Technology Enhanced Learning differentiate from the way and the degree of the use of technologies. The range is wide and includes a) the use of digital technologies for the enrichment and the implementation of the educational processes while implementing education mainly face to face e.g. in the traditional classrooms, b) the combination of traditional and online processes with a mixed approach (blended model) and c) delivering education exclusively online in synchronous and asynchronous forms.

Considering ASYMPTOTE's settings briefly described above, and García-Tudela' s et al. (2021) conceptual map, it's evident that the system lies on all three main concepts of Technology Enhanced Learning: face to face, blended and distance. In order to highlight ASYMPTOTE's possible implementations and finally analyse its settings through all of the educational concepts, the following figure was created (Figure 1.2).

Figure 1.2. ASYMPTOTE's implementations in the concepts of Technology Enhanced Learning



It's apparent that Figure 1.2 shows many variations regarding García-Tudela' s et al. (2021) conceptual map. The decision to eliminate many of the main concepts' branches was made to accommodate the aim of this chapter. It didn't seem purposeful to analyse all the possible variations of the main concepts of Technology Enhanced Learning and as a result the focus was eliminated to the most common and broader practices of each one of them.

Another differentiation can be noticed in the replacement of the term distance learning with online learning. Distance learning is a broader term that can refer to both online learning and older forms of education such as correspondence-based courses that take place via the postal service (Keegan, 2005; Pregowska et al., 2021). Online learning on the other hand is more specific and it refers to educational processes that use the internet as the main multimodal communication medium. In the literature, online learning has been outlined as a special case of distance learning, regarding the access to educational opportunities, the flexibility, and the interactivity (Moore et al., 2011).

Lastly, mobile learning here is considered as a concept of Technology Enhanced Learning that is parallel to the different learning concepts of the continuum. The advancement in mobile technology and generally portable devices slowly offsets the once prominent desktop computer (Meletiou-Mavrotheris et al., 2015). Mobile technologies' capabilities offer a new dimension to curriculum, making learning accessible anywhere, anytime (Handal et al., 2016). Consequently, mobile learning will be perceived as a quality factor that can be combined with every aspect of the learning continuum and may transform it drastically (Meletiou-Mavrotheris et al., 2015) (see D. Mobile learning).

A. Face to face Technology Enhanced Learning

The basic idea of this concept is the connection of traditional face to face teaching with digital tools, in order to improve the education process. At the centre of the program is still the typical face to face teaching and the digital tools and environments are being used in parallel – delivering additional educational material, such as assessment tools, task delivery systems, inquiry instruments, mindtools to construct knowledge etc. The main characteristics of a face to face technology enhanced classroom are (Roblyer, 2006):

- All the meetings occur face to face
- The use of digital tools aims to enrich and leverage the education process
- Educational material is a mix of traditional and digital, and can be provided through the world wide web
- Online communication and support are possible
- Tasks and activities can be implemented online

As Redmond (2015 p. 108) states in Technology Enhanced Learning *"information and communication technology (ICT) is used within face to face classes, or the web might be used to post written information also provided in the face to face class".* A common example of this type of use is a teacher's website/blog.

ACTIVITY

Design your own face to face Technology Enhanced Learning instruction for a specific mathematics topic. In what way can Asymptote's features (see page 3-4) foster the chosen instructional design?

B. Blended learning

The second concept of Technology Enhanced Learning is called blended learning and combines the traditional, face to face instruction with online learning processes (Osguthorpe & Graham, 2003). Blended learning environments are based on the construct that by combining traditional face to face and online learning, the instruction strengthens and student achievements and satisfaction increase, hence improving student learning (Cakir et al., 2009). Thus, the term blended learning refers to a Technology Enhanced Learning environment where the curriculum, the teaching materials, and the assessment methods are centrally developed, delivered and implemented both online, and face to face (Delialioglu & Yildirim, 2007).

The main characteristics of a blended learning concept are (Delialioglu & Yildirim, 2007):

- Recurring meetings in person
- 30% to 79% of the course is provided online (Allen & Seaman, 2013)
- Online communication and support are important.
- Learning material are provided online
- Activities and assignments are conducted off and online

B.1. Flipped classroom

One of the most popular sub-models of Blended-Learning is Flipped Classroom (FC) (Staker & Horn, 2012). The main idea behind this pedagogical approach is to transfer the centre of the teaching-learning relationship from the educator to the students. The educator-centred part of teaching that used to take place in class is now accessible at home, mostly by instructional videos, therefore space and time in class session are maximised to implement more activating learning methods (Bergmann & Sams, 2012; EDUCAUSE, 2012; Estes et al., 2014; Tucker, 2014).

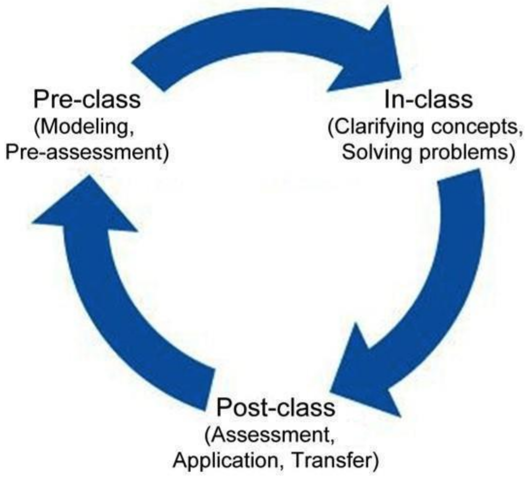
DEFINITION

Bishop and Verleger (2013, p.5) define Flipped Classroom as *"an educational technique that consists of two parts: interactive group learning activities inside the classroom, and direct computer-based individual instruction outside the classroom".*

In one of the most common models of FC, Estes et al. (2014) include three general stages in a circular continuous format:

- Pre-class
- In class and
- Post-class stage (Figure 1.3).

Figure 1.3. The stages of flipping a class (Estes et al., 2014)



Pre-class stage mostly consist of instructional and assessment material, such as short video-lectures, online exercises or quizzes, and some sort of online support (hints, discussion, comments, messages etc). The face to face part of FC is the In-Class stage, in which activities with interaction and collaboration are taking place in order to explore in depth topics and clarify misunderstandings. In the third stage (post-Class) the main goal is to assess, apply or transfer various learning contexts of what has been accomplished by the students in the previous stages (Estes et al., 2014; Lo et al., 2017).

ADDITIONAL READING MATERIAL

Lo, C. K., Hew, K. F., & Chen, G. (2017). Toward a set of design principles for mathematics flipped classrooms: A synthesis of research in mathematics education. Educational Research Review, 22, 50-73.

ACTIVITY

Design your own FC model for a specific mathematics topic. In what way can Asymptote's features (see page 3-4) foster each stage of the circular continuous format described above (see Figure 1.3)?

C. Online learning

Online learning is the education process that is implemented entirely using Computer Mediated Communication means and Information and Communication Technologies (ICT) tools and applications. As Nichols (2003, p. 4) states *"The fundamental applications of online learning include digital materials storage and distribution and synchronous and asynchronous communication, simulative interactivity, multimedia, and access tracking (processes) – each of which is subject to multiple applications of use and innovation".* Its main characteristics are (Allen & Seaman, 2013):

- The instructions are solely online
- Communication and support occur only remotely though the internet (synchronously and/or asynchronously)
- Learning material, activities, assignments, and assessment are provided exclusively online
- Digital tools are the main instrument of the instruction

C.1 Synchronous

In this variation of online learning, teaching takes place in real time. In other words, at the same time, all stakeholders are connected on the same platform. The place of each participant differs; however, the time is common to all. Commonly used tools for synchronous online learning are (Finkelstein, 2006):

- Text-Based Tools
- Live Audio and Video Tools
- Content, Display, and Other Interactive Tools

The most widespread form of synchronous online learning is videoconferencing. During the Covid – 19 pandemic the synchronous online learning concept was one of the forms of teaching and learning for schools all around the world (Barlovits et al., 2021; Mishra et al., 2020; Zhang et al., 2020)

When talking about synchronous interactions, the first thing that comes to mind is face to face real time interactions, but the major competencies of face to face learning are also carried out by synchronous, online learning environments (Finkelstein, 2006):

- Teaching: The pedagogical methods and approaches that can apply in a synchronous online teaching are the same as any offline educational setting (Finkelstein, 2006).
- Collaboration: A key element to the success of an online learning environment (Conrad & Donaldson, 2004).
- Support: Crucial element for retaining and motivating learner (Finkelstein, 2006)

- Socialization and informal exchange: Very important elements that are difficult to quantify. As Finkelstein (2006, p. 4) states "*Interactions in this realm often dispense with formality and can even be short of substance, yet without them a crucial foundation on which to build instructional activities is lacking*"

C.2 Asynchronous

In contrast to the synchronous variation, in this concept the educational process takes place in a flexible time and place. Specifically, the participants, following their personal program, choose the time as well as the pace they will study the educational material. The flexibility that asynchronous online education offers an example of how people can be given more possibilities on self-education and self-construction of knowledge (Nichols, 2003; Papachristos et al., 2010). Online learning tools used in asynchronous education can become the means to encourage students to further explore topics on their own and take ownership of their learning (Nichols, 2003).

The asynchronous education process is carried out online, using electronic tools, digital educational material, and resource repositories. Commonly used tools for Asynchronous online learning are Learning Management Systems, Audio and Video Tools etc.

DEFINITION

Learning Management System (LMS) is a collection of eLearning tools available through a shared administrative interface. A LMS can be thought of as the platform in which online courses or online components of courses are assembled and used from (Nichols, 2003).

ACTIVITY

Design an online instruction with synchronous and asynchronous aspects for a specific mathematics topic. In what way can Asymptote's features (see page 3-4) foster the chosen instructional design? Where could you find or how could you develop your own tutorial material?

D. Mobile learning

As a result of the popularity of mobile learning, in recent years there has been a huge growth of Mobile learning research across all sectors of education, in which the definition of the term differs (Winters, 2007). Perspectives on mobile learning, are summarised in the following broad categories according to Winters (2007):

i. Technocentric: This is the most common perspective in the literature where mobile learning is defined as learning using a mobile device.
ii. Relationship to online learning: This perspective defines mobile learning through its link to online learning, as a more flexible delivery medium, while lacking in the characterization of its distinctive nature.
iii. Enhancing traditional education*:* This perspective defines mobile learning through its link to formal education and its use as an enriching tool*.*
iv. Learner-centred: In this perspective the focus shifts from the device and centres on the mobility of the learner. As O'Malley et al., (2005) state mobile learning is "*…any sort of learning that happens when the learner is not at a fixed, predetermined location, or learning that happens when the learner takes advantage of the learning opportunities offered by mobile technologies*" (O'Malley et al., 2005, as cited in Winters, 2007).

The main debate among scholars, concerning the definition of mobile learning, is related to the mobility of both technology and learning itself (Sönmez et al., 2018). In this construct, Yamamoto' s (2013) mobile learning definition will be adopted merely because it links those two perspectives.

DEFINITION

According to Yamamoto (2013, p.16) "*Mobile learning is a technological infrastructure that removes the barriers on accessing information in learning (e.g., teachers, time, space, and resources), it is an interactive method of learning which offers personal, social and contextual learning opportunities, which can be offered anywhere without breaking apart from life. These opportunities", Yamamoto adds, "are offered in real/virtual environments with various mobile instruments that can provide learning material and enriched multimedia, while placing the student in the centre of the learning process*".

Even from the different definition approaches of the term, it's evident that mobile learning can be linked to many Technology Enhanced Learning settings. From face to face (i, iii) to online learning (ii, iv) the range and variety of implications, set mobile learning as an education process that can be linked and applied to each of the three main technology enhanced concepts that have been presented above.

1.3 Teacher roles

The application of digital technologies in education even though it can enhance teaching and learning, also alters the educational processes in many ways. This change results in a role shift for the teacher (Redmond, 2015). The shift can become clear if one considers the dramatic change that the transition from traditional face to face towards technology enhanced, blended and fully online teaching, has on a teacher's practices. From an educational setting where they mainly disseminate information, they transit to designing a learning environment where students co-construct knowledge (Vaughan, 2010).

In any technology enhanced concept, it is important for the teachers to understand their role and support their teaching with effective practices. The pedagogical approaches adopted, should allow students to make decisions about what, how, and when they need to learn. In this lengthy process, teachers' role is the key to creating and maintaining students' engagement, relationships, inquiry, and intervention along the learning process, as well as a deep understanding of how technology can and is going to enhance the teaching and learning process.

Researchers from the University of Birmingham (n.d.) suggest that a teacher should:

- Establish academic and behavioural rules, roles, and responsibilities for the participants.
- Articulate how technology tools will be used and for how long.
- Define the conditions under which students will receive whole-group, small-group, and one-on-one instruction.
- Set expectations regarding the evidence students must provide of their learning and parameters for asking for help from the teacher and their peers.
- Establish standards for acceptable and unacceptable work.
- Define the behaviours that will and will not be tolerated.
- Articulate the support that is available and under what conditions the participants can obtain it.

These teacher's responsibilities although very significant are mostly procedure-oriented and refer to the guidelines that form an instruction. On a more pedagogical note, Palloff & Pratt (2003) define: flexibility, collaboration, the ability to learn from others and the ability to share control with the participants, as the main characteristics a teacher should have.

On the same note, Berge (1995) identified four main roles an online teacher has: **pedagogical, social, managerial, and technical**. In more detail, the **pedagogical role** regards the clear definition of objectives, providing feedback, exploring different perspectives, encouraging participation, and questioning. The **social role** of the teacher helps them create an environment that helps participants trust and support their peers, while being able to challenge each other in a respectful manner. As Berge (1995) states the goal of this role is to create a *"cohesive learning community".* The managerial role includes all the "*organisational, procedural,"* and "*administrative tasks".* This role includes the designing and circumscribing phase of the instruction, where the objectives and the timelines are set, the content is formed, and all the rules and routines are introduced. Lastly, the **technical role** of the teacher revolves around the technological tools and media involved in the educational process. The goal of the teacher is to encourage and support the participants in order to make them comfortable with the technology that is incorporated in the instruction. As Berge (1995) states *"the ultimate technical goal for the teacher is to make the technology transparent".* Overall, the general nature and the importance of each one of these roles could make them valuable in any technology enhanced educational concept and not only in online learning as Berge originally stipulated them for.

Serdyukov (2015) identified three main types of teachers in online environments: **Leaders**, **Facilitators** or **Mediators**. These types can be observed, with some variations, in most teachings from traditional face to face to online. The first type of teacher, **Leaders**, are the ones who lead the educational processes and are excessively active throughout the teaching process. In the second type, **Facilitators**, the teachers are more passive. They mostly respond to participants' questions and provide support when needed. The third and final type, **Mediators**, is defined as artfully active throughout the teaching. They are on a par with the participants, engaging and interacting but without direct management (Serdyukov, 2015).

As stated above, an effective teacher should allow participants to make decisions about their learning, while increasing their engagement, collaboration, inquiry, and involvement. From this, it is evident that the preferred type of teacher in all Technology Enhanced Learning concepts is the Mediator.

ADDITIONAL READING MATERIAL

Berge, Z. L. (1995). Facilitating computer conferencing: recommendations from the field. Educational Technology & Society, 15 (1), 22–30

Ecoshock

Introducing technology in educational processes results in an increase of pedagogical and methodological possibilities that are available for the teacher to use. In parallel learners may be unfamiliar with the technologies that are incorporated in the teacher and/or with the new process itself. These new conditions can result in ecoshock.

Learners or teachers new to online processes experience challenges that are similar to those faced by people who travel and interact with different cultures. In both cases the person feels vulnerable, when experiencing the unknown (San Jose, & Kelleher, 2009). Ecoshock is the physiological and psychological reaction to a new, diverse, or changed ecology and it affects the quality of experience, performance and motivation (Fontaine, 2000). For example, the unfamiliarity of the new technologies can affect the participant's motivation and confidence to complete a task. Simultaneously, the teachers may struggle with the lack of physical presence, the difference in preparing and presenting the educational content, and the new communication methods etc. Each individual's adaptation to the new ecology is different and it is related to their previous experiences. Regardless of the symptoms and their severity, in order to develop the necessary skills, one needs to continue interacting with the new ecology (course, task etc.) (San Jose, & Kelleher, 2009).

1.4 Teacher standards

The existing phenomenon of ecoshock, in combination with the sudden changes in the educational processes that the pandemic brought, increased the need for guidance on how to best design and deliver effective online courses. As a result, emphasis has been given on the development of standards for online teaching, to both assess quality instruction and guide development efforts in course design. On that note, EU's Digital Education Plan, on action 7 specifically states that by September 2022, the Commission will have developed common guidelines and standards to help teachers and educators, promote digital literacy and address disinformation through education and training.

DEFINITION

Standards for online teaching, refer to the roles, characteristics, competencies, and skills required for a competent and successful online teacher (Albrahim, F. A., 2020)

Competencies for online teaching have been categorized at different levels in the literature, and several approaches have been adopted to classify them. Albrahim, F. A. (2020), states that the categories that are more frequently displayed and have received more focus in a larger number of studies in the literature are: pedagogy, technology, design, content, management and institutional, communication and social. This result is compatible with Technological Pedagogical Content Knowledge (TPACK), according to which, effective teaching with technology occurs when teachers have a body of knowledge that resulted from a complex interaction among the knowledge of content, pedagogy, and technology (Koehler et al., 2013). Albrahim' s F. A. (2020) categorization of competences is also in line with the standards for online teaching, set by many international bodies, such as National Standards for Quality (NSQ), Quality Matters Rubic Standards (QM), Virtual Learning Leadership Alliance (VLLA), @One, North American Council for Online learning (NACOL), International Association for K-12 online learning (iNACOL), OAKS History Cohort, Idaho State Department of Education and more.

ADDITIONAL READING MATERIAL

Goodyear et al. (2001) identify eight roles for an instructor in online teaching: researcher, content facilitator, technologist, designer, manager or administrator, process facilitator, advisor or counselor, and assessor.

Based on the review of the above, the most commonly used standards for each category are summarized below:

Pedagogical skills

- The online teacher supports learning and facilitates presence (teacher, social, and learner) with digital pedagogy.
- The teacher knows, understands, and applies to their teaching the value of active learning, participation, and collaboration within the online classroom.
- The online teacher motivates students and shows enthusiasm and interest, while encouraging knowledge construction based upon learners' prior knowledge and life experience.
- The online teacher personalizes the learning process based on the learner's diverse academic, social, and emotional needs, while incorporating accommodations into the online environment.
- The online teacher understands how students learn and develop, and provides opportunities that support their intellectual, social, and personal development.

- The teacher ensures that course material is accessible to student with disabilities.

Technological Skills

- The teacher effectively uses a range of technology tools existing or emerging - both within and outside of the Learning Management System - that support student learning and engagement in the online environment.
- The online teacher understands the learning and teaching capabilities and limitations of these tools.
- The online teacher demonstrates competencies in creating and implementing assessments in online learning environments in ways that ensure validity and reliability of the instruments and procedures.
- The teacher knows and understands methods for collecting data regarding student learning and uses this data to modify instructional methods and content, and assess student's performance.
- The teacher arranges media and content to help students and teachers transfer knowledge most effectively in the online environment.

Design Skills

- The online teacher understands the central concepts, tools of inquiry and structures in online teaching and creates learning experiences that take advantage of the transformative potential in online learning environments.
- The online teacher curates and creates instructional materials, tools, strategies, and resources to engage all learners and enable student success.
- The online teacher plans and teaches well-structured lessons

Content Skills

- The online teacher demonstrates good subject and curriculum knowledge.
- The online teacher is able to link the subject and content with scientific, social, cultural, and any other relevant phenomena.
- The online teacher develops a course outline that includes all course components and elements, as well as an inventory of existing content, resources and any additional material that will be needed.
- The teacher develops and delivers assessments, projects, and assignments that meet standards-based learning goals and assesses learning progress by measuring student achievement of learning goals.
- The online teacher plans and prepares learning plans based upon knowledge of subject matter, students, the community, and curriculum goals.

- The online teacher understands, uses, and interprets formal and informal assessment strategies to evaluate and advance student performance and to determine program effectiveness.

Social and Communication Skills

- The online teacher uses sufficient and commonly understandable language, requests information and asks questions clearly, while clarifying the purpose and meaning of messages and feedback.
- The online teacher uses a variety of communication techniques including verbal, nonverbal, and media to foster inquiry, collaboration, and supportive interaction in and beyond the classroom.
- The online teacher interacts in a professional, effective manner with colleagues, parents, and other members of the community to support students' success.
- The online teacher creates and develops respectful relationships and a sense of community among the learners while maintaining a warm, friendly, and inviting atmosphere.
- The online teacher personalizes messages and feedback and makes them more lively by adding the appropriate sense of humor when possible and by showing sensitivity and empathy.
- The online teacher facilitates and maintains interactive discussion and information exchange, while respecting and considering cultural differences.

Management and Institutional Skills

- The teacher meets the professional teaching standards established by a state-licensing agency or the teacher has academic credentials in the field in which they are teaching.
- The online teacher is a reflective practitioner who demonstrates a commitment to professional standards and is continuously engaged in purposeful mastery of the art and science of online teaching.
- The teacher knows, understands, facilitates, complies, and encourages legal, ethical, and safe technology use, and copyright issues and standards.
- The teacher provides online leadership, management, mentoring, and coaching in a manner that promotes student success through regular feedback, prompt response and clear expectations.
- The teacher is able to manage the course time and apply time-saving techniques.
- The online teacher establishes and declares clear rules and regulations for participation, submission of assignments, timeliness, sending and seeking feedback, and communication protocols.

- The online teacher is tracking the course and students' progress on a regular basis.

ACTIVITY

Using the form included in the Appendix A. Online Teaching Skills Checklist (Activity 1.4), rate your online teaching skills, and write down the ways that you could improve yourself.

1.5 ASYMPTOTE's uses in the various educational settings

As stated above, the ASYMPTOTE project was inspired by the difficulties that the pandemic arose. It is a tool for secondary and university level Mathematics, consisting of an App and a web portal (repository of tasks, task formulations, hints, and sample solutions). Its features enable teachers to conduct adaptive online education in Mathematics, while providing evaluation data for the students' progress. In the spectrum of Technology Enhanced Learning, as it was briefly mentioned above, ASYMPTOTE can be implemented in face to face, blended and online educational concepts.

In a face to face technology enhanced concept ASYMPTOTE can be implemented as a teaching and learning tool

ASYMPTOTE's repository of tasks for Mathematics, the learning graph designer and its adaptivity features can help the teacher design learning activities adopted to each student' s individual learning progress, thus reinforcing their learning process. The teacher can choose to incorporate the usage of the app during the time of the teaching or at home as a practice and/or assessment tool.

In a blended learning concept ASYMPTOTE can be implemented as both a teaching and learning tool and a self-learning tool

In the blended learning concept, the teacher can choose to incorporate the usage of ASYMPTOTE's app both during the face to face portion of the teaching (as it is been analysed in the face to face concept above) or as a part of the online learning process as a learning activity distribution tool or an assessment instrument. In both cases ASYMPTOTE is used as a teaching and learning tool but could also be a self-learning tool that the participants use on their own time for their personal development in the currently instructed topic of Mathematics.

As stated above (see 1.2/B.), blended learning environments are based on the construct that by combining traditional face to face learning and online learning, students' learning improves (Cakir et al., 2009). A traditional learning environment for example provides inherent teaching advantages, such as the immediate feedback which is essential for any learning environment. ASYMPTOTE in this case, can offer systematic and immediate feedback on student's entered solutions. Furthermore, the system provides also the possibility of concurrent direct communication between the participants and their peers and/or the teacher. This feature can prove to be an asset in a blended learning environment, providing in the online learning parts of the teaching the same direct communication that is taking place in the face to face portion of it.

Specifically for the Flipped classroom model, ASYMPTOTE as a learning activity distribution tool, an assessment instrument and a self-learning tool could play a meaningful role both in Pre-class and Post-class stages. In addition, through the communication possibilities and the adaptivity features, ASYMPTOTE can also contribute to In-Class stages where data-driven decisions are important to modify and adjust teaching plans based on students' learning performance (cf. Lo et al., 2017).

In an online learning concept ASYMPTOTE can be implemented as an online teaching and learning tool, a self-learning tool and a 1-to-1 interaction tools

In an online educational concept, both synchronous and asynchronous, ASYMPTOTE can be one of the main technological tools used to conduct the teaching. As in the concepts before, ASYMPTOTE can be used, here too, as an online teaching and learning tool, a self-learning tool but also as a 1-to-1 interaction tool substituting the practice with teacher support phase of face to face teaching. Lastly through the "Digital Classroom" mode the whole learning group can communicate directly bringing some of the in-person aspects of face to face learning to the online process.

ACTIVITY

In which of the three Technology Enhanced Learning concepts do you think ASYMPTOTE has the most beneficial role and why?

As mentioned, in the study of Barlovits et al. (2021), Mathematics teachers reported that one of the main problems they faced during the shift in educational processes due to Covid-19, regarded feedback and personal contact.

ASYMPTOTE's direct feedback and hints and its communication channels can provide solutions to these problems. ASYMPTOTE's "Digital Classroom" mode for direct communication between a learners' teacher and their peers can make the communication more immediate and personal, minimising the barriers of online learning. ASYMPTOTE in this case can be used as an interaction tool that simulates the traditional face to face communication.

ASYMPTOTE's implementations in the three main concepts of Technology Enhanced Learning (face to face TEL, blended learning, and online learning) are summarised in Table 1.1. In the same table the key characteristics of each learning concept are briefly presented.

Table 1.1. TEL concepts - ASYMPTOTE's role

	Face to face	Blended learning	Online
Space	Teacher and learners interact in the same space - Classroom	Teacher and learners interact mainly in the same space (e.g. Classroom) but interact online too in virtual spaces (e.g. in >=30% of the interaction a Learning Management System) is used.	Teacher and learners interact mainly (>=80%) or solely online in a virtual space
Time	Same time synchronous	Mostly same time - Synchronous and different time – Asynchronous	Synchronous and Asynchronous
Communication	Direct and in person	Both direct/in person and Computer Mediated Communication	Computer Mediated Communication
ASYMPTOTE's role	Teaching and learning Technology Enhanced Learning tool. E.g., reinforcing learning, for practice, for assessment etc	Teaching and learning tool / Self-learning tool.	Online teaching and learning tool. Self-learning tool. 1-1 interaction tool. Immediate Feedback and assessment, chatroom and 1-1 discussions.

References

Albrahim, F. A. (2020). Online teaching skills and competencies. *Turkish Online Journal of Educational Technology* - TOJET, 19(1), 9-20.

Agostinelli, F., Doepke, M., Sorrenti, G., & Zilibotti, F. (2020). *When the great equalizer shuts down: Schools, peers, and parents in pandemic times* (No. w28264). National Bureau of Economic Research.

Aldon, G., Cusi, A., Schacht, F., & Swidan, O. (2021). *Teaching Mathematics in a Context of Lockdown: A Study Focused on Teachers' Praxeologies*. Education Sciences, 11(2), 38.

Barlovits, S., Kolokytha, A., Ludwig, M., Fessakis, G., (2022). *Designing mobile environments for mathematics distance education: The theory-driven development of the ASYMPTOTE system.* Accepted for publication at the Congress of European Research in Mathematics Education 2-5 FEB 2022 - CERME12, https://www.cerme12.it

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.

Berge, Z. L. (1995). *Facilitating computer conferencing: recommendations from the field.* Educational Technology & Society, 15 (1), 22–30.

Bergmann, J., & Sams, A. (2012). *Flip your classroom: Reach every student in every class every day*. Washington, DC: International Society for Technology in Education.

Bishop, J. L., & Verleger, M. A. (2013). The flipped classroom: A survey of the research. *In 120th ASEE national conference and exposition*, Atlanta, GA (paper ID 6219). Washington, DC: American Society for Engineering Education.

Black, P., & Wiliam, D. (2003). 'In praise of educational research': Formative assessment. *British educational research journal*, 29(5), 623-637.

Cakir, H., Delialioglu, O., Dennis, A., & Duffy, T. (2009). Technology Enhanced Learning environments for closing the gap in student achievement between regions: Does it work?. *AACE Journal*, 17(4), 301-315.

Chronaki, A., & Matos, A. (2014). *Technology use and mathematics teaching: Teacher change as discursive identity work.* Learning, media and technology, 39(1), 107-125.

Conrad, R., and Donaldson, J. *Engaging the Online Learner: Activities and Resources for Creative Instruction.* San Francisco: Jossey-Bass, 2004.

Crompton, H., Burke, D., Jordan, K., & Wilson, S. W. (2021). Learning with technology during emergencies: A systematic review of K-12 education. *British Journal of Educational Technology.*

Delialioglu, O., & Yildirim Z. (2007). Students' perceptions on effective dimen-sions of interactive learning in a blended learning environment. *Journal of Educational Technology & Society*, 10(2) 133-146.

EDUCAUSE. (2012). *7 things you should know about flipped classrooms*. Retrieved 10.10.2021, from https://library.educause.edu/-/media/files/library/2012/2/eli7081-pdf.pdf

Estes, M. D., Ingram, R., & Liu, J. C. (2014). A review of flipped classroom research, practice, and technologies. *International HETL Review*, *4*(7), 1-8.

Finkelstein, J. E. (2006). *Learning in real time: Synchronous teaching and learning online* (Vol. 5). John Wiley & Sons.

Fontaine, G. (2000). *Skills for successful international assignments to, from, and within Asia and the pacific: Implications for preparation, support, and training*. Management Decision, 35, 635-647.

García-Tudela, P. A., Prendes-Espinosa, P., & Solano-Fernández, I. M. (2021). *Smart learning environments: a basic research towards the definition of a practical model*. Smart Learning Environments, 8(1), 1-21.

Goodyear, P., Salmon, G., Spector, J. M., Steeples, C., & Tickner, S. (2001). Competences for online teaching: A special report. *Educational Technology Research and Development*, 65-72.

Hall, T., Connolly, C., Grádaigh, S. Ó., Burden, K., Kearney, M., Schuck, S., ... & 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.

Handal, B., Campbell, C., Cavanagh, M., & Petocz, P. (2016). Characterising the perceived value of mathematics educational apps in preservice teachers. *Mathematics Education Research Journal*, 28(1), 199–221.

Hattie, J., & Timperley, H. (2007). The power of feedback. Review of educational research, 77(1), 81-112.

Keegan, D. (2005). *Theoretical principles of distance education*. Routledge.

Koehler, M. J., Mishra, P., & Cain, W. (2013). What Is Technological Pedagogical Content Knowledge (TPACK)?. *Journal of Education*, 193(3), 13-19.

Larmann, P., Barlovits, S., Ludwig, M. (2021). MCM@home: Analyzing a Learning Platform for Synchronous Distance Education. In Book of accepted contributions of the *15th International Conference on Technology in Mathematics Teaching, ICTMT* 15, Copenhagen, Denmark, 13–16 September.

Lo, C. K., Hew, K. F., & Chen, G. (2017). Toward a set of design principles for mathematics flipped classrooms: A synthesis of research in mathematics education. *Educational Research Review*, *22*, 50-73.

Ludwig, M., & Jablonski, S. (2019, July). Doing math modelling outdoors-a special math class activity designed with MathCityMap. In *HEAD'19. 5th International Conference on Higher Education Advances* (pp. 901-909). Editorial Universitat Politècnica de València.

Meletiou-Mavrotheris, M., Mavrou, K., & Paparistodemou, E. (2015). *Preface Integrating touch-enabled and mobile devices into contemporary mathematics education*. IGI Global, Hershey, PA.

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.*

Moore, J. L., Dickson-Deane, C., & Galyen, K. (2011). e-Learning, online learning, and distance learning environments: Are they the same?. *The Internet and higher education*, 14(2), 129-135.

Nichols, M. (2003). A theory for eLearning. *Journal of Educational Technology & Society*, 6(2), 1-10.

O'Malley, C., Vavoula, G., Glew, J. P., Taylor, J., Sharples, M., Lefrere, P., .. & Waycott, J. (2005). *Guidelines for learning/teaching/tutoring in a mobile environment.*

Osguthorpe, R. T., & Graham, C. R. (2003). *Blended learning environments: Definitions and directions*. Quarterly review of distance education, 4(3), 227-33.

Palloff, R. M., & Pratt, K. (2003). *The virtual student. A profile and guide to working with online learners.* San Francisco, CA: Jossey-Bass.

Papachristos, D., Arvanitis, K., Vassilakis, K., Kalogiannakis, M., Kikilias, P., & Zafeiri, E. (2010). An Educational Model for Asynchronous E-Learning. A Case Study in a Higher Technology Education. *International Journal of Advanced Corporate Learning* (IJAC), 3(1), 32-36.

Pregowska, A., Masztalerz, K., Garlińska, M., & Osial, M. (2021). A worldwide journey through distance education—from the post office to virtual, augmented and mixed realities, and education during the COVID-19 pandemic. *Education Sciences*, 11(3), 118.

Redmond, P. (2015). A pedagogical continuum: The journey from face to face to online teaching. In *Educational innovations and contemporary technologies* (pp. 107-132). Palgrave Macmillan, London.

Roblyer, M. D. (2006) *Integrating educational technology into teaching*. Pearson Education Inc

San Jose, D. L., & Kelleher, T. (2009). Measuring ecoshock and affective learning: A comparison of student responses to online and face to face learning ecologies. *MERLOT Journal of Online Learning and Teaching*, 5(3), 469-476.

Scanlon, E., & Conole, G. (2018). Interdisciplinarity in Technology Enhanced Learning: an interview study. *Journal of Interactive Media in Education*, 2018(1), 11.

Serdyukov, P. (2015). Does online education need a special pedagogy?. Journal of computing and information technology, 23(1), 61-74.

Sönmez, A., Göçmez, L., Uygun, D., & Ataizi, M. (2018). A review of current studies of mobile learning. *Journal of Educational Technology and Online Learning*, 1(1), 12-27.

Staker, H., & Horn, M. (2012). *Classifying K-12 blended learning*. Retrieved from the Innosight Institute website http://files.eric.ed.gov/fulltext/ED535180.pdf.

Tikhomirov, V., Dneprovskaya, N., & Yankovskaya, E. (2015). Three dimensions of smart education. In *Smart Education and Smart e-Learning* (pp. 47-56). Springer, Cham.

Tucker, B. (2012). The flipped classroom. Education next, 12(1), 82-83.

University of Birmingham, (n.d.). *Orienting Students to Blended Learning*. Retrieved from http://dodlbham.pbworks.com/f/Blended_Learning_Orientation_Fact_Sheet.pdf

Vaughan, N. D. (2010). *A blended community of inquiry approach: Linking student engagement and course redesign*. The Internet and Higher Education, 13(1-2), 60-65.

Winters, N. (2007). *What is mobile learning*. Big issues in mobile learning, 7-11.

Yamamoto, G. T. (2013). *Mobile learning workshop report Turkey*. Okan University, İstanbul.

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*.

Chapter 2. Online Pedagogy Theoretical Frameworks

Moving towards online learning offers both opportunities and challenges, not only for learners but also for teachers. Shifting from face to face to blended or online teaching environments is usually difficult for teachers. The new online teachers often end up replicating face to face teaching online, instead of taking advantage of the affordances of the online environment. With all the available pedagogical possibilities, teachers suffer an “ecoshock” (Redmond, 2015), as when travelling to different countries and cultures. The need to return to “what is familiar” (Redmond, 2015) is quite strong. Thus, it is important for teachers to re-evaluate their values, beliefs, and assumptions about teaching in general and particularly for teaching online. They need to learn to be flexible and open to learning and sometimes to not be afraid to give control to their learners. It is, therefore, important for teachers to gain online pedagogy knowledge to be able to effectively use educational tools, such as ASYMPTOTE.

Aim

- To get familiar with online pedagogy theoretical frameworks
- To identify a pedagogical model for ASYMPTOTE

Key Competencies and Skills

After reading this chapter, you will be able to

- Describe the Community of Inquiry theoretical framework and explain in your own words the process of creating a learning experience
- Describe the 5 Stage Model
- List the five competences that online teachers must possess to assist learners in interacting with the teacher and the content

Keywords

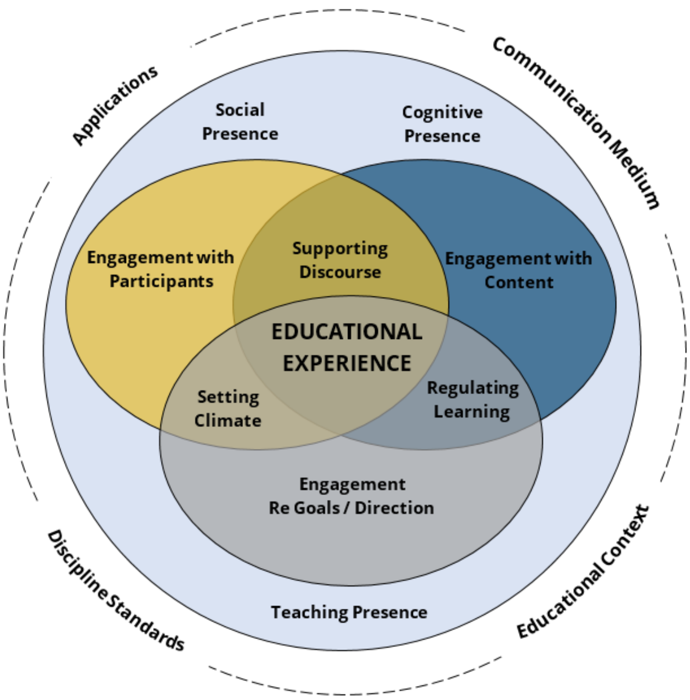
Online Pedagogy, Community of Inquiry (CoI), e-moderator, e-tivities, 5 Stage Model

2.1. Community of Inquiry (CoI)

A well-known, successful, and widely researched approach to designing an educational experience is the **Community of Inquiry theoretical framework** (Garrison et al., 2000). The Community of Inquiry (CoI) framework guides online teachers in how to select content, how to set the learning climate and how to support discourse to establish a quality educational experience through collaborative and constructivist approaches.

The CoI framework consists of three overlapping key elements: **cognitive presence, social presence,** and **teaching presence**. **Cognitive presence** means *"the extent to which the participants in a community of inquiry can construct meaning through sustained communication"* (Garrison et al., 2000, p: 89), especially in terms of online learning. **Social presence** is *"the ability of the participants to identify with the community, communicate purposefully in a trusting environment, and develop inter-personal relationships by way of projecting their individual personalities"* (Garrison, 2009, p. 352). **Teaching presence** includes *"the design, facilitation and instruction directed toward creating and sustaining a community of inquiry"* (Garrison, 2009, p. 355). Teaching presence is considered as the key presence, as it impacts both on social and cognitive presence.

Figure 2.1. The Community of Inquiry theoretical framework.



In a survey by Akyol & Garrison (2008) it was found that the three elements described above appear to develop and progress in different ways in an online environment. However, it was suggested that the development and progression of each presence might be different when applied in other contexts and that *"the* *integration of the elements of a community of inquiry should be designed, facilitated and directed based on the purpose, participants and technological context of the learning experience"* (Akyol & Garrison, 2008, p.18).

Engagement and motivation in the CoI Framework

Engagement, or, in other words, the state of being mentally and emotionally actively involved, focused, devoted, motivated, interested in educational activities and tasks which relate to positive outcomes (such as efficient learning, high grades, personal satisfaction or sense of community) is a significant factor for efficient learning experiences, positively related to academic success (Beer et al., 2010; Dixson, 2015; Vytasek et al., 2020).

According to Dixson (2015), *"Social construction in general and the CoI framework in particular support the need for student engagement with content, other students, and the instructor"*. Especially in an online learning environment, where learners can easily be distracted, passive or feel isolated and disconnected from their peers and teacher, it is important to establish connections between those three factors, to create and maintain an active, interactive, and collaborative as well as engaging online learning environment.

In the table below, suggested activities are presented to promote engaging and interactive activities for students to achieve a better connection with the content, the teacher, and the other students.

Table 2.1. Suggested engaging activities in the CoI framework

Content	• Make students comfortable with the online tools (Conrad & Donaldson, 2011) • Minimize distractions (Novak & Rodriguez, 2018) • Provide authentic, relevant, valuable tasks/activities to the students (Novak & Rodriguez, 2018) • Provide a variety of tasks/activities that are alternated (Gov.uk, 2021) • Provide challenging tasks/activities (Gov.uk, 2021) • Provide adaptive tasks/activities to the students' needs and learning styles • Give immediate and varied feedback (Gov.uk, 2021) • Build in Rewards and incentives to make learning game-like (Gov.uk, 2021) • Create rubrics to define students' expectations (Conrad & Donaldson, 2011) • Provide options for self-regulation (Novak & Rodriguez, 2018) • Provide options for reflective self-assessment (Conrad & Donaldson, 2011; Novak & Rodriguez, 2018)

Students	• Provide icebreaker tasks/activities (Conrad & Donaldson, 2011) • Organize team/peer assessments (Conrad & Donaldson, 2011) • Provide collaborative tasks/activities (Conrad & Donaldson, 2011) • Provide ways for synchronous and asynchronous communication and share contents (chatrooms discussions, forums, messages, 1-to-1 interaction tools) • cultivate the sense of community (Novak & Rodriguez, 2018)
Teacher	• Create rubrics to define students' expectations (Conrad & Donaldson, 2011) • Give immediate and varied feedback (Gov.uk, 2021) • Provide hints and comments during the activities/tasks • Provide continuous support via synchronous and asynchronous communication (chatroom discussions, forums, announcements, messages, interactive touch-screen questions in live recorded lessons)

ACTIVITY

In teams, select one of the presences described in the CoI framework. Find more about what the presence you chose is about and present your findings in plenary.

2.2. E-moderation, 5 Stage Model and e-tivities

The Community of Inquiry framework explains how an online learning experience is created and how the relationship between social presence, teaching presence and cognitive presence is developed in an online environment. In this section, there will be presented another "*overarching framework for creating online pedagogy appropriate design of collaborative interactive learning and teaching in online environments*" (Wright, 2015, p.18). That is the framework developed by Gilly Salmon, and includes E-moderation, the 5 Stage Model and e-tivities. Educators are expected to utilise Salmon's framework in order to "*align their teaching and design practices with the CoI framework*" (Wright, 2015, p.18).

E-moderation

To assist learners in making meaning from their interactions, online teachers, who often act as ***e-moderators***, are expected to have the following five competences (Salmon, 2011):

1. Understanding of the online learning processes,
2. Technical skills to use the software features,
3. Online communication skills (non-verbal, verbal, and written),
4. Content expertise to share with and support students' personal learning,
5. Personal characteristics such as empathy, creativity, confidence, and flexibility.

It is important to highlight that e-moderators do not need many years of experience or too many qualifications and they don't have to be experts in their field. Instead, they can and should be trained on how they can use all the available online tools to extend their teaching, since the transition from face to face to online environments is quite challenging, even for the most experienced lecturers and trainers (Salmon, 2011).

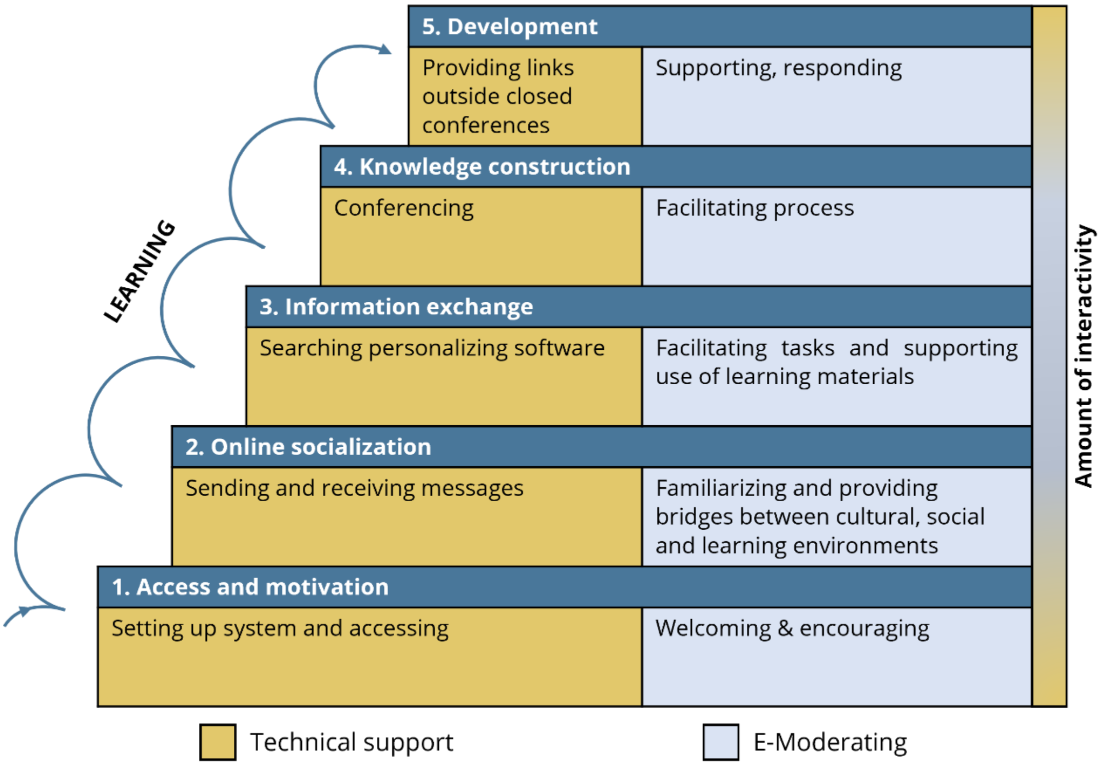
Therefore, it is understood that online learning strategies must address issues that relate to online learning facilitation, tutoring and support but also to the appropriate use of online learning materials and tools to enable fruitful interactions between the teacher, the learners, and the educational material. Concerning facilitation, online learning is hosted usually in Virtual Learning Environments (VLE) or Learning Management Systems. However, those environments create additional problems since they are usually considered as complicated to use by the learners and difficult to moderate by the tutors.

5 Stage Model

To address some of these issues, Salmon proposed the Five-Stage model (Figure 2.2), a pedagogical model for the management of online teaching, which offers *"essential support and development to learners at each stage as they build up expertise in learning online"* (Salmon, 2013, p.15). The Five-Stage Model divides online teaching into successive stages with different needs in technical support and moderation. In other words, the Five-Stage Model describes how to apply the Community of Inquiry framework to develop cognitive, social, and teaching presence with a series of steps.

Stage 1 is about establishing access for each one of the learners and giving them reasons to actively engage and participate in the community. At this stage, learners will be unfamiliar with the online environment and tools, and they need support to feel confident and motivated. Depending on the level of familiarity they have with the online learning software in use, learners will need more or less time in each stage before progressing. In *Stage 2*, learners establish their online identities, and they start to exchange messages with others. They need to understand the value of learning together online and ways of contributing to group work. In *Stage 3*, learners interact with the course materials, and they exchange information with others, while contributing to learning at their own pace. Knowledge construction begins in *Stage 4*, through course-related group discussions and small, collaborative, and sequenced e-tivities (see next section). In Stage 5, learners feel confident to work with others online and they can fully exploit the benefits of their own learning. They are able to self-reflect and make judgments about their experience.

Figure 2.2. The Five-Stage Model of teaching and learning online, as proposed by Salmon



As depicted in Figure 2.2, each stage requires different technical and e-moderating skills. In addition, different levels of interactivity are expected at each stage as shown in the interactivity bar. In the first stages, learners are expected to have the minimum technical skills required to make use of the online environment, while they gradually develop more complex skills, i.e., getting familiar with conference tools. At the same time, each stage requires different e-moderating skills. The main benefit of using this model is that the teacher will know *"how participants are likely to exploit the system at each stage"* (Salmon, 2011) to avoid common difficulties.

e-tivities

A model for designing activities online, that is based on the Community of Inquiry framework and on e-moderating that were described previously, is "**E-tivities**" as proposed by Salmon (2013). E-tivities are for:

- at least two people that work or learn together, whether they are in the same location or not,
- people with special needs that can be assisted through technology,

- learning designers, academics, teachers, and trainers.

E-tivities can be applied to entirely online programs or to blended learning, or mobile learning environments. They are designed beforehand and are quick and easy to produce, since they are reusable, scalable, and customizable. Concerning Mathematics teaching, it may seem difficult for e-tivities to be applied in the traditional teaching of Mathematics, however, they could be applied in authentic problem-solving learning scenarios that require Mathematical modelling, with the aim of consolidating the concepts after traditional teaching. See for example Daher (2010), who used math apps for mobile devices were used to solve authentic modelling problems using the CoI model and e-tivities.

To design e-tivities, designers need to think about the purpose and process of each e-tivity and create a draft storyboard. After that, they need to place it into a learning sequence, and write it in such a way that can be applied online, so that learners can follow it. That is known as "the invitation". Below is presented the e-tivity framework (Salmon, 2013).

Table 2.2. E-tivity framework: the invitation (Salmon, 2013)

Numbering, sequencing, pacing	e.g. 1.3 would refer to the e–tivity for week 1, task 3
Title	A brief description of the invitation. Creative but short.
Purpose	Explain what will be expected with each activity. Link with the learning outcomes and/or objectives for the unit/module/course/program.
Task summary	Clear instructions on how to participate and what to do
Spark	Ignite interest with titles and content, to start a dialogue
Individual contribution	Clear instructions for the individual participant as to what to do, in what media (e.g. wiki, discussion board) and when (day and date).
Dialogue begins	Request response from an individual to others. Use links to the response-posting location
E-moderation interventions	What will the e-moderator do and when
Schedule and time	Total calendar/elapsed time for the e-tivity, completion date, estimated total study time required
Next	Link to next activity, additional resources. Use links.

Below, there are indicative examples of e-tivities that can be created for each one of the stages of the Five-Stage Model. E-tivities are considered as design patterns that can be used when creating online learning activities. To learn more about design patterns and learning design in general, also read sections *3.1 Teaching as a design science*, and *3.3. General Pedagogical Patterns*.

Table 2.3. Examples of e-tivities for each stage (Salmon, 2013).

	Ideas for e-tivities
Stage 1	• Icebreakers • Quiz • Images • Descriptions • Mapping

Stage 2	• Scenarios for discussion • Introduce yourself using six descriptive words • If you were an animal, what would you be and why? • If we were setting up a business, what could you contribute? What products would you like to make or what processes would you like to set up? • Offer one website or blog that illustrates your favourite hobby. • Do you drive on the left or right? Why? Should it be changed?
Stage 3	• Debates • Creative techniques (brainstorming, metaphors, etc) • Questions (Where did the Titanic sail from? What kind of people were on board?) • Offer text, audio, or video of great speeches. Participants condense them into 12 words, discuss the meanings and share them (use a micro-blog, perhaps). • Practice summarizing information—for example, the theory of relativity—in 12 words • Investigate the best way for teams to work online, share ideas and evaluate them. • Try out some online competitive and collaborative games. • Try 'reversal'. What would happen if we did the opposite of what's advised by some authority?
Stage 4	• Take a key diagram, model or concept from your course or discipline. Ask each participant to apply it or find examples. Compare and contrast between the examples offered. Draw it online and collectively improve it. • Introduce staged case-study information with questions. • Introduce challenging problems with a variety of solutions. • Ask individual participants, teams or groups to undertake investigation of one topic or area to contribute to a whole piece of work or report.
Stage 5	• Offer essays, reports or collated Web or social media sites from previous students on the course (with permission or disguised, of course) and run an e-tivity on how participants would have marked, assessed and graded them. • Would the group have worked differently if it had met physically too? If so, in what way? • If the group were designing an online environment, what would it need? • Ask participants to review one of their own messages and rework it to show how they would like it to appear now.

ACTIVITY

Choose a specific Mathematics topic and design e-tivities for each one of the stages of the 5 Stage Model. Take into account the examples provided in table 2.3.

2.3. Mobile learning pedagogy

Mobile learning model was mentioned in the previous chapter. In the following sections, a more specific elaboration of the pedagogical model will be presented, as well as mobile learning applications in Mathematics teaching and learning.

2.3.1. General m-learning

Mobile learning can be defined as *"any educational provision where the sole or dominant technologies are handheld or palmtop devices"* (Traxler, 2005, p. 262). Stevens and Kitchenham (2011) described m-learning as *"meaningful learning that occurs through the use of wireless handheld devices such as cell phone, personal digital assistant, mini-computer, or iPod"*. With such devices, students have access to knowledge anytime and anywhere. However, the concept of *just in time learning, or situated learning,* is not new. *Just in time learning* has the ability to engage learners because of its authentic learning and context-based applications (Silander & Rytkönen, 2005).

Mobile learning definitions have shifted from technocentric to learner-centered, leading to more recent definitions that focus on the mobility of both technology and learning itself. Although there is not still an agreement among scholars on the definition of the term, Yamamoto (2013) manages to meet all aspects of mobile learning in her definition. As she states, mobile learning is not just a means of supplying learners with barrier-free accessibility of information, but it is also a way of enlightenment that can be presented *"without breaking apart from life"* (Yamamoto, 2013). It is obvious that, in the context of education, mobile learning can be used in many different Technology Enhanced Learning settings.

2.3.2. Math m-learning

Although "*mobile devices provide opportunities for interaction in many different formats such as individual or collaborative gamification of activities*" (Attard, 2018), it is not quite clear how these mobile devices can relate to other resources in the classroom. Especially for Mathematics learning, mobile technologies are a recent addition and, as a result, it is quite challenging for teachers to create didactical situations that promote positive pedagogical relationships and interactive behaviors. According to Botzer & Yerushalmy (2007), there is a need to "*formulate appropriate pedagogical models and to develop innovative strategies to integrate mobile applications in learning and teaching*".

For example, the COVID-19 pandemic created an emerging need for teaching Mathematics online. To explore the challenges that Mathematics teachers faced during the implementation of Emergency Remote Teaching, Ferguson (2020) conducted research from which emerged the benefits, the difficulties, and the favourite aspects of teaching Mathematics online. A summarized overview of the results is presented in Table 2.4.

Table 2.4. Benefits, difficulties, and favourite aspects of teaching Math online.

Benefits	**Difficulties**	**Favourite Aspects of Teaching Math Online**
Detailed	Cheating	Flexibility
Flexibility	Attrition (in terms of dropout rate)	Interactive Tools
Self – Sufficient	Student Feeling of Isolation	Meeting Students' Needs
Variety	Graphing	Student Diversity
Personalization	Typing Accurate Mathematics	Teaching Resources
Pacing	Interfacing with Online Environment	
Resources	Difficulty With Building Relationships with Students	
Differentiation		
Convenience		
Accommodating		

Considering that flexibility, interactive tools, meeting students' needs, student diversity and teaching resources are favourite aspects of teaching Mathematics online, it is obvious that mobile technologies have many things to offer. *"The potential for visual, interactive engagement with some learning experiences, coupled with the haptic and oral/aural affordances of the technology, change the nature of the Mathematical activity"* (Calder et al., 2018).

One example for good practices in Mathematics teaching with mobile learning, is the study conducted by Dahler (2010) on middle school students' building of Mathematical knowledge using mobile devices outside the classroom. The study tried to highlight the knowledge building collaborative phases of learning Mathematics by solving authentic problems in a mobile phone environment by Mathematical modelling, and the characteristics of knowledge building that are offered in a mobile phone environment for learning Mathematics in an authentic context. The learning setting was developed using the CoI model. The results suggest that "*learning through authentic activities involving the use of mobile phones can encourage and enrich K-12 students' knowledge building in Mathematics*" (Dahler, 2010, p. 101).

To conclude, although there are many different mobile applications developed to support teaching and learning online, there is a lack of theoretical frameworks regarding the use of mobile technologies for Mathematics learning (Calder et al., 2018). It is important to conduct more research on how to apply these technologies in and out of the classroom. To address this need, the ASYMPTOTE pedagogical model was created. The model will be shaped by the experience that will be gained by using the system.

ADDITIONAL READING MATERIAL

Holden, C. L., & Sykes, J. M. (2011). Leveraging Mobile Games for Place-Based Language Learning. *International Journal of Game-Based Learning (IJGBL), 1*(2), 1-18. http://doi.org/10.4018/ijgbl.2011040101

Crompton, H. (2013). A historical overview of m-learning. In Z. Berge and L. Muilenburg (Eds.) *Handbook of Mobile Learning*, (pp.: 3-14). New York: Routledge

ACTIVITY

In small teams, using your mobile devices:

A. Visit DESMOS (https://www.desmos.com). Select the graphing calculator and try to create a small house with a roof. Alternatively, select the Math Tool of your choice and create a short mathematics activity. Discuss your experience.

B. Create a simple Augmented Reality experience by using one of the following AR apps. You can add links to YouTube videos or webpages similar to the subject you choose.

Blippar https://www.blippar.com/
Zappar https://www.zappar.com/

C. Create a simple Augmented Reality experience for Mathematics teaching, by using:

GeogebraAR (https://www.geogebra.org/m/R8Qd7U8y) or
Photomath (https://photomath.com/en/)

2.3.3. ASYMPTOTE's pedagogical model principles

Taking into consideration both the online and mobile pedagogy theoretical frameworks that were described in the previous sections and the benefits and favourite aspects of teaching Mathematics online, as they emerged from Ferguson's research (2020), a synthesis of pedagogical principles for the meaningful utilization of ASYMPTOTE in teaching and learning is described below.

To start with, ASYMPTOTE, provided as a Web Portal in combination with a mobile app, offers an innovative Mathematics learning environment, with the following main affordances (table 2.5): adaptivity, barrier-free online Mathematics education, synchronous online learning and personal communication and assessment, a rich repository of high-quality student tasks, and 1-to-1 learning providing immediate feedback.

Table 2.5. ASYMPTOTE's pedagogical affordances.

Adaptivity	Teachers compile task sequences (which in ASYMPTOTE are called learning graphs) from a selected set of tasks with adaptive elements. Tasks and learning graphs (see chapter 3.5) are tailored to students' needs and individual educational level
Barrier-free online Mathematics education	Marked tasks with formulation given in an easy language to support students with less profound language skills. Zoom in pictures, and task formulation read out for students with visual impairment
Synchronous online learning & personal communication	Pre-defined timespan in which synchronous online learning will take place in a Digital Classroom environment. Functionalities that exchange information between learner's progress and teacher's web interface. Information about student's progress in real-time. Helping hints, support, and feedback
Long-term assessment	Automated evaluation of the conducted learning session. Graphical and numerical outputs on students' performance.
Rich repository of high-quality student tasks	The web portal provides access to a repository with high-quality student tasks on different Mathematics topics for secondary and university level.
1-to-1 learning providing immediate feedback	Students solve tasks that are embedded in a learning graph designed specifically for their needs and educational level and they can interact with the teacher individually to receive immediate feedback.

These affordances support the implementation of an effective online pedagogy that emphasizes student-centered learning and implements active learning activities. An effective online pedagogy, according to Bill Pelz (2009), a Professor of Psychology and Sloan Consortium Award for Excellence in Online Teaching winner, provides three principles (p. 3):

- Principle 1: Let the students do (most of) the work. The more time students spend engaged with the content, the more they will learn.
- Principle 2: Interactivity is the heart and soul of effective asynchronous learning.
- Principle 3: Strive for presence: social, cognitive, and teaching presence.

ASYMPTOTE, being a 1-to-1 interaction tool, offers students the flexibility to solve individually and at their own pace a selected set of tasks that are embedded in a learning graph by the teacher. This adaptive learning graph, which will be explained more in Chapter 3, is tailored to the students' needs and educational level. If they manage to solve each task successfully, they proceed to the next task. However, if they find it difficult, they are given supportive tasks that are easier than the main task.

Concerning tasks, ASYMPTOTE attempts to be inclusive, by adding marked tasks with formulations given in an easy language to support students with less profound language skills. Moreover, to support students with visual impairment, ASYMPTOTE provides a zoom-in feature for the images that are included in the tasks and an acoustic readout of the task formulations.

ASYMPTOTE supports students by providing a Digital Classroom environment, in which they can communicate and interact with each other in chatrooms and ask for feedback from the teacher. The teacher, on the other hand, is able to provide individual support and assessment to the students, by monitoring their progress on the tasks in real-time and also through the provided graphical and numerical outputs on students' performance. As perceived, ASYMPTOTE, with the feature of the Digital Classroom, can be applied synchronously, in a pre-defined timespan.

As follows, ASYMPTOTE, since it is compatible with the CoI framework, manages to create a deep and meaningful educational experience through collaborative and constructivist approaches. Students can construct meaning through their interactions with the content (cognitive presence) and identify with the community by communicating and interacting in the Digital Classroom environment (social presence). The teacher is able to design, re-design and adapt the tasks and the learning graphs according to the learner's needs, creating worthwhile learning outcomes (teaching presence).

To conclude, ASYMPTOTE's pedagogical principles can be summarized as:

1. Learners are provided with engaging and interactive tasks that are adapted to their educational needs.
2. Learners build fundamental knowledge by solving training or learning tasks and they deepen their understanding by solving reasoning tasks (see chapter 3.5).
3. Learners construct their own meaning when solving tasks for modelling (see chapter 3.5).
4. Learners interact and maintain their social skills in a supportive, digital, inclusive environment.
5. Teaching using ASYMPTOTE is a long-term enterprise aiming to build an online CoI using the 5-Stages process model.

6. Teachers facilitate learning through ASYMPTOTE in combination with any other technique to provide real-time individual feedback, support, and assessment by monitoring learner's progress through the data provided by the system about their performance.
7. Teachers' presence is visible and maintained both in a synchronous and an asynchronous environment.
8. ASYMPTOTE's tasks provide the means to maintain cognitive presence.
9. Teachers' role shifts from explaining Maths in the classroom to setting a learning environment for the students to build Mathematical knowledge. Direct teaching is delivered through videos, while practice, knowledge reinforcement and problem solving are implemented through the ASYMPTOTE app by moderated sessions where teachers provide support and feedback by text message synchronous communication.

References

Akyol, Z., & Garrison, D. R. (2008). The development of a community of inquiry over time in an online course: Understanding the progression and integration of social, cognitive and teaching presence. Journal of Asynchronous Learning Networks, 12(2-3), 3-23.

Beer, C., Clark, K., & Jones, D. (2010). Indicators of engagement. Proceedings ascilite Sydney, 2010, 75-85

Botzer, G. & Yerushalmy, M. (2007) Mobile Applications for Mobile learning. *In the proceedings of IADIS International Conference Cognition and Exploratory Learning in the Digital Age (CELDA).* December. Algarve, Portugal.

Calder, N., Larkin, K., & Sinclair, N. (Eds.). (2018). *Using Mobile Technologies in the Teaching and Learning of Mathematics* (Vol. 12). Cham: Springer.

Conrad, R. M., & Donaldson, J. A. (2011). Engaging the online learner: Activities and resources for creative instruction (Vol. 38). John Wiley & Sons.

Daher, W. (2010). Building mathematical knowledge in an authentic mobile phone environment. *Australasian Journal of Educational Technology*, *26*(1).

Dixson, M. D. (2015). Measuring student engagement in the online course: The Online Student Engagement scale (OSE). Online Learning, 19(4), n4.

Ferguson, S. (2020). Online Mathematics Education, the Good, the Bad, and the General Overview. *Teaching and Learning Mathematics Online*, 405-418.

Garrison, D. R., Anderson, T. & Archer, W. (2001). Critical thinking, cognitive presence, and computer conferencing in distance education. *American Journal of Distance Education*, 15(1), 7-23.

Garrison, D. R., Anderson, T., & Archer, W. (2000). Critical inquiry in a text-based environment: Computer conferencing in higher education model. The Internet and Higher Education, 2(2-3), 87-105

Garrison, D. R. (2009). Communities of Inquiry in Online Learning: Social, Teaching and Cognitive Presence. In C. Howard et al. (Eds.), Encyclopedia of distance and online learning. Hershey, PA: IGI Global, in press. p. 352-355

Kukulska-Hulme, A., & Traxler, J. (2005). Mobile teaching and learning. In A. Kukuluska-Hulme & J. Traxler (eds). *Mobile learning. A handbook for educators and trainers* (pp. 25-44). London: Routledge.

Kukulska-Hulme, A., & Traxler, J. (2005). *Mobile learning. A handbook for educators and trainers*. London: Routledge.

Martin, F., & Ertzberger, J. (2013). Here and Now Mobile Learning: An Experimental Study on the Use of Mobile Technology. Computers & Education, 68, 76-85.

Novak, K., & Rodriguez, K. (2018). UDL progression rubric.

Redmond, P. (2015). A pedagogical continuum: The journey from face to face to online teaching. In *Educational innovations and contemporary technologies* (pp. 107-132). Palgrave Macmillan, London

Salmon, G. (2011). *E-moder@ting: the key to teaching and learning online* (3rd ed.). New York, NY: Routledge.

Salmon, G. (2013). *E-tivities: the key to active online learning* (2nd ed.). New York, New York, NY: Routledge.

Silander, P. & Rytkönen, A. (2005). An intelligent mobile tutoring tool enabling individualisation of students' learning processes. *mLearn 2005, 4th World conference on mLearning: Mobile technology: The future of learning in your hands*. Cape Town, South Africa.

Stevens, D., & Kitchenham, A. (2011). An analysis of mobile learning in education, business and medicine. In Kitchenham (Ed.), Models for interdisciplinary mobile learning: Delivering information to students (pp. 1–25). IGI Publication.

The UK Government, (2021, January 11). *What's working well in remote education*. GOV.UK. Retrieved from https://www.gov.uk/government/publications/whats-working-well-in-remote-education/whats-working-well-in-remote-education

Traxler, J. (2005). Defining mobile learning. P. Isaias, c. Borg, P. Kommers & P. Bonnanno (eds) In *Proceedings of IADIS International Conference on Mobile Learning* (pp. 261-266). Qawra, Maldives: IADIS

Vytasek, J. M., Patzak, A., & Winne, P. H. (2020). Analytics for student engagement. In Machine learning paradigms (pp. 23-48). Springer, Cham.

Wright, P. (2015). Comparing e-tivities, e-moderation and the five stage model to the community of inquiry model for online learning design. *The Online Journal of Distance Education and e-Learning*, *3*(2), 17-30.

Yamamoto, G. T. (2013). *Mobile learning workshop report Turkey*. Okan University, İstanbul.

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Chapter 3. Teaching and Learning Design for ASYMPTOTE

The ASYMPTOTE project is following the teaching and learning design principles as described by Laurillard (2012) and Goodyear (2015), where teaching is considered as a "design science" aiming to improve the world. Teachers who design learning experiences need to participate in a community of practice. They need to be able to continuously improve their design competence by exchanging knowledge about which designs are effective and which are not. *"Teaching is more like a design science because it uses what is known about teaching to attain the goal of student learning and uses the implementation of its designs to keep improving them"* (Laurillard, 2012). To understand teaching as a design language, Goodyear's teaching design model is presented below.

Aim

The aim of this chapter is to present learning design principles, online teaching strategies and feedback strategies that can be implemented in the context of ASYMPTOTE to create meaningful and interesting learning experiences for students. Additionally:

- Task design for Mathematics using ASYMPTOTE will be explored.
- The sequencing of tasks will be analysed
- The functions of ASYMPTOTE's Learning graph will be outlined, and
- The adaptivity of the system will be examined.

Key Competencies and Skills

After reading this chapter, you will be able to

- Describe the principles behind teaching as a design science
- Utilize Pedagogical Scenarios and Design Patterns to create collaborative learning activities
- Utilize Instructional Strategies that support Constructivist-based pedagogy models
- Describe ASYMPTOTE's task sequencing, learning graph function and adaptivity specs.

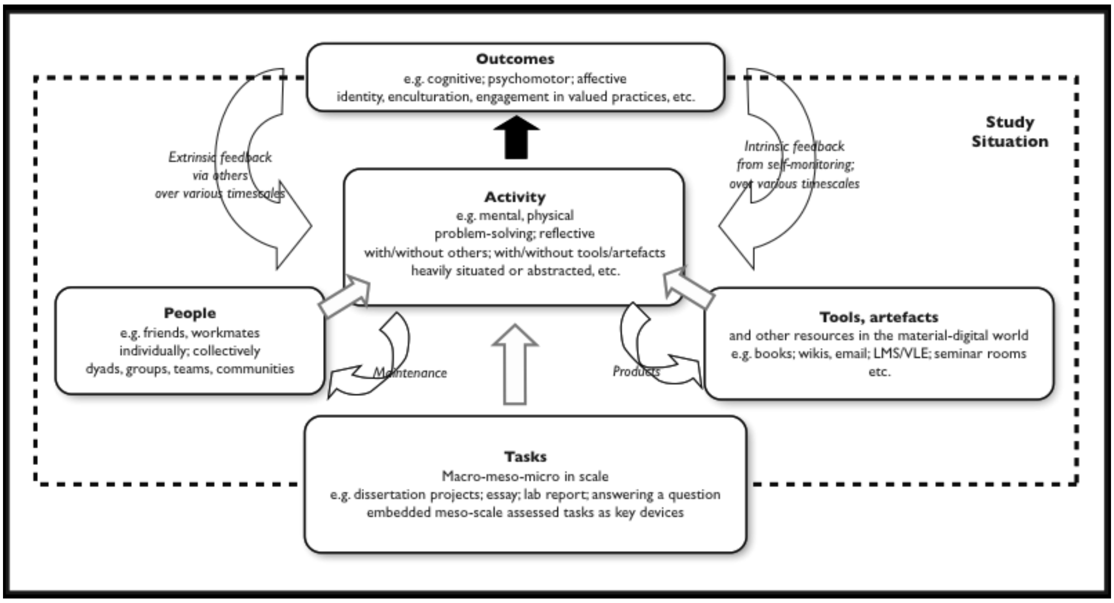
Keywords

Teaching as design, Learning activity, Pedagogical Scenarios, Design Patterns, Feedback strategies, Task sequencing, Learning graph, Adaptivity

3.1. Teaching as a design science

According to Goodyear (2015), teaching is a form of design science *"that uses a distinctive mode of thought and set of tools and methods".* In Goodyear's approach, the student task is the key building block for the creation of the pedagogical patterns. As depicted on Figure 3.1, there are three key learning design components: good tasks, supportive physical and digital environments (Tools, artefacts), modes of social organization and divisions of labour (People).

Figure 3.1. Goodyear's activity-centered design model (Goodyear, 2015).



This model brings into focus the concept of "*learning activity*". To implement a task, students are allowed to freely explore and re-shape their learning environment by using the tools and resources provided. In addition, students choose how they will interact with other people for the task completion. That way, they actively participate in the learning process, making their own meaning in the context of the learning activity. So, learning activity is the unique experience each student has when they are engaged in the implementation of a task.

3.2. Pedagogical scenarios – Learning scripts

The outcome of teaching design consists of a) a set of learning resources, b) the description of a learning environment and c) a set of instructions that define the learners' interactions to complete a sequence of tasks or solve a problem. This set of instructions, along with the description of everything needed for their implementation, is called a **learning script or pedagogical scenario** (Dillenburg, 2002).

There are many ways to represent a pedagogical scenario since there is not a commonly acceptable standard form. For example, designs are presented as case studies, as solution templates, or as diagrams. The sequence of tasks/activities usually follows traditional models. However, in the context of ASYMPTOTE, it is focused on student-centered models.

Through their interactions with students, teachers can discover which techniques or methods are more effective when designing learning scenarios. This knowledge, when shared within teachers' communities of practice, leads to pedagogical approaches of higher quality. From this exchange of practices, it is possible that a generalized form of a scenario will appear, or as it is called "**learning design pattern**" (e.g. math trails, learning graphs, etc.). Design patterns have the potential to make a major contribution to the sharing of techniques and expert knowledge among developers of learning activities and teachers.

3.3. General Pedagogical Patterns

The term "pattern" was first introduced by Alexander, an Austrian architect who used the term when he proposed a new theory of architectural design. According to Alexander (1979), "*each pattern describes a problem which occurs over and over again in our environment, and then describes the core of the solution to that problem, in such a way you can use this solution a million times over, without ever doing it the same way twice*". This definition found recognition in many different disciplines, leading to a common understanding of the term as *"an abstract solution of a class of problems that can be used in many different ways in various subject areas*" (Hadzhikolev et al., 2021).

Concerning education, pedagogical patterns support teachers in the preparation and implementation of a flexible learning process. Pedagogical patterns *"describe the experience of experts for various successful practices in the field of teaching and learning*" (Hadzhikolev et al, 2021). In other words, pedagogical patterns are a great tool to share best practices and create meaningful learning experiences.

There have been many significant works developed on the design and creation of pedagogical patterns (Pedagogical Patterns Project, 2012; Bergin et al., 2012; Iba et al., 2009; Mor et al., 2014; Fioravanti & Barbosa, 2016). However, in the context of ASYMPTOTE, special design patterns will rise and existing will be adopted such as *Collaborative Learning Flow Patterns (CLFPs)* (Hernández-Leo et al., 2005). These patterns, or scripts, *"represent broadly accepted techniques that are repetitively used by practitioners when structuring the flow of learning activities involved in collaborative learning situations*" (Hernández-Leo et al., 2006). Below, are presented three of the most known collaboration patterns, the Jigsaw script, the Pyramid script and the MathTrail.

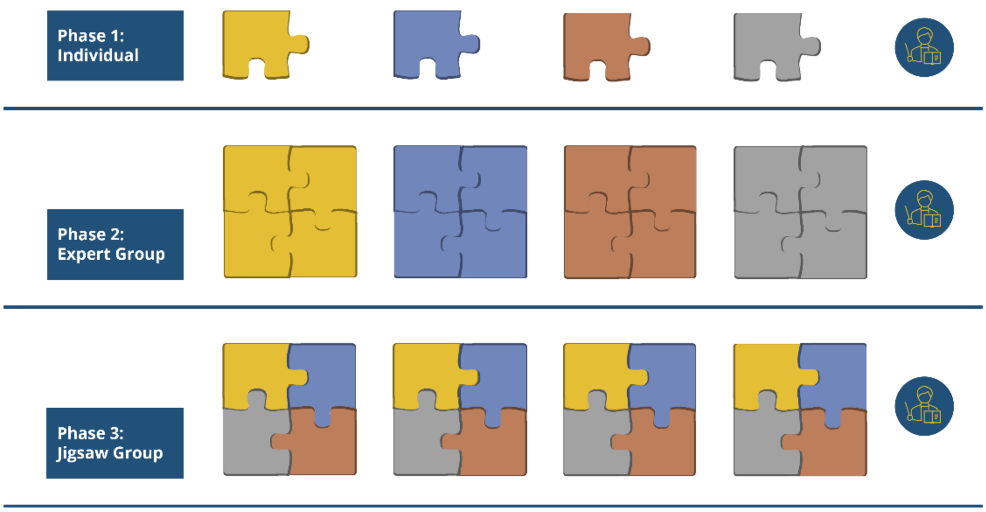
DEFINITION

Collaborative Learning Script: is a set of instructions prescribing how students should form groups and how they should interact and collaborate in order to solve a problem (Dillenbourg, 2002).

The Jigsaw

The most known collaborative script is the Jigsaw. In this script, students work in small groups and study a lot of information to solve the same problem. The Jigsaw script consists of three phases. In the first phase, students individually or in initial groups work on one sub-problem. Then, in the second phase, members of each student group that worked on the same sub-problem meet in Expert Groups to exchange their ideas. They can use a chat or other online collaboration tools. In the final phase, students, who are now experts in each sub-problem that was assigned to them, return to Jigsaw Groups and discuss their ideas in order to complete the activity and find the solution to the whole problem.

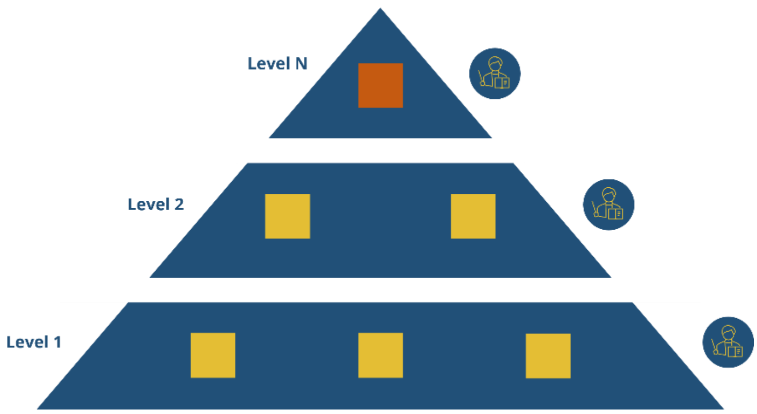
Figure 3.2. Jigsaw script



The Pyramid

In the Pyramid script, students collaborate to solve the same problem. Students, in the first level, study individually, or in small groups, the problem and propose a solution. Then, in the next level, they join larger groups in which they discuss their ideas and generate a new proposal. In the final level, all students must propose a final and agreed solution to the problem. In the Pyramid script, there are usually two or more phases, depending on the needs of learning design.

Figure 3.3. Pyramid script



There are many different patterns available that can be implemented in the design of online learning activities. Patterns as those described above, can be used individually or in combination to challenge more interactions among the students. In any case, it is important to keep scripts "*simple and easy to adopt by the learners*" (Dillenbourg, 2002).

ADDITIONAL READING MATERIAL

Dillenbourg, P. (2002). Over-Scripting CSCL: The risks of blending collaborative learning with instructional design. In Kirschner, P. A. (Ed.), *Inaugural Address, Three Worlds of CSCL. Can We Support CSCL?* Heerlen: Open Universiteit Nederland, 61-91.

The MathTrail

Seeking a systematic way of learning design for mobile learning for Mathematics education, the MathTrail concept can be utilized (Cross, 1997) as a pattern of a learning activity. MathTrail concept can be used to exploit the advantages of mobile devices in combination with the approach of Realistic Mathematical Education (Fesakis et al., 2018).

According to Shoaf et al. (2004), a Mathematical path is a walk towards the discovery of Mathematics. A MathTrail includes a pre-planned path, which is defined by a sequence of stops in which students examine Mathematics in real life (Cross, 1997). A remarkable collection of Mathematical paths is available on Mathcitymap project of the University of Frankfurt (https://mathcitymap.eu) (Gurjanow et al., 2020).

In more detail, a Mathematical trail is a model of learning activity that combines problem solving, creating connections of school knowledge with the real world and other disciplines, communication, practical application of knowledge in a conceptual environment and physical movement (Richardson, 2004). In the advantages of the Mathematical path, Richardson (2004) states that they create an atmosphere of adventure and exploration because they are implemented outside of the classroom. The common sense of expectation and discovery that naturally develops, leads to communication of the Mathematical ideas on which the path focuses. Students observe, measure, collect and record data to process and interpret. As they complete activities on the trail, students use Mathematical concepts taught in class and discover various uses of these concepts in everyday life (Fesakis et al., 2018).

ADDITIONAL READING MATERIAL

Gurjanow, I., Zender, J., & Ludwig, M. (2020). MathCityMap–Popularizing mathematics around the globe with math trails and smartphone. In *Research on Outdoor STEM Education in the digital Age*. Proceedings of the ROSETA Online Conference in June 2020 (pp. 103-110).

3.3.1. Pedagogical patterns in ASYMPTOTE

Using design patterns online is a challenge that can be met when they are implemented in Virtual Learning Environments or Learning Management Systems or Virtual Learning Environments. Hadzhikolev et al. (2021) proposed a pedagogical design pattern framework according to which a "*pedagogical pattern instance* or *instance*" can be used in a Learning Management System (LMS) for self-learning, for face to face or online communication, or for hybrid learning.

ASYMPTOTE, since it is offered as a web-portal with access to a high-quality tasks repository allows the implementation of various pedagogical patterns for Mathematics teaching. More specifically, the tasks repository, in combination with a mobile app, and the Digital Classroom feature that allows synchronous and/or asynchronous communication, manages to combine and implement all the aspects that are included in a pedagogical pattern instance, thus making it a great tool for teachers to create meaningful and interesting learning experiences for students. Some learning design patterns that are obviously compatible with ASYMPTOTE include Gagne's Nine Events of Instruction, the Study-Reinforce-Apply-Extend pattern, the MathTrail pattern, the Learning Graph pattern etc. During the professional development program, the participants will explore learning design patterns utilizing ASYMPTOTE to produce meaningful, engaging, student-centered and effective learning experiences in any setting and especially for remote teaching.

3.4. Online teaching strategies – methods and pedagogical practices

As already mentioned in previous chapters, teachers need to revise their teaching methods and pedagogical practices to align with constructivist-based pedagogical models according to the properties and needs of online-remote educational settings. Dabbagh & Bannan-Ritland suggest that to implement any pedagogical model in an online learning context, it is important to "*identify specific instructional strategies that support the model characteristics and to enact these strategies by using Web-based technologies*" (Dabbagh & Bannan-Ritland, 2005, p. 201).

Instructional strategies-methods (or pedagogical approaches-practices) are "*what instructors or instructional systems do to facilitate student learning*" (Dabbagh & Bannan-Ritland, 2005, p. 203). In other words, instructional strategies are all the techniques an instructor or an instructional designer uses to engage the students and facilitate learning. According to Dabbagh, instructional strategies *operationalize* pedagogical models, meaning that they depict how pedagogical models can be put into practice.

There are 13 instructional strategies that support constructivist-based pedagogical models. These strategies are "*highly interdependent and intersect vertically and horizontally*" (Dabbagh & Bannan-Ritland, 2005, p. 206).

Figure 3.4. Relationships of Instructional Strategies that support Constructivist-based pedagogy models.

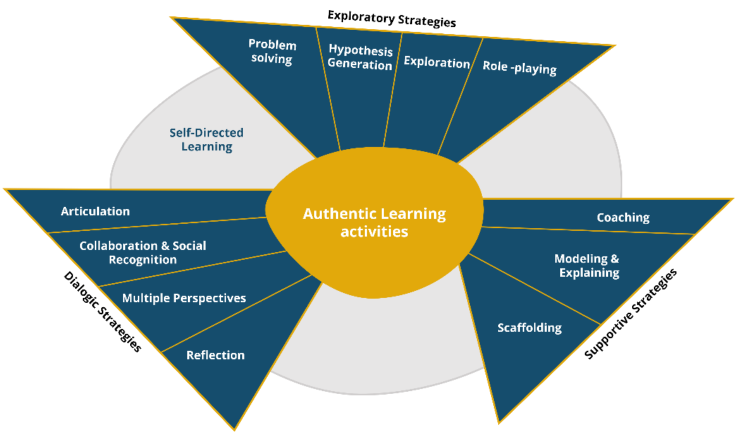


Figure 3.4 shows that all three clusters or groups of instructional strategies (exploratory, dialogic, and supportive) promote the creation of authentic learning activities. Additional, self-directed learning *"is promoted as an outcome or a consequence of the collective implementation of all instructional strategies"* (Dabbagh & Bannan-Ritland, 2005, p.207).

DEFINITION

Exploratory strategies: strategies that promote exploratory-type activities (problem-solving, exploration, hypotheses generation and role-playing, modelling).

Dialogic strategies: strategies that promote dialogic activities (engaging students in articulation, reflection, collaboration, and multiple perspectives).

Supportive strategies: strategies that are usually enacted by the instructor, to model the desired performance, skill, or process, but also to support students during the execution of a task (Dabbagh, 2005).

When students are engaged in instructional strategies as those depicted in Figure 3.4, they manage to make meaning and learn through authentic situations that are relevant to their needs and interests. When it comes to Mathematics teaching online, though, the COVID-19 pandemic created an emerging need for instructional strategies that can be best applied.

A report conducted by UCL (Hodgen et al., 2020), found that remote practices applied by schools in England offered less opportunities to students to interact with each other and with the teacher during their learning. Moreover, they found that there *"were very limited opportunities for feedback, interaction with teachers, for pupils to engage in metacognitive tasks or to express their Mathematical ideas verbally"* and they identified that *"the attainment gap between pupils from more and less disadvantaged backgrounds is likely to increase substantially as a result of the school closures"* (Hodgen et al., 2020, p. 21).

To conclude, it is important for teachers to get more experienced with the interactive tools and resources that are currently available, to get more familiar with the features that are provided in an online environment, in order to engage students in more interactive and meaningful learning and social activities that meet their needs and their educational level – even more in online learning situations.

Feedback strategies

The supportive strategies mentioned above include models in which feedback plays a key role. Referring to chapter 1 feedback represents a difficulty in times of digital learning. The term feedback generally refers to information that is provided after a process has been completed and is intended to have a regulating effect (Narciss, 2006, p. 14). In the context of teaching and learning situations feedback includes information presented to students by external sources of information, such as teachers or learning programmes, during or after the completion of tasks. A basic distinction is made between informative feedback and motivational feedback. Numerous variations of motivational feedback refer to the assessment of learning outcomes and do not primarily serve to provide information about the correctness of the solution (Narciss, 2006, p. 18-19).

DEFINITION

Informative feedback includes information offered with the aim of helping students to solve a task correctly and to cope with similar learning situations in the future (Narciss, 2006, p. 18).

The **effects** of informative feedback are described in four complementary functions. Feedback can be used as a reinforcer of correct answers and as a source of motivation, it can provide information about mistakes with the aim of correction and can also be understood as a tutor in the processing of tasks (Narciss, 2006, p. 24-37).

Further in the text content, forms and designing principles of informative feedback are explained. The spectrum of feedback content is wide. Narciss (2006, p. 19) classifies different commonly used types of feedback according to content.

- *Knowledge of performance (KP):* Learners receive summative feedback on the level of performance achieved (e.g., 60% of tasks correctly solved).
- *Knowledge of the result/ response (KR)*: Indication of whether the answer is correct or incorrect.
- *Knowledge of the correct response (KCR)*: A correct answer or solution is presented.
- *Answer until correct or multiple try feedback (AUC/ MTF)*: The learner receives KR and is offered the opportunity to repeat the task (for AUC until the correct answer is given; for MTF there is a fixed number of attempts before KCR is offered).
- *Elaborated feedback (EF)*: KR or KCR is used in combination with additional information to correct mistakes and solve similar tasks in the future.

Five components of elaborated feedback are presented in Table 3.1.

Table 3.1. Classification of different elaborated feedback components (Narciss, 2006, p. 23)

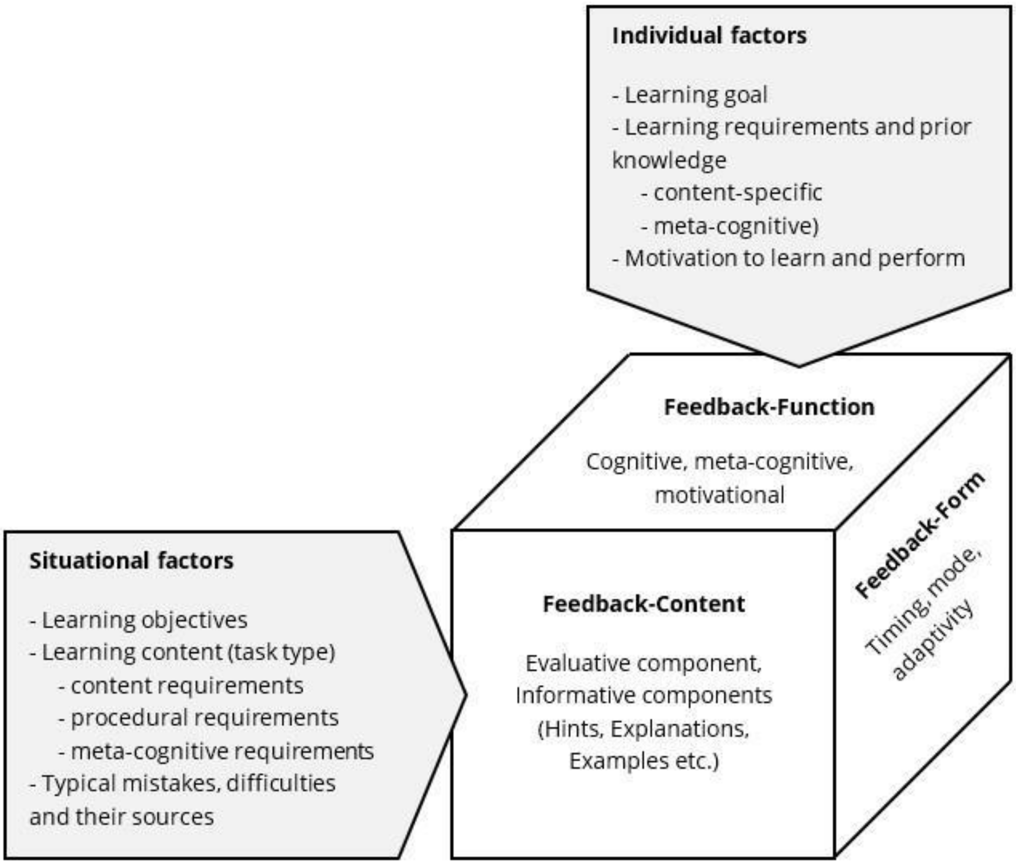
Elabo rated Feed back Com	Knowledge on task constraints	KTC	Hints/ notes on... ... type of task ... processing rules ... subtasks ... task requirements

ponents	Knowledge about concepts	KC	Notes on technical terms Examples of terms Notes on the context of terms Explanations of terms
	Knowledge about mistakes	KM	Number of errors/ mistakes Location of the mistake(s) Type of mistake(s) Cause(s) of the mistake(s)
	Knowledge on how to proceed ("Know how")	KH	Mistake-specific correction hints Task-specific solution hints Hints on solution strategies Guiding questions Solution examples
	Knowledge on meta-cognition	KMC	Hints on meta-cognitive strategies Meta-cognitive guiding questions

Meta-analyses show that the use of feedback as opposed to no feedback clearly has positive effects on learning processes. Regarding the different types of feedback, scientific findings so far have been inconsistent (Schimmel, 1983; Clariana, 1993; Bangerts-Drowns et al., 1991). Trends show that feedback consisting of at least the correct solution (KCR) is more effective than feedback type KR (Bangerts-Drowns et al., 1991). Several studies show that the use of elaborated feedback (EF) is more effective than no feedback, knowledge of result and knowledge of the correct response (McKendree, 1990; Birenbaum & Tatsuoka, 1987). This argues for the use of more elaborated feedback that goes beyond the presentation of a solution (Staiger, 2016, p. 70-78; Narciss, 2006, p. 42-65).

The multidimensionality and multifunctionality of tasks and feedback is reflected in the different classifications of feedback types as well as in the inconsistency of the empirical results. When designing feedback, it is essential to consider different factors. Figure 3.5 shows the design principles according to Narciss (2006, p. 81-83). The design is based on situational and individual factors. Situational factors (learning content, learning objectives and task type) describe the learning object and its requirements. Feedback design presupposes knowledge about typical mistakes and difficulties. On this basis information on how to cope with the task requirements is determined. Individual factors include students learning requirements and motivation. Based on these factors, the functions, contents and forms of the feedback components are elected. Whether cognitive, meta-cognitive and/ or motivational functions are in the foreground is primarily determined by the teaching and learning objectives. In terms of content, KR or KP can take on an evaluative component, while elaborated feedback represents an informative component through additional information. Formally, the feedback presentation can be written or oral, direct or delayed, with graphic or linguistic elements.

Figure 3.5 Overview of determinants of the information value of feedback (Narciss, 2006, p. 81)



The selection and specification of feedback components follows five steps:

1. Concrete teaching and learning objectives are selected based on the curricula.
2. Typical student tasks are assigned to the specified learning objectives.
3. Due to the multidimensionality of tasks, requirement analyses for the typical tasks are carried out in the third step. The following questions are to be answered:
    a. What prior knowledge is necessary to be able to solve the tasks?
    b. Which cognitive operations must be mastered (e.g., remembering, transforming, reasoning, inferring)?
    c. What meta-cognitive strategies are helpful in the context of mastering the tasks?
4. The next important step is the mistake analysis, in which typical mistakes are identified and responsible task requirements are to be found.
5. The results of task and mistake analyses are used to construct helpful information for mastering the student task and correcting mistakes (Narciss, 2006, p. 85-87).

From theoretical and empirical findings in teaching-learning research, the following principles emerge for the presentation of feedback components:

- Feedback should only be provided after the task has been completed,
- elaborated feedback components should not be offered directly with knowledge of the correct response (KCR),
- complex feedback content should be presented successively – from initially strategic information to progressively more concrete information,
- learners should be given the opportunity to use feedback information for a next attempt to solve the problem (MTF) and
- at least one other task of the same type should be set to have the knowledge acquired with the help of the feedback applied (Narciss, 2006, p. 269f.)

ACTIVITY

Select a student task based on your curricula. Design feedback following the five steps to select appropriate feedback components. Think of three hints (EF) and KCR.

Additional guiding questions:

Should MTF be available for your task?
When will KCR be presented?
Did you think about implementing strategic and concrete information as feedback components?

3.5. Tasks Design for Mathematics learning using ASYMPTOTE

In Mathematics education designing, selecting, modifying, using, sequencing, observing, and evaluating tasks takes a big part of teaching and learning processes (Margolinas, 2013). Task design lies in the centre of Mathematics' methodology and pedagogy (Artigue & Perrin-Glorian, 1991) because task engagement brings learners across Mathematics concepts, ideas, strategies and helps them develop Mathematical thinking.

The term "task" can be found in the literature having different interpretations. Leont'ev (1978) in his activity theory defines a task as an operation bound with specific restrictions and requirements. Others specify the task more empirical, as something that the learners are requested from the teacher to do (Mason & Johnston-Wilder, 2006). Sometimes it is used to describe material or environments which are destined to promote activities (Becker & Shimada, 1997). It's also common for the term to get tangled with activity. Activity's terminology is evidently associated with task's, but its distinction lies on the fact that the activity unravels from the interactions between learners, teachers, the educational material, the environment and the task itself (Goodyear, 2015). A more empirical definition of activity, would suggest that it is a situation constituted by the teacher where the learner has to engage, maintaining set standards and following certain rules. In this chapter Margolinas's, (2013) definition of the term task will be adopted:

DEFINITION

Margolinas, (2013) defines task as any practice, construction, problem solving, decision between different possibilities, experimentation, or inquiry, that can incite teaching and learning. The term does not refer only to something that the teacher requests from the learners to do, but it also includes whatever the learners decide to do on their own.

As mentioned in Chapter 1. ASYMPTOTE provides a repository of tasks for primary, secondary and university level Mathematics. Through the web portal teachers can search for and select existing tasks or create their own. Tasks in ASYMPTOTE are divided into 3 broad categories regarding their focus: training, reasoning, and modelling.

- **Training** tasks include Mathematics and/or Mathematical techniques.
- **Reasoning** tasks require the student to use a Mathematical argument, interpretation, or explanation.
- Lastly, **modelling** tasks have a strong connection to the real world. This connection can range from easy standard modelling up to real-world-problem solving. Modelling tasks usually include a picture for identification in the corpus of the task. This picture has to be an obvious connection to reality.

Tasks in ASYMPTOTE are created from a predefined task form, facilitating the ability to address as many different problems and topics as possible throughout all classes and skill levels. This form consists of basic information about the task such as its title and description, its author's information etc, core components such as the task type and solution format and metadata such as its assigned grade and tags.

A very important factor for task creation when using technologies is the answer types that the system can support. It is one of the main elements that sets the limitations and the prospects for the creators. In ASYMPTOTE the answer format is the core of each task because it determines the answer behaviour in the app. ASYMPTOTE currently provides eight different answer formats:

- Exact value
- Interval - especially useful when the answer cannot accurately be calculated e.g. for more complex modelling tasks
- Multiple choice - this category also includes the answer type of true or false.
- Fill in the blanks - The basic requirement when designing a task with this answer type is that the student should have no difficulty in understanding the data and the question asked despite the blanks.
- Vector (exact value) - Useful in finding the coordinates of a point
- Vector (interval) - Used when the coordinates cannot be accurately calculated
- Set - The solution set can contain several elements. A typical example is an equation that has many solutions.
- Fractions
- Matrices.

Some are interdisciplinary, e.g., multiple-choice or closed texts, and some are particularly relevant for mathematical tasks such as exact values, vectors, sets, fractions and matrices.

Supporting a self-guided working process, each task can and should be given a well-explained sample solution which not only displays the correct result but also describes all steps in between. The sample solution should be detailed enough that students are able to compare their own answer and understand the thought process of the creator. A sample solution might contain text, image, and video files which can be viewed by the students after completing or failing the task. In line with the importance of immediate elaborate feedback (Gurjanow, et al., 2019, Van der Kleij, et al., 2012), instant validation by the app and automatic feedback depending on the given answer format (e.g. whether the entered fraction is completely reduced or not) is available. Moreover, tasks can be equipped with a maximum of three stepped hints, ideally leading the students along the solution process. An example for a suitable succession of stepped hints could be (a) a different, more implying wording of the question, then (b) an indication towards one possible formula followed by (c) providing the formula itself. Hints can include text, images and videos, which follows the ideas of (Beal, et al., 2007, Kochmar, et al., 2020) in assisting multimedia material to foster the student's learning progress.

Another feature that the system provides, and is required in the task form, is task Metadata. Every task can be described by Mathematical tags so that both teachers and learners can easily identify and select them. Simultaneously, each task is also addressed to a stage of thematical hierarchy. The ASYMPTOTE curriculum that was created after analysing comparing and combining the constituted curriculums for

Mathematics in Italy, Germany, Greece, Portugal, and Spain, defines the hierarchy of the tasks. The tasks are divided into 5 main categories: primary, lower secondary, upper secondary, and university. Each level consists of specific mathematical subjects that are developmentally appropriate. The Mathematical subjects that are involved in each task, define their place in the hierarchy.

To help teachers assess better whether a task is relevant and suitable for their students, several smaller assistive features are in place. A voting system allows users to recommend a task they experienced to be useful. This voting will lead to a ranking for tasks of every topic instantly displaying the most frequently used ones. Inspecting a task will also provide information about how often it has been used as support, challenge or main task (see 3.5.1), as well as, how often it has been used in total. Moreover a list with all public learning graphs (see 3.5.1) that this task has been used in will offer best-practice examples and inspiration for the teachers. Last but not least, teachers will receive recommendations for other tasks which have most frequently been used together when using a certain task. All these features together should grant a quick and proper insight about the quality and usefulness of a task.

In closing, a completely different type of task supported by the system is the loop task. Loop tasks provide a collection of permutations of the same task, allowing students to train their skills on a certain topic/task via repetition. Moreover, by posing every student a slightly different version of the same task students should be less tempted to cheat. As an example, the teacher could type in the equation ax+b=c, specify the number space for a,b,c, and x and choose the number of tasks which are then automatically generated by the system. A mode to manually create multiple permutations of a text-based task is supported as well.

3.5.1 Task sequences and Learning graph

In ASYMPTOTE, tasks are not presumed only as single events. The focus is concentrated in sequencing them to produce a complete learning path for a specific Mathematics' topic.

DEFINITION

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; Yang, & Lau, 2010).

In a task sequence, prior or first tasks should provide experiences that scaffold the solution of subsequent tasks, thus giving opportunities to the learner to engage in more sophisticated Mathematics and grasp more abstract concepts (Margolinas, 2013). A task sequence is important to transform knowledge from implicit, in-action, to a format that is formulated, formalized, memorized and culture related (Margolinas, 2013). As Margolinas (2013, p. 11) states *"a task sequence starts with situated problems, (…) to evoke informal strategies and representations, and continues by changing the focus to formalizing and generalizing solution procedures (…)".*

In a sequence, earlier tasks might be of a more technical nature, providing learners with the tools and techniques that they will need to use in order to undertake subsequent tasks with situational understanding. Earlier tasks might include images, graphs, equations, or technical components that lie in the base of the subject's knowledge. Margolinas, (2013) defines 3 types of sequences in Mathematics education: **i)** the first type maintains the problem formulation throughout the sequence while the numbers selected for each task increase the complexity gradually, **ii)** another type of sequence is one where the problem is presented progressively more complex, by the addition of steps or variables, **iii)** finally, the third type is related to the topic of Mathematics that is under examination. For example, if the topic is the calculation of the area of geometric shapes, the tasks could start with simple shapes and progress to composite and irregular shapes.

In ASYMPTOTE task sequences are presented in the form of a learning graph. This format includes 3 main categories of tasks: **main tasks**, **support tasks** and **challenge tasks**. The learning graph is represented visually by a kind of fishbone diagram which consists of a central spine, where the main tasks lie and branches that connect it with the subtasks (challenge - left side, support - right side) (figure 3.7).

- **Main tasks** (yellow) are mandatory tasks and form the backbone of a LG. In a desirable scenario, each main task covers an aspect of the overall topic. Hence, a student who solves all main tasks encounters and learns about the minimum requirements for the LG's topic. This implies that students should solve as many main tasks as possible.
- **Support tasks** (green) are linked to the right side of a corresponding main task and provide related tasks on a lower level, which can help solve the main task afterward. This might be an easier version of the task or a repetition of a topic needed in order to solve the main task. Multiple support tasks can be assigned to one main task and solving them will never pose any drawbacks for the students.
- **Challenge tasks** (purple) are located to the left side of the main task and are supposed to be of higher difficulty than the latter, challenging those students who finish early or seek to dive even deeper into the topic.

Challenge tasks are unlocked upon solving their respective main task or preceding challenge tasks since more than one challenge task can be associated with one main task.

In general, a LG in ASYMPTOTE is a collection of different tasks with varying difficulty concerning one mathematical topic. The aforementioned task state (main, support or challenge task) is determined by the task location in the LG. Therefore, it is important to mention that a task can, for instance, be a support task in one but a challenge or main task in another LG.

Thanks to the combination of mandatory main tasks, optional challenge tasks and individually selected support tasks, the ASYMPTOTE LG architecture ensures two core concepts. Firstly, the main tasks aim to cover the most important concepts of the mathematical topic which, for instance, have been taught in the previous lesson in school. Thus, by solving as many main tasks as possible and resorting to support tasks, if necessary, students can train the underlying topic and achieve a profound understanding of it. Secondly and most importantly, the entire learning process is self-guided and autonomous, following the self-determination theory by Deci & Ryan (Deci & Ryan, 2008). The only mandatory target of a LG for students is to solve all main tasks. Everything else apart from that (support and challenge tasks) is optional. Eager students can strive to solve all available challenge tasks, whereas other students struggling with the main tasks can optionally visit and learn from support tasks and many other students likely choose one way in between. The possibility to invoke support tasks on demand can support lower-performing students in the distance learning process. Hence, what matters here is the fact that every student can choose a personal way through the same LG, giving the opportunity to all students to work autonomously on tasks, meeting their own performance level.

Moreover, the system's shallow gamification, where students receive points for a successful task solving process (Van der Kleij, 2012, Lieberoth, 2015), can motivate students and foster learning. While progressing in the LG, the student is always able to see the already achieved points and the status of their own progress in the LG. Every task that was once unlocked and is not yet completed (solved/failed/given up) can be attempted at any time. Finishing a LG enables a summary of all tasks, the given answers and the received points. Once a LG is completed, it can be restarted with the possibility to skip tasks that have been solved in a previous run to focus on those topics which were not yet completely understood.

Figure 3.7 shows in more detail 3 cases of students' journeys through a LG. In order to understand the different possible states of the three task types of a learning graph, see figure 3.6.

Note: The following figures do not contain realistic visuals from the App or the web portal. They are visual representations created to strengthen reader' s understanding.

Figure 3.6. Representations of the possible states of the three main task types.

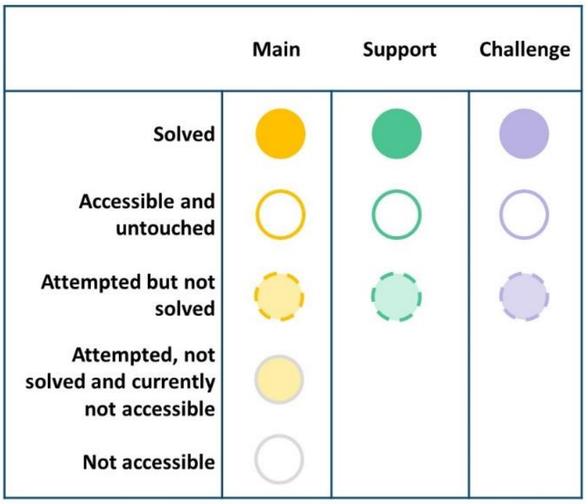
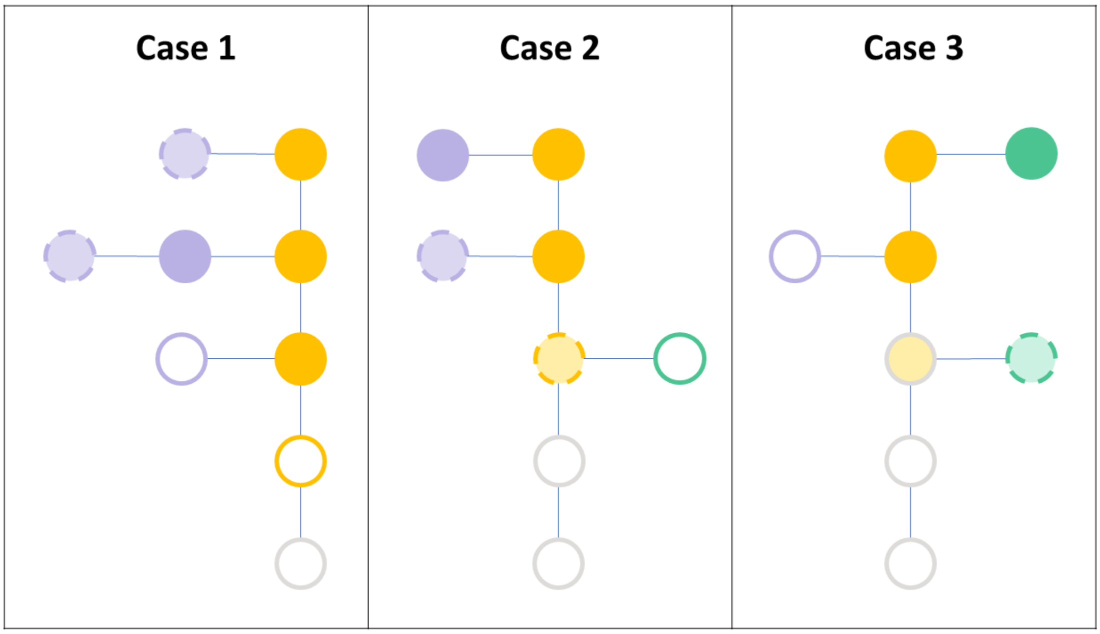


Figure 3.7. Indicative cases of students' journey in a learning graph.



In more detail, an example of how the system works, can be seen in case 2 (Figure 3.7). In this example, the student successfully solved the first main and challenge tasks, solved the second main task but didn't manage to solve the second challenge task. Finally, they unsuccessfully attempted to solve the third main task and the system provided them with the corresponding support task; a task that is now accessible but untouched by the student.

3.5.2. Adaptive task sequences in ASYMPTOTE

As stated in previous chapters, adaptivity has been a priority in ASYMPTOTE's development. Automatizations built in the system give the opportunity to the teachers to adapt the learning processes to each student, according to their performance (Barlovits et al., 2022).

DEFINITION

As Slavuj et al. (2017, p. 65) specify, "*Adaptivity in instructional systems can be broadly defined as the ability of a system to adjust instruction based on learner abilities and/or preferences, at any particular point of the instruction process, with the goal of acting on identified learner characteristics and improving the efficiency and efficacy of learning.*"

Adaptive learning systems focus on personalizing the learning processes in order to improve or accelerate students' performance (Oxman & Wong, 2014). The goal of such systems is to make the educational process challenging but not discouraging for each student. In ASYMPTOTE, advanced tasks are provided to students who have successfully solved the main task, making learning challenging but at the same time advanced tasks are optional, thus learning does not get intimidating for the user.

In general, ASYMPTOTE system, allocates tasks for the user (providing supporting or challenging tasks) based on their performance in previous tasks. The system follows the idea of micro adaptivity with ongoing measurement of students' work progress (Plass & Pawar, 2020). Hereby, the system validates the student's entered solution, i.e. giving corrective feedback (Moreno, 2004; Hattie & Timerley, 2007) and thus providing the next task depending on its correctness (challenging supporting).

According to Oxman and Wong (2014), adaptive learning tends to:

- achieve outcomes more effectively:
  ASYMPTOTES, as mentioned before, offers the possibility to the students to use hints or supporting subtasks, when they encounter difficulties. This function of the system provides the users with the missing knowledge and thus increases the effectiveness of the student towards the achievement of the set learning outcomes. Moreover, adaptive task assignment forces learners to work on the support tasks after they have failed at least twice in solving a main task. On the other hand, after successfully solving a main task, learners can independently decide whether to work on the more challenging task. Consequently, ASYMPTOTE learning graphs, that are based on a mixture of adaptive task assignment and autonomous task

invocation, can provide effective learning environments for online instruction.

- help teachers with educational processes (providing useful information, conserving time etc.):
  ASYMPTOTE, from a teacher's perspective, contributes by providing the means to create tasks fitting to the requirements of each student. The repository of tasks and the user-friendly learning graph creation process, allow teachers to design individualized learning experiences for their students quickly and efficiently. Moreover, the system through its Digital Classroom provides graphical and numerical outputs about students' performance on the completed learning graphs, helping the teacher have a clear image of the development of the teaching and learning process.

In more detail, ASYMPTOTE's Digital Classroom is supposed to adopt a classroom-like atmosphere by allowing the work on several LG for different topics, with more elaborate statistics during and after a session. Thus, a Digital Classroom could be opened for a long time, e.g., over the current unit, several months, or the entire term and provide teacher with useful information in order to personalize and adapt their teaching and learning processes to their students' needs.

The individual progress display facilitates the teacher to monitor each student's progress even from a distance. This includes: the current state of the LG, all points earned so far, all hints utilized, and all entered answers to every task in the LG. The latter is especially important for the teacher to gain insights into the chosen approach and adjust it by precise feedback to the student. This progress display also shows the student's individual learning path through the LG. This highlights the aspect of self-guided learning by visualizing the strategy that the student chose to complete the LG, e.g., by solving only the necessary main tasks or by seeking all challenge tasks or making use of every support task.

The class overview summarizes the individual progress data of the entire class on a well-structured analytic page. Every way chosen through the graph is displayed in one LG, which shows immediately where the majority was heading, which challenge task was most appealing, and which main task was the most difficult. More detailed statistics cover the average time spent on each task, the average amount of points earned, the most popular answers, the average number of hints required, and many more parameters either for each task or the entire LG. Hence, this class overview holds the potential for an efficient LG improvement loop, e.g., by removing/improving support tasks, which were never used, or by editing hints in a way that target the most common false inputs, or by restructuring the LG to improve the workflow through it and many more cases.

To put it in a nutshell: The Digital Classroom not only strives to create a fostering distance-learning environment with classroom-like features such as team chats and direct contact to the teacher. It also offers teachers detailed analytic feedback that allows for pinpointed interventions and help by evaluating the individual answers, as well as the overall progress of the entire class. Moreover, this information allows for improving specific tasks, intensifying the effort on a topic that was discovered to be lacking, and long-term assessment of the learning process conveniently.

These possibilities allow teachers to provide individualized support to the student in the sense of formative assessment (Black & Wiliam, 2003). The system provides user interaction data for an effective monitoring and evaluation of students' progress, rendering the design process easier for the teachers who can design learning graphs, with tasks adopted to each students individual learning progress. Thus, the system further allows assessment and the use of adaptive elements in online learning.

Lastly, to facilitate learning for students with disabilities, a read-out-loud mode and a zoom function are available. All the available tasks in the system are translatable in various languages which helps bridge language barriers, by facilitating teachers from around the globe to translate and use tasks into their language, and by enabling foreign students who are still learning the language to solve tasks in their mother tongue.

References

Alexander, C. (1979). *The Timeless Way of Building*. New York: Oxford University Press, ISBN: 0-19-502402-8

Artigue, M., & Perrin-Glorian, M. J. (1991). *Didactic engineering, research and development tool: some theoretical problems linked to this duality*. For the learning of Mathematics, 11(1), 13-18.

Bangert-Dorwns, R.L./ Kulik, C. C./ Kulik, J. A./ Morgan, M.T. (1991). The instructional effect of feedback in test-like events. *Review of Educational Research*, 61, 213-238.

Barlovits, S., Kolokytha, A., Ludwig, M., Fessakis, G., (2022). *Designing mobile environments for mathematics distance education: The theory-driven development of the ASYMPTOTE system*. Unpublished manuscript.

Becker, J. P., & Shimada, S. (1997). *The Open-Ended Approach: A New Proposal for Teaching Mathematics*. National Council of Teachers of Mathematics, 1906 Association Drive, Reston, VA 20191-1593.

Beal, C. R., Walles, R., Arroyo, I., & Woolf, B. P. (2007). On-line tutoring for math achievement testing: A controlled evaluation. *Journal of Interactive Online Learning*, 6(1), 43-55.

Birenbaum, M./ Tatsuoka, K. (1987). Effects of „on-line" test feedback on the seriousness of subsequent errors. *Journal of Educational Measurement*, 24, 145-155.

Brusilovsky, P. L. (1992, June). A framework for intelligent knowledge sequencing and task sequencing. In *International Conference on Intelligent Tutoring Systems* (pp. 499-506). Springer, Berlin, Heidelberg.

Chevallard, Y. (1999). *The analysis of teaching practices in the anthropological theory of the didactic*.

Clariana, R.B. (1993). A review of multiple-try feedback in traditional and computer-based instruction. *Journal of Computer-Based Instruction,* 20, 67-74.

Clow, D. (2013). An overview of learning analytics. *Teaching in Higher Education*, 18(6), 683-695.

Cross, R. (1997). Developing Math Trails, Mathematics Teaching, 158, 38–39.

Dabbagh, N. (2005). Pedagogical models for E-Learning: A theory-based design framework. *International Journal of Technology in Teaching and Learning*, 1(1), 25-44.

Dabbagh, N., Bannan-Ritland, B. (2005). *Online learning: Concepts, strategies, and application* (pp. 68-107). Upper Saddle River, NJ: Pearson/Merrill/Prentice Hall.

Deci, E. L., & Ryan, R. M. (2008). Self-determination theory: A macrotheory of human motivation, development, and health. *Canadian psychology/Psychologie canadienne*, 49(3), 182.

Dillenbourg, P. (2002). Over-Scripting CSCL: The risks of blending collaborative learning with instructional design. In Kirschner, P. A. (Ed.), *Inaugural Address, Three Worlds of CSCL. Can We Support CSCL?* Heerlen: Open Universiteit Nederland, 61-91.

Ferguson, S. (2020). Online Mathematics Education, the Good, the Bad, and the General Overview. *Teaching and Learning Mathematics Online*, 405-418.

Fesakis, G., Karta, P., & Kozas, K. (2018). Designing Math Trails for Enhanced by Mobile Learning Realistic Mathematics Education in Primary Education. *International Journal of Engineering Pedagogy* (iJEP), 8(2), 49-63.

Goodyear, P. (2015). *Teaching as design*. HERDSA Review of Higher Education, 2, 27-50.

Gurjanow, I., Oliveira, M., Zender, J., Santos, P. A., & Ludwig, M. (2019). Mathematics trails: Shallow and deep gamification. *International Journal of Serious Games,* 6(3), 65-79.

Hadzhikolev, E., Hadzhikoleva, S., Hristov, H., Yonchev, E., & Tsvetkov, V. (2021). Modeling of Pedagogical Patterns in an E-learning System. *International Journal of Emerging Technologies in Learning (iJET)*, 16(24), pp. 205–219. https://doi.org/10.3991/ijet.v16i24.26775

Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of educational research,* 77(1), 81-112.

Hernández-Leo, D., Asensio-Pérez, J. I., Dimitriadis, Y., Bote-Lorenzo, M. L., Jorrín-Abellán, I. M., & Villasclaras-Fernández, E. D. (2005). Reusing IMS-LD formalized best practices in collaborative learning structuring. *Advanced Technology for Learning*, *2* (4).

Hernández-Leo, D., Villasclaras-Fernandez, E. D., Asensio-Pérez, J. I., Dimitriadis, Y., Jorrín-Abellán, I. M., Ruiz-Requies, I., Rubia-Avi, B. (2006). COLLAGE: a collaborative Learning Design editor based on patterns. *Educational Technology & Society, 9*(1) pp. 58–71.

Hodgen, J., Taylor, B., Jacques, L., Tereshchenko, A., Kwok, R., Cockerill, M. (2020). *Remote mathematics teaching during COVID-19: intentions, practices and equity*. London: UCL Institute of Education.

Kochmar, E., Vu, D. D., Belfer, R., Gupta, V., Serban, I. V., & Pineau, J. (2020, July). Automated personalized feedback improves learning gains in an intelligent tutoring system. In *International Conference on Artificial Intelligence in Education* (pp. 140-146). Springer, Cham.

Larmann, P., Barlovits, S., Ludwig, M. (2021). MCM@home: Analyzing a Learning Platform for Synchronous Distance Education. In Book of accepted contributions of the *15th International Conference on Technology in Mathematics Teaching, ICTMT* 15, Copenhagen, Denmark, 13–16 September.

Laurillard, D. (2012). *Teaching as a design science: Building pedagogical patterns for leaning and technology*. New York: Routledge.

Leont'ev, A. N. (1978). *Activity, consciousness, and personality* (Hall, M. J., Trans.). Englewood Cliffs, NJ: Prentice-Hall. (Original work published 1975)

Lieberoth, A. (2015). Shallow gamification: Testing psychological effects of framing an activity as a game. *Games and Culture*, 10(3), 229-248.

Macfadyen, L. P., & Dawson, S. (2012). Numbers are not enough. Why e-learning analytics failed to inform an institutional strategic plan. *J. Educ. Technol. Soc.*, *15*(3), 149-163.

Margolinas, C. (2013, July). Task design in mathematics education. *Proceedings of ICMI study 22*. In ICMI Study 22.

Mason, J., & Johnston-Wilder, S. (2006). *Designing and using mathematical tasks*. Tarquin Publications.

McKendree, J. (1990). Effective feedback content for tutoring complex skills. *Human-Computer Interaction*, 5, 381-413.

Mor, Y., & Winters, N. (2007). Design approaches in Technology Enhanced Learning. *Interactive Learning Environments*, *15*(1), 61–75.

Moreno, R. (2004). Decreasing cognitive load for novice students: Effects of explanatory versus corrective feedback in discovery-based multimedia. *Instructional science*, 32(1), 99-113.

Narciss, Susanne (2006). *Informatives tutorielles Feedback. Entwicklungs- und Evaluationsprinzipien auf der Basis instruktionspsychologischer Erkenntnisse.* Münster: Waxmann.

Oliver, R., Harper, B., Hedberg, J., Wills, S. & Agostinho, S. (2002). *Formalising the descriptions of learning designs*, 496-504. https://ro.uow.edu.au/edupapers/193

Oxman, S., Wong, W., (2014). White paper: Adaptive learning systems. *Integrated Education Solutions*, 6-7.

Plass, J. L., & Pawar, S. (2020). Toward a taxonomy of adaptivity for learning. *Journal of Research on Technology in Education*, 52(3), 275-300.

Richardson, M. (2004). Designing Math Trails for the Elementary School, Teaching Children Mathematics, 11(1), 8-14

Schimmel, B. J. (1983). *A meta-analysis of feedback to learners in computerized and programmed instruction.* Paper presented at the Annual Meeting of the American Educational Research Associates Montreal, Canada (ERIC document Reproduction Service No. ED233708).

Shoaf, M. M., Pollak, H., & Schneider, J. (2004). Math trails. Lexington: COMAP

Sin, K., & Muthu, L. (2015). APPLICATION OF BIG DATA IN EDUCATION DATA MINING AND LEARNING ANALYTICS--A LITERATURE REVIEW. *ICTACT journal on soft computing*, *5*(4).

Slavuj, V., Meštrović, A., & Kovačić, B. (2017). Adaptivity in educational systems for language learning: a review. *Computer Assisted Language Learning, 30*(1-2), 64-90.

Staiger, C. M. (2016). *Entwicklung und Erprobung gestufter Feedbackkomponenten zu ausgewählten Themen der Bruchrechnung in Klasse 6 zur Implementierung in ein dynamisches Testverfahren. Qualitative Fallanalysen zur Wirkungsweise und weiteren Umsetzung der Feedbackinhalte (*Dissertation, Pädagogische Hochschule Weingarten).

Van der Kleij, F. M., Eggen, T. J., Timmers, C. F., & Veldkamp, B. P. (2012). Effects of feedback in a computer-based assessment for learning. *Computers & Education*, 58(1), 263-272.

Yang, F., Li, F. W., & Lau, R. W. (2010, December). An open model for learning path construction. In *International Conference on Web-Based Learning* (pp. 318-328). Springer, Berlin, Heidelberg

Appendix A. Online Teaching Skills Checklist

Activity 1.4

Assess your online teaching by using the following rating scale. For each of the standards that your rating is below 4, write down the ways that, in your opinion, could help you improve. Discuss your answers with your peers.

Rating Scale

0: Absent - component is missing
1: Unsatisfactory - needs significant improvement
2: Somewhat satisfactory - needs targeted improvements
3: Satisfactory - discretionary improvement needed
4: Very satisfactory - no improvement needed

Pedagogical skills

Standard	Rating	Ways to improve
The online teacher supports learning and facilitates presence (teacher, social, and learner) with digital pedagogy.		
The teacher knows understands and applies to their instruction, the value of active learning, participation, and collaboration within the online classroom.		
The online teacher motivates students and shows enthusiasm and interest, while encouraging knowledge construction based upon learners' prior knowledge and life experience.		
The online teacher personalizes instruction based on the learner's diverse academic, social, and emotional needs, while incorporating accommodations into the online environment.		
The online teacher understands how students learn and develop, and provides opportunities that support their intellectual, social, and personal development.		

The instructor ensures that course material is accessible to student with disabilities.		

Technological Skills

Standard	Rating	Ways to improve
The instructor effectively uses a range of technologies tools existing or emerging - both within and outside of the Learning Management System - that support student learning and engagement in the online environment.		
The instructor knows understands and applies to their instruction, the value of active learning, participation, and collaboration within the online classroom.		
The online instructor understands the learning and teaching capabilities and limitations of these tools.		
The online teacher demonstrates competencies in creating and implementing assessments in online learning environments in ways that ensure validity and reliability of the instruments and procedures.		
The instructor knows and understands methods for collecting data regarding student learning and uses this data to modify instructional methods and content and assess student's performance.		
The teacher arranges media and content to help students and teachers transfer knowledge most effectively in the online environment.		

Design Skills

Standard	Rating	Ways to improve
The online teacher understands the central concepts, tools of inquiry and structures in online instruction and creates learning experiences that take advantage of the transformative potential in online learning environments.		
The online teacher curates and creates instructional materials, tools, strategies,		

and resources to engage all learners and enable student success.		
The online teacher plans and teaches well-structured lessons		

Content Skills

Standard	Rating	Ways to improve
The online teacher demonstrates good subject and curriculum knowledge.		
The online instructor is able to link the subject and content with scientific, social, cultural, and any other relevant phenomena.		
The online teacher develops a course outline that includes all course components and elements, as well as an inventory of existing content, resources and any additional material that will be needed.		
The teacher develops and delivers assessments, projects, and assignments that meet standards-based learning goals and assesses learning progress by measuring student achievement of learning goals.		
The online teacher plans and prepares instructions based upon knowledge of subject matter, students, the community, and curriculum goals.		
The online teacher understands, uses, and interprets formal and informal assessment strategies to evaluate and advance student performance and to determine program effectiveness.		

Social and Communication Skills

Standard	Rating	Ways to improve
The online instructor uses sufficient and commonly understandable language, requests information and asking questions clearly, while clarifying the purpose and meaning of messages and feedback.		
The online teacher uses a variety of communication techniques including		

verbal, nonverbal, and media to foster inquiry, collaboration, and supportive interaction in and beyond the classroom.		
The online teacher interacts in a professional, effective manner with colleagues, parents, and other members of the community to support students' success.		
The online teacher creates and develops respectful relationships and a sense of community among the learners while maintaining a warm, friendly, and inviting atmosphere.		
The online teacher personalizes messages and feedback and making them more lively by adding the appropriate sense of humor when possible and by showing sensitivity and empathy.		
The online teacher facilitates and maintains interactive discussion and information exchange, while respecting and considering cultural differences.		

Management and Institutional Skills

Standard	Rating	Ways to improve
The teacher meets the professional teaching standards established by a state-licensing agency or the teacher has academic credentials in the field in which they are teaching.		
The online teacher is a reflective practitioner who demonstrates a commitment to professional standards and is continuously engaged in purposeful mastery of the art and science of online teaching.		
The instructor knows, understands, facilitates, complies, and encourages legal, ethical, and safe technology use, and copyright issues and standards.		
The teacher provides online leadership, management, mentoring, and coaching in a manner that promotes student success through regular feedback, prompt response and clear expectations.		

The instructor is able to manage the course time and apply time-saving techniques.		
The online instructor establishes and declares clear rules and regulations for participation, submission of assignments, timeliness, sending and seeking feedback, and communication protocols.		
The online teacher is tracking course and students' progress on a regular basis.		