

E-learning for fostering the growth of students responsible for their own learning: didactic organization and theoretical reflections

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Abstract. Nella nostra ricerca, abbiamo progettato alcuni workshop di valutazione formativa online per aiutare gli studenti a diventare responsabili del proprio apprendimento. Questi workshop sono stati sperimentati con studenti universitari di due diversi corsi (ingegneria e futuri insegnanti delle scuole elementari) e di due diverse università italiane. Il lavoro ha due obiettivi: descrivere la progettazione delle attività e proporre una riflessione teorica basata sul cosiddetto “tetraedro dell’e-learning”, un adattamento del classico triangolo didattico ai nuovi ambienti offerti dalle piattaforme online.

1. Introduction

This work has its roots back in 2003-2004 when the use of the e-learning platform IWT (Albano et al., 2007) was introduced at the University of Salerno to support face-to-face mathematics courses for engineering students. On that occasion, preliminary investigations were conducted on the students’ expectations and beliefs concerning the relevance of the platform support on their learning, on their relationship with mathematics and with the teacher, on the perceived quality of the online course (Albano, 2005). It was found that most of the students welcomed the use of an e-learning platform in a very positive way, assuming that this surely would enhance learning just because the use of technology was in tune with the time. This belief was not shared by many teachers at the time. A more interesting result of the investigation was the students’ expectation of an improvement of the relationship with the teacher, who was perceived as closer, being always present and reachable by means of the platform. This expectation is particularly related to difficulty encountered by the Italian students shifting from the high school context (around 25 students per classroom) to the university context (around 150 students per classroom). Later studies (2007-2009) focused on the exploitation of the e-learning platform IWT for personalizing individual learning paths and for promoting a more active and critical attitude towards mathematics learning by engaging students in a cooperative learning methodology based on role-play. On the one hand, due some IWT features allowing an ontology-based knowledge representation and a student model representation, the platform was able to deliver an appropriate sequence of learning objects to each student, that could be suitably adjusted on-the-fly according to update information on the student’s assessment (Albano, 2011). On the other hand, drawn from the very idea of “web”, the individualized learning paradigm was flanked by putting the students in a cooperative learning context where each of them has a specific role and her part of work was essential to make the whole activity successful. Students were required to assume subsequently the role of a teacher investigating learning about a given topic so that they are required to formulate suitable questions; then the role of a student answering some given questions with the aim of showing her successful learning; finally the role of a teacher assessing the quality of questions and answers (Albano, 2009). The first role has been perceived the most challenging for students and has allowed them to bring into play various mathematical competencies (Albano & Pierri, 2014). An initial systematization of the studies on e-learning and mathematics was the focus of the PRIN 2007 project “Insegnamento- apprendimento della matematica ed e-learning: utilizzo di piattaforme per personalizzare l’insegnamento nella scuola secondaria superiore, nel raccordo secondaria- università, e

all’università” (Bottino, Ferrari & Ott, 2011), and later of the Seminario Nazionale di Ricerca in Didattica della Matematica 2013 “La ricerca in e-learning e in didattica della matematica: integrazione, esperienze e riflessioni” (<https://www.airdm.org/xxx-seminario-nazionale-in-didattica-della-matematica/>). The main result of this systematization was a new systemic model expanding the classic didactic triangle (Chevallard, 1985) into the so called “e-learning tetrahedron”, where the new vertex “Author” was introduced (Figure 1).

In order to take into account the complexity of the design in the e-learning environment, the role of the teacher has been split into two actors: the Tutor, who takes on that part of the teacher who actively cares about helping the student to learn, and the Author, who takes on the teacher’s task of being in charge of planning, developing and managing the didactic organization and the resources. Differently from the classical didactic triangle, in the e-learning tetrahedron the vertices are intended as roles that can be assumed by any actor in the teaching/learning process (Albano, 2017). As we will see below, this character of dynamicity of the vertices may shed light on the designed e-learning activity.

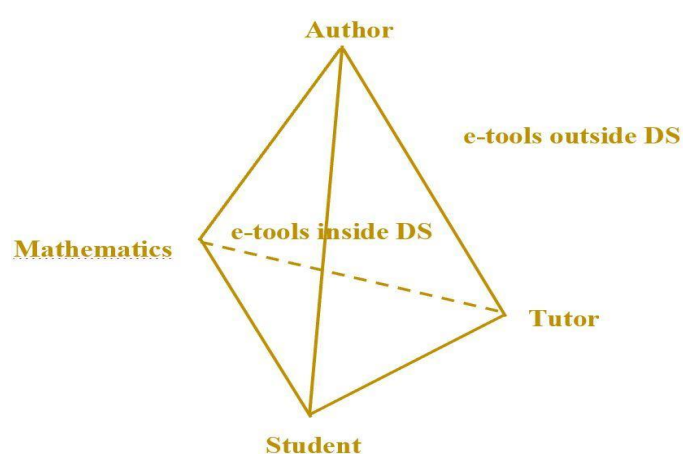


Figure 1. The e-learning tetrahedron model

From 2017 on, moving definitively to Moodle platform, a slightly different activity was designed, inspired by the above-mentioned cooperative learning activity and exploiting the Moodle tool called “workshop”. The Moodle workshop was born as an empty box allowing peer-assessment. It foresees the delivery of a task and students are required to solve it and then to assess a peer solution, according to given criteria.

Taking a formative assessment perspective, we designed and experimented online formative assessment workshops with University students showing mainly an operational view of mathematics (such as engineering students) and in students with a low motivation and low competences in mathematics (such as prospective primary teachers). The didactical aim is promoting critical thinking through argumentation.

The future teachers’ feelings about their participation in the activity and their perceived impact on their learning process have been investigated and presented at the CIEAEM 71 conference (Sabena, Albano & Pierri, 2020). An overview of the FA impact on the students’ argumentation competence has been presented at the ICTMT14 (Albano, Pierri & Sabena, 2020).

In this paper, besides describing the design of the activities, we propose a theoretical reflection based on the so called “e-learning tetrahedron” in order to highlight the complexity of the e-learning environment. Before introducing the online FA workshops, we will outline the theoretical elements grounding the design.

2. Formative assessment in technology-based environment

Within education literature, in contrast to assessment *of* learning, formative assessment (FA) or assessment *for* learning includes all the activities and practices that teachers enact in order to improve students’ learning.

FA is thus conceived as a teaching method, where “evidence about student achievement is elicited, interpreted, and used by teachers, learners, or their peers, to make decisions about the next steps in instruction that are likely to be better, or better founded, than the decisions they would have taken in the absence of the evidence that was elicited” (Black & Wiliam, 2009, p. 7). Wiliam and Thompson (2007) have elaborated a theoretical framework for FA, highlighting that it can be developed through five key strategies and three main actors: the teacher, the peers, and the learner. The FA strategies are shown in Figure 2:

	Where the learner is going	Where the learner is right now	How to get there
Teacher	1 Clarifying learning intentions and criteria for success	2 Engineering effective class-room discussions and other learning tasks that elicit evidence of student understanding	3 Providing feedback that moves learners forward
Peer	Understanding and sharing learning intentions and criteria for success	4 Activating students as instructional resources for one another	
Learner	Understanding learning intentions and criteria for success	5 Activating students as the owners of their own learning	

Figure 2. FA strategies according to Wiliam and Thompson (2007)

The teacher is responsible for clarifying learning objectives and criteria for success, which become assessment criteria (key strategy 1), for organising class activities and discussions in which she can have evidence of pupils' understanding (key strategy 2) and for providing feedback to enable students to progress in learning (key strategy 3). Learners have important roles, both in understanding the learning objectives and criteria for success (key strategy 1), and in taking responsibility for the learning of their fellow students and themselves (key strategies 4 and 5).

Within this model, feedback plays a crucial role. It concerns the information that the student receives about his/her performance and is undoubtedly one of the most important tools for building a bridge between actual and expected learning. Following the definition of Ramaprasad (1983), feedback only becomes formative if the information given to the student is used in some way to improve her/his performance. It is therefore important that the feedback goes beyond a simple green or red 'traffic light' for the student, which would merely orient the student's behaviour, and that it rather shows him what any errors, deficiencies, inaccuracies and possibly what may cause them. Based on these reflections, Hattie and Timperley (2007) then distinguished four types of feedback:

- a) *feedback on the task*: attention is focused on the interpretation of the text of the task or the correctness of the response provided (a sort of feedback on the *product*);
- b) *feedback on the performance of the task*: it regards the *processes* necessary to understand and effectively address the task;
- c) *feedback for self-regulation*: it addresses the individual's ability to self-monitor and consciously direct her/his own actions;
- d) *feedback on the individual as a person*: it concerns issues related to the individual and includes emotional aspects.

Based on extensive meta-analysis, Hattie and Timperley (ibid.) highlight the effectiveness of feedback on the task (type a) and its performance (type b), while minor effects are found on feedback on the person, such as compliments and reprimands (type d).

Due to the great amount of data that is involved, and the individual nature of effective feedback, FA practices usually are highly demanding for teachers. Recently, innovative projects have given attention to the

new possibilities offered by technology in this respect, such as the STEP project (Chazan et al., 2016) and the European project FaSMEd (*Improving Progress for Lower Achievers through Formative Assessment in Science and Mathematics Education*, <https://microsites.ncl.ac.uk/fasmedtoolkit/>). Within FaSMEd, a new framework for the design and implementation of technologically-enhanced formative assessment activities has been proposed (Aldon et al., 2017; Cusi et al., 2017). This framework points attention, besides the five FA *key-strategies* and the different *agents* involved in FA, on how *technology* may support FA processes within educational contexts. Specifically, three main *functionalities for technology in mathematics FA* have been identified:

- (1) *Sending and displaying*, e.g. sending and receiving messages and files, displaying and sharing screens or documents to students;
- (2) *Processing and analysing* data collected during the lessons, e.g. showing the statistics of students' answers to polls or questionnaires, or the feedbacks given directly by the technology to the students when they are performing a test;
- (3) *Providing an interactive environment*, in which students can interact to work individually or in groups on a task or to explore mathematical/ scientific contents (e.g. the use of specific software where it is possible to dynamically explore specific mathematical representations).

In our research study, we refer to the sending-and-displaying and the processing-and-analysing functionalities of an online platform to promote mathematics formative assessment processes involving the three agents—teacher, students and peers—and in particular peers in a blended modality. Shared experiences and literature review (Larreameydy-Joerns & Leinhardt, 2006) show evidence of benefits from the integration of online instruction practices at University level. These benefits seem to be mainly found in the freedom of the students to move at their own pace. Nonetheless, there is not enough literature reporting the actual added-value of online with respect to the traditional face-to-face instruction.

3. The design of the FA online workshops

On the base of the theoretical elements outlined above, the design of FA online workshops consists of various phases (Figure 3).

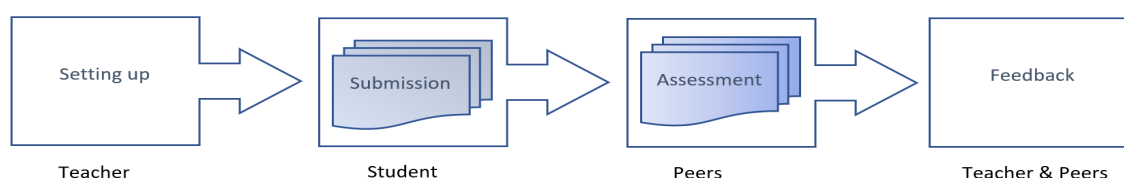


Figure 3. The phases of the FA online workshops

The first phase, that is the “Setting up of the workshops”, requires a didactical design on various levels:

1. *The task*: the choice of tasks appropriate to the educational goal to be reached is required.

In Figure 4 an example of task assigned to engineering students is shown. Besides the standard exercises/problems on linear algebra, the added request of suitably justifying the solution is stressed, together with the explicit reference to the correctness, completeness and clearness criteria.

Let us consider the following matrix

$$A = \begin{pmatrix} -h & 1 & 0 & -h \\ 0 & -2 & 2 & 1 \\ h & 2 & h & -2h \end{pmatrix}$$

a) for every real h compute the dimension and a basis B of the vector space V generated by the rows of the matrix A ;
b) for $h=1$ say if $u=(-1,4,3,3)$ belongs to V and, if so, compute $|c_B(u)$ where B basis computed at the point a);
c) for $h=1$ compute the dimension and a basis of V^\perp .

For each question, give suitable justifications.
Take care of solving in a correct, complete and clear manner.

Figure 4. Task assigned to engineering students

Figure 5 shows an example of task assigned to prospective primary teachers, concerning reasoning and argumentations with natural numbers.

Answer to the following questions and justify your answers in a correct, clear and complete way:

1. Consider a natural number and find the difference between its square and its previous one's square. Repeat the operation for different numbers: which regularities do you observe?
2. Consider the sum between a natural number and its square. Repeat the operation for different numbers: which regularities do you observe?
3. For each of the following statements, tell if it is true or false, and justify:
 - a. if two numbers are multiples of 6, hence their sum is multiple of 3;
 - b. if two numbers are multiples of 3, hence their sum is multiple of 6;
 - c. if the product of two numbers is odd, hence their sum is even;
 - d. if the sum of two naturals is odd, hence their product is odd.

Figure 5. Task assigned to future primary teachers

2. *The assessment criteria*: according to the FA strategy 1, it is necessary that the teacher shares with the students the criteria that determines success in the disciplines. The same criteria are to be used by students to assess the solutions given by their peers. This is a crucial point: indeed, students often have a completely different vision of successful learning, from the teacher's one (for instance, some students may value positively the ability to repeat the exact words reported in a book or to reproduce a solving procedure without awareness).

In our workshops we chose three criteria to assess the argumentation processes:

- a. *Correctness*: it concerns the presence of errors, either in the result or in the solving process, the accuracy of theoretical notes, and of mathematical symbols used.
- b. *Completeness*: it refers to identifying possible missing parts or jumps in reasoning as well as unjustified conclusions.
- c. *Clarity*: it pertains to the clear and unambiguous expression of the sentences and reasoning.

In order to make the assessor clear and focused on what is required to assess, and in particular to support them to give feedback on the processing of the task and not only on the task or on the individual as a person, ad hoc prompts have been formulated for each criteria (e.g. Are the mathematical symbols used correctly? Is there any missing step in the argumentation?). In particular, students were encouraged to provide suggestions to their mates to help them to overcome their mistakes (FA strategies 4 and 5); here it is an example:

If you identify errors or aspects that you think are not fully correct, report them to the student.

It may be useful for you to mark the errors directly on the paper you are evaluating, after having printed it out or processed it with an electronic device. Remember to upload the file with your feedback on time!

In any case, write a comment about the correctness of the paper.

If you have found frequent errors or unanswered questions, give some suggestions to your partner (indicating how to solve them, but also what you need to review, or other suggestions that you think are useful to improve).

3. *The organization*: some parameters need to be set, regarding the administration of the workshop:
 - a. *Number of reviews*: this parameter allows to set how many reviews each student has to carry out. In our case, we set to three this number. This means that each student reviews three peers' products and she receives three peers' reviews on her submission.
 - b. *Distribution plan*: how students will receive the submissions of their peers should be fixed. Choosing scheduled allocation, as in our case, there is an automatic switch from the submission phase to the assessment phase, once the deadline for submissions is over. The distribution of the submissions to the students is carried out randomly by the platform, according to the fixed number of reviews.
 - c. *Availability*: it deals with setting submission times and assessment times, that is starting and deadline for solving the task and for assessing the peers' work. In our case, we considered two days for submission and four days for assessment.

In the second phase of the workshop (“Solve and justify”), students are asked to solve the problems and to return the solution within the given submission time. At the end of the second phase, the platform allocates for every student the set number of reviews.

The third one is the “Peer assessment” phase, where the students review the peer's work according to the suggested criteria, activating as an instructional resource for their mates (FA strategy 4).

In the fourth phase the teacher chooses some students' productions as optimal and provides feedback on typical mistakes, by making them available on the platform. This phase is not built-in to the Moodle workshop, but we consider it as fundamental.

According to the FaSMEd three-dimensional framework, during the second and the third phases, the two functionalities of *Sending and displaying* and *Providing an interactive environment* have been exploited by means of the Moodle workshop tool. Moreover the three FA strategies of *Clarifying and sharing learning intentions and criteria for success* (FA1) and of *Activating students both as instructional resources for one another* (especially in the third phase, where students and peers are engaged) (FA4) and *as the owners of their own learning* (especially in the second phase where only students are engaged) (FA5). In the fourth phase, the teacher's involvement and her work shift the focus of the FA strategies towards *Providing feedback that moves learners forward* (FA3).

3.1 Participants and data collection

Students from the University of Salerno and the University of Torino were involved in the online FA workshops, during the years 2018-2019. In the former case, they attended a traditional f2f course of Geometry, Algebra and Logic for Computer Engineering (first year, second term), dealing with linear algebra and logic contents. In the latter case, the students attended a course of Mathematics and Mathematics Education for prospective primary teachers, addressing arithmetic and early algebra (first year, first term).

The two courses are very different in content and in students' background. Nevertheless, a common major goal of the courses was developing argumentative competence in mathematics, besides content's knowledge and procedural skills. This allowed us to elaborate a common design for students' online activities.

Reports and materials available on Moodle for each enrolled student served as data collection.

3.2 FA delivery plan

The delivery plan was specific for each course. At the University of Salerno, four online FA workshops were delivered along the course. Since the students were expected to carry out two written tests (one mid-term and one final), the FA workshops served to refresh the memory and critically review the course's contents covered by the upcoming test. Hence the workshops have been concentrated before the tests, delivering two of them before the mid-term test and two more before the final test. For every workshop, each student

received one problem to work on. For each workshop, about 40 different problems have been prepared, distributed to the students so that at most 4 students worked on the same problem.

At the University of Torino, five online FA workshops have been carried out along the course, about one every two weeks. Each student received about 3 problems, concerning the topics introduced during the f2f classes attended just before the delivery of the workshop.

In both cases, all the students registered in the course on the Moodle platform were allowed to participate in the workshops, even those not attending the f2f course.

For all the students, participation was not mandatory and the workshops have been proposed as a learning support.

4 The FA online workshop through the lens of the e-learning tetrahedron

Grounding on our experience with the FA online workshops, we will present some theoretical reflections that try to grasp the complexity of the didactical system in which the FA activity is immersed, and in particular the role played by technology. In doing this, we exploit the “e-learning tetrahedron” introduced by Albano (2017) and presented above (Figure 1).

As mentioned above, the e-learning tetrahedron redefines the classical didactic system taking into account the changes due to the introduction of an educational e-environment, and more precisely an e-learning platform. Besides the classical two entities consisting in Mathematics, that is knowledge to be taught/learned, and Student, that is the end user of the teaching/learning process, the third entity, the teacher, has been split into two figures: the Tutor and the Author. Because of the e-environment, the design of the resources has to be extremely precise, and various different skills: that’s why the Author is a collective entity, constituted of people with different expertise, collaborating among them. It is worthwhile to note that the e-learning tetrahedron foresees the technology inside and outside it. The difference lies not in the type of technology but in the didactic intention of its use: if an e-tool is chosen because it accomplishes a certain didactic function, then it is to be considered internal to the tetrahedron, otherwise it is outside.

The e-learning tetrahedron allows us to have a *double lens*:

- at a *macro* level: from each vertex of the tetrahedron one can observe the face generated by the other three vertices, focusing on the inter-relationships within the face, without completely separating each element from the others;
- at a *micro* level: each vertex of the tetrahedron is assumed as a role that can be played by any actor of the system, who is involved at a specific moment and in an appropriate situation during the teaching/learning process.

In the following, we will first draw some reflections using the e-learning tetrahedron at a macro level.

Being in the Author vertex, one looks at the classical didactical triangle which concerns the teaching/learning process (Figure 6a). In this respect, the Author is therefore responsible for:

- defining the learning objectives, on the basis of theoretical frameworks she chose explicitly or implicitly: in the described experiences, the teachers of the courses (which are part of the Author) assume a relational view of mathematics (Skemp, 1976) and believe that the development of argumentative competency enables a relational approach to mathematics learning to be fostered;
- designing the learning activity, that means on the one hand setting roles and actions of the agents involved, and on the other hand choosing appropriate functionalities of the e-tool to be used: in the FA workshop experiences, this means setting that the student plays two roles, the one who solves a task and the one who assesses the work of a peer, that each of these two roles is played simultaneously by all students in a restricted time; it also means choosing the assessment criteria as well as choosing to share them with the students, and from these choices come out the functionalities of the e-tools needed for their implementation, such as the possibility to distribute among peers the students’ solutions together with specific guidance on the evaluation criteria;
- organizing the e-environment: in the described experiences, the Author has organized the e-environment as a Moodle course, where the students have been enrolled and were able to access the learning activity

implemented as Moodle workshop, then the Author set the organization of the workshop as explained in section 3.

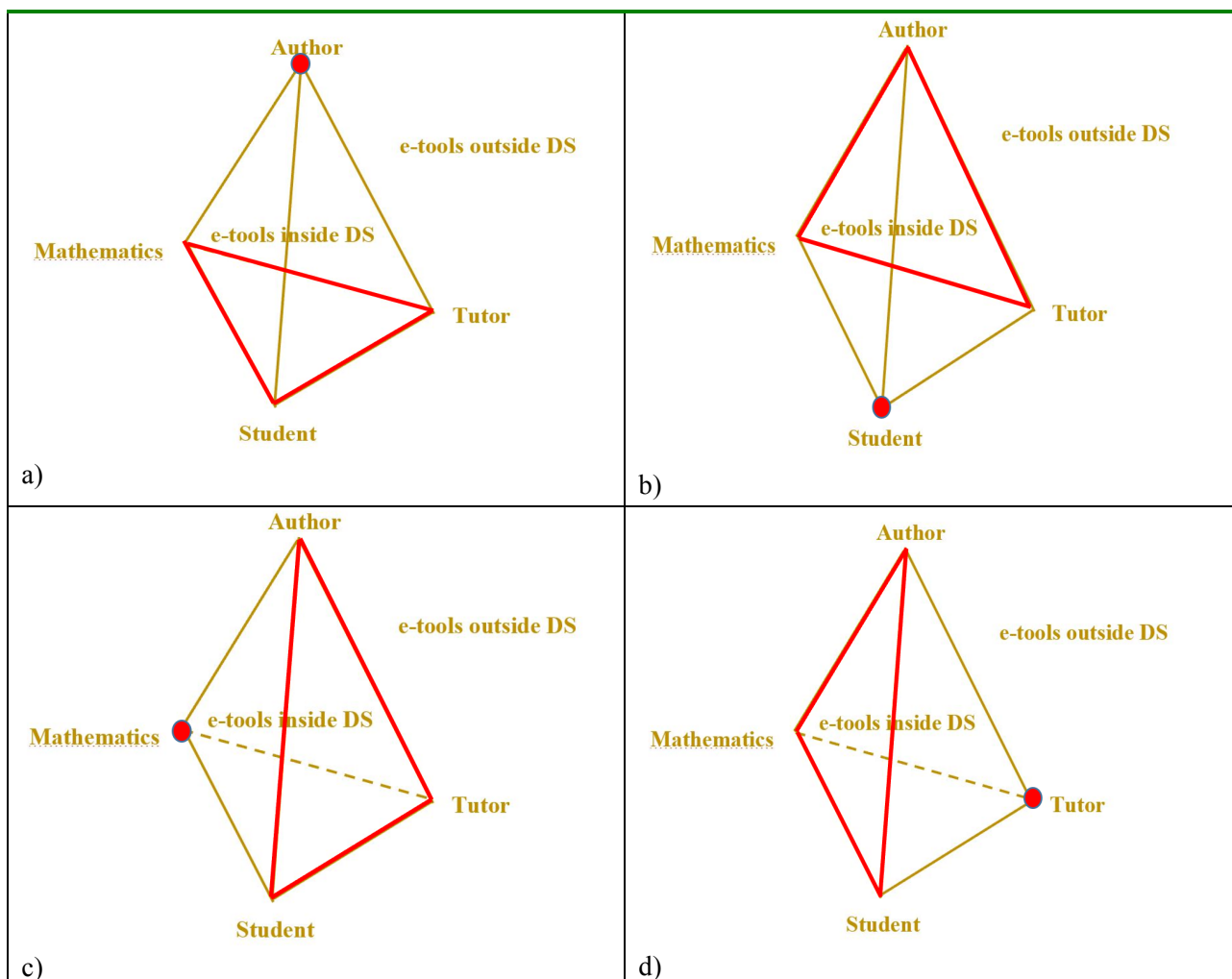


Figure 6. The e-learning tetrahedron. Different points of view and faces are highlighted in red colour.

Being in the Student vertex, one looks at the face Author-Mathematics-Tutor (Figure 6b)). Here the design pre-set by the Author, which refers to certain educational objectives related to Mathematics, is plunged in a specific student context that is reported by the Tutor. As a result, adaptations and redesigns can come out. This has been the case of the course for engineers (at the University of Salerno), where not all the students were required to solve the same task and thus in the assessment phase the student might find herself assessing a different task from the one she had solved in the previous phase.

This face concerns also the setting of the e-environment, including technical organizational issues, such as the creation of a course on the platform, the students enrolment, and so on.

Being in the Mathematics vertex, one looks at the face Author-Student-Tutor (Figure 6c). This face allows to focus on the methodological choices made by the Author, which can be shared with the students by the Tutor. In the case of the University of Torino, as the learning activity has been devoted to prospective teachers, this sharing of theoretical frameworks and assumptions on the teaching-learning process is of utmost importance. As well established in several research studies, the sharing of theoretical tools and of practices between researchers and teachers is a key-element for teachers' professional development (for instance, Arzarello et al., 2014 speak of meta-didactical transposition processes). In particular, through the

participation of online FA workshops and through a guided reflection on their own experience, students may encounter theoretical models for FA and feedback (as those presented in this paper), which become “boundary objects” between the community of future teachers and the research community (represented by the teacher): “A boundary object allows different communities to work together without preliminary consensus, due to its “interpretive flexibility” (Star, 2010). Boundary is not intended as a line of demarcation, but rather as a “metaphorical place” where different communities can act and possibly interact and create” (Robutti et al., 2020, p. 213).

Being in the Tutor vertex, one looks at the face Author-Mathematics-Student (Figure 6d). Here the focus is on the Student who interacts with the Mathematics starting from the e-environment and the resources pre-set by the Author. On the one hand, the interaction can develop by an individual learning process, that means interaction with automatic resources implemented and available in the platform (e.g. applet, maps, quiz). On the other hand, spontaneous collaborative learning processes can be stimulated and activated by the fact that the students are getting involved in various activities and interacting with different resources available in the platform. This way the students move from being a classroom group towards being a learning community (Wenger, 1998).

In these spontaneous processes we can see the entrance in the tetrahedron of technological tools external to the didactic system (in the sense that the didactic use had not been foreseen by the Author), as for example some chats of Whatsapp or other social media, that become a learning space and not just news retrieval.

Now let us make some remarks using the e-learning tetrahedron at micro level, which allows to give evidence of the dynamicity of the vertices conceived as roles.

As the design shows, the second task of the FA workshops provide for the student to assess the work of a peer, according to given criteria. Using the lens of the e-learning tetrahedron, we can say that in this phase the student is required to move in the Tutor vertex. Indeed, in FA online workshops the assessment does not consist in grading the solutions produced by the peer, but the student is asked to help her peer and give suggestions in order to allow her to improve subjects’ learning, to recover gaps, to deepen, to mathematically reason (see above). All these activities are usually charged to a Tutor.

It is worthwhile to note that the task solution produced by the students becomes a digital didactic resource on which the students work for the assessment phase, and the students are aware of it. In the e-learning tetrahedron view, this can be interpreted as a movement of the Student in the Author vertex, producing resources to be used during the learning activities. These resources are also reviewed by the actual tutor, who selects some of them and notes them with further explanations to highlight both positive and negative aspects present in the selected resources. Indeed, we can say that there is a co-construction between the students and the tutor in order to produce final models of solutions to be made available to all the students enrolled in the platform’s course.

The above theoretically-driven reflections suggest further research lines, in particular on how to take into account the community of students, that is created as result of the engagement in the FA online workshops or generally in e-learning activities. Both the classical triangle and the e-learning tetrahedron are focused on the student as an individual. A second possible integration could deepen the integration between the technology inside and outside the tetrahedron, specifically to consider the spontaneous use of other technological tools by students as support for their learning.

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