The role of formative assessment in fostering individualized teaching at university level

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Annalisa Cusi[1] and Agnese Ilaria Telloni[2]

[1]Sapienza University of Rome; annalisa.cusi@uniroma1.it

[2]University of Ancona; agnesetelloni@gmail.com, telloni@dipmat.univpm.it

In this paper we present the design of individualized online teaching/learning paths at university level, within a formative assessment frame. Moreover, we discuss the preliminary results of a pilot study aimed at investigating the students' perception of the impact of these online paths to support their learning, their elaboration of the external feedback that the digital environment provides and their awareness about their difficulties and the strategies they could activate to overcome them.

Keywords: Formative assessment, individualized teaching, tertiary level, teaching/learning of probability.

The individualization of teaching/learning at university level by means of e-learning environments

This paper focuses on a pilot study aimed at investigating how a formative assessment (FA) frame could support the design of a sequence of tasks to foster individualized teaching at university level. Many obstacles are encountered by teachers and students at university level: the large number of students per teacher, the heterogeneity of students' background, the small number of hours per course, the impossibility of creating a close and frequent relationship between lecturer and students (De Guzman, Hodgson & Villani, 1998). In relation to this, Nardi (2017) stresses that there is an "aspiration (institutional but not only) for a more approachable, more inclusive and more engaging learning experience in university mathematics that is tailored to individual student needs" (p.10) and suggests that e-learning could give a significant answer to this aspiration.

In the past few years, research highlighted the effectiveness of designing e-learning environments to support the teaching-learning processes at tertiary level (Descamps et al. 2006; Albano & Ferrari 2008; Albano 2011; Bardelle & Di Martino 2012; Calvani 2005). In fact, these environments allow teachers to keep trace of students' work and mistakes, to provide an automatic or semi-automatic evaluation and to share feedback and comments. Moreover, they enable students to overcome the fear of being judged and of revealing lack of knowledge by requesting clarifications. In this way gaps in students' knowledge can be reduced, even within the heterogeneity of large classes.

These last observations make us concentrate our attention on the crucial role that e-learning could play in fostering individualized and personalized teaching at university level (Bardelle & Di Martino 2012; Albano & Ferrari 2008; Albano 2011). Bardelle and Di Martino (2012) stress that an e-learning environment could be an effective context through which it is possible to counteract students' mathematical difficulties in the tertiary transition, since it enables to foster both the personalization of the learning path and the students' collaboration during the activity. Also, Albano and Ferrari (2008) discuss the strong impact that these online environments could have at all levels of learning (cognitive, metacognitive and affective), allowing the automatic individualization of learning path according to the student's profile.

Theoretical framework: FA as a tool to support individualized teaching/learning

In this study, we refer to the distinction between individualization and personalization proposed by Baldacci (2006). According to Baldacci, *individualizing* means differentiating the didactical paths in order to enable all the students to reach common objectives, while *personalizing* is differentiating the formative goals and objectives to promote individual potentialities.

In our research we focus on the individualization of teaching/learning paths because, in our opinion, the specific characteristics of university teaching, such as the large number of students per teacher and the impossibility of differentiating formative goals (since all students need to reach minimum levels to attend subsequent courses), prevent from realizing a complete personalization. Moreover, we think that individualization could represent a useful approach to support students in the gaps of knowledge due to the heterogeneity of their background.

Jenkins (2004) suggests to looking at web technologies to promote the use of different assessment methods, especially in the context of higher education, stressing that this kind of technologies can encourage collaborative and reflective styles of learning and can also become adaptive. In tune with these ideas, we decided to set the design of a sequence of tasks for university students within a FA framework, where FA strategies are conceived as critical tools to foster the individualization of teaching/learning.

We refer to the model for the use of technology to support FA developed within the European project FaSMEd (Cusi, Morselli & Sabena, 2017). The model extends the one introduced by Wiliam and Thompson (2007), which considers two main dimensions. These are the agents involved in FA processes (the teacher, the learner, the peers) and the key strategies for FA: (a) clarifying and sharing learning intentions and criteria for success; (b) engineering effective classroom discussions and other learning tasks that elicit evidence of students' understanding; (c) providing feedback that moves learners forward; (d) activating students as instructional resources for one another; (e) activating students as the owners of their own learning. According to Wiliam and Thompson, FA should be designed with the aim of enabling the teacher and the students to establish: *where the learners are in their learning*; *where they are going*; *what needs to be done to get them there*. Within FaSMEd, a third dimension has been added, that is the functionalities of technology that could support FA: sending and displaying; processing and analyzing; providing an interactive environment.

Another important element for our framework is the role played by feedback in FA. Nicol and Macfarlane-Dick (2006) define feedback as an "information about how the student's present state (of learning and performance) relates to goals and standards" (p.2). The authors propose a model that distinguishes between *internal feedback*, generated by students' monitoring of their interactions with the task and the internal and external outcomes of their work, and *external feedback*, provided by the teacher, by a peer or by other means; external feedback must be interpreted, constructed and internalized by students to have a significant influence on subsequent learning. We refer also to

Hattie and Timperley's (2007) distinction between different levels of feedback. In particular, we focus on feedback about (i) the task; (ii) the processing of the task; (iii) self-regulation.

The tree of tasks: the design of individualized teaching/learning paths

In this section, we present a sequence of online tasks that is conceived as an intertwined collection of individualized teaching/learning paths. The tasks are organized in a tree (the tree of tasks, TT) and dynamically connected, so that the learners could face them within intertwined different paths, depending on the answers they give and the difficulties they encounter. The TT has been designed with the aim of supporting undergraduate students in the learning of basic topics of elementary and conditional probability. It is constituted by five main tasks, implemented with Geogebra and submitted to the students by using the university Moodle platform.

The diagram in figure 1 summarises the structure of the TT. All the possible intertwined paths begin with the same task (E1), concerning the definition of conditional probability, the probability of the intersection and of the complementary events. For all the tasks, students are required to give open (numerical) or multiple-choice answers to some questions and can choose to ask for specific hints. An immediate *feedback about the task* is provided whenever a student gives an answer and an overall feedback (again *about the task*) is given both at the end of the task and the whole path. The functionalities of technology that are activated to carry out this online self-assessment are *processing and analyzing* and *providing an interactive environment*.

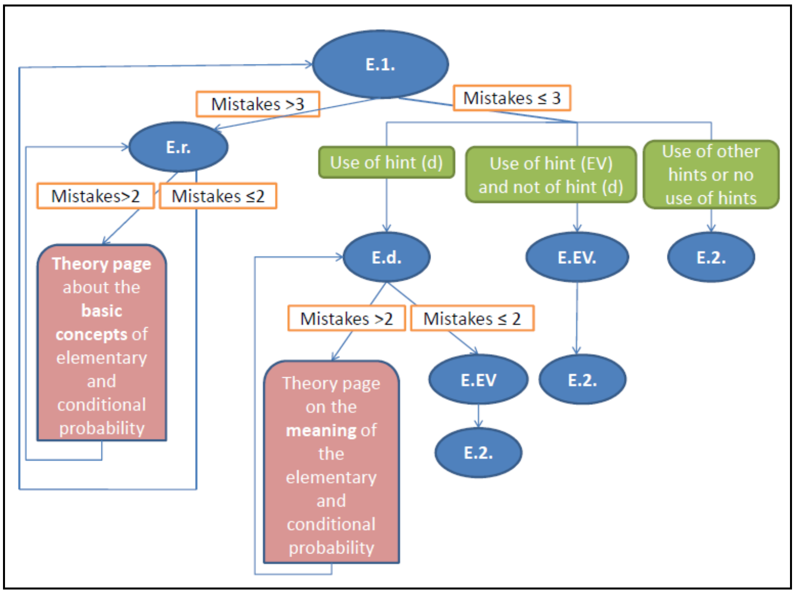

Figure 1: The tree of tasks

According to the number of mistakes and the kind of hints the students ask for, they are directed to different tasks. For example, if students make more than three mistakes in E1, they are directed to the task Er. After this, if they make more than two mistakes, they are directed to a theory page and then again to Er, otherwise they are directed to E1.

Because of space limitations, here we present only task E1 and the corresponding feedback and hints. Within this task, a brief text in natural language, introducing some events and their probabilities (their values are random), appears on the screen (see fig. 2). The student is required to fill six input fields by inserting the probability of various events: the probability of A and its complementary, the probability of the intersection $A \cap B$ and the probability of the conditional events $B|A$, $\bar{B}|\bar{A}$ and $\bar{B}|A$. Three of the required values are given in the text, so that the students should carefully interpret it; the other three input fields can be filled by using the definition of conditional probability, the property that a conditional probability is a real probability with respect to the conditioned event and the generalized rule for the probability of the intersection event. If all the six fields are correctly filled, two other questions, about the independency and the incompatibility of the events A and B, appear on the screen (see fig. 2).

When facing task E1, the students can ask for five different hints (see fig. 2): a summary of the data given within the text, represented through symbolic expressions (d), the Euler-Venn diagrams of the events (EV), a calculating machine (c), a sheet and a pen (sp) and a list of useful formulae (f).

As summarised earlier, if a student makes more than three mistakes, he/she is directed to a reinforcement task (Er), which is focused on the probability of the complementary of an event and on the definition of conditional probability. If not, the next task depends on the specific hints that are required: if a student asks for the hint d, he/she is directed to a specific task about the understanding of the given elements in a text expressed in verbal language (task Ed); if he/she does not ask for the hint d, but he/she asks for the hint EV, he/she is directed to a specific activity about the meaning of events in terms of set operations (task EEV); if the student does not ask nor for hint d, neither for hint EV, he/she is directed to task E2.

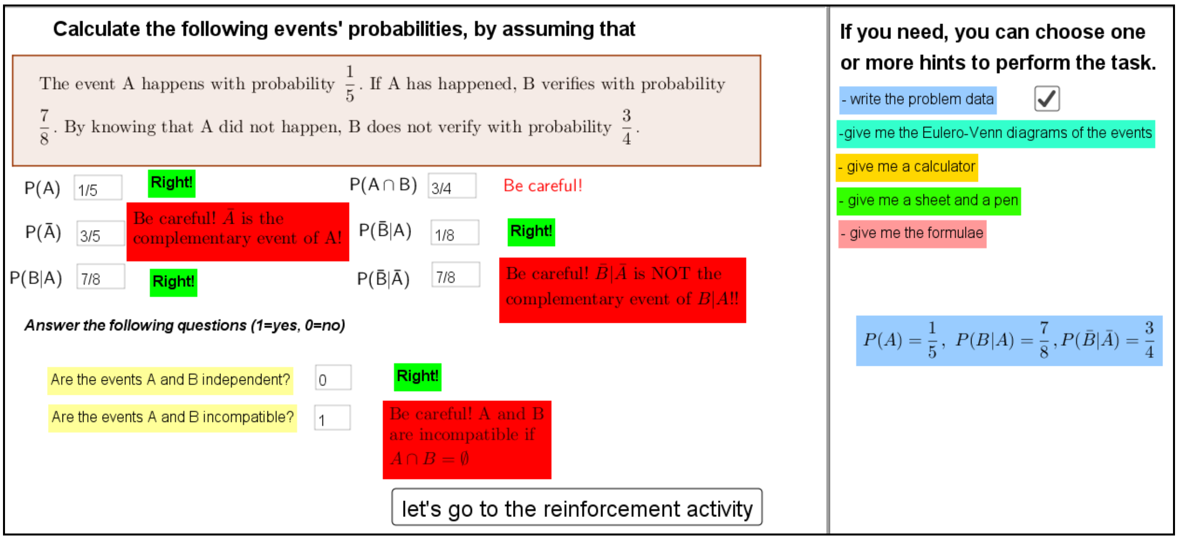

Figure 2: A screenshot from task E1

All the tasks are designed by taking into account misconceptions and typical mistakes that affect the teaching/learning of elementary and conditional probabilities (Diaz & de la Fuente, 2002). Moreover, as the above description highlights, the TT is engineered in order to gather information not only about students' mistakes, but also about their preferred approaches, displayed thanks to the hints they ask for. Students' behaviour and choices within the interactive environment determine the sequence of tasks proposed to them, that is the *individualized path* within which each of them is involved. We can speak about individualized paths because students are stimulated through various learning channels (graphical, symbolic, verbal …), they are given the possibility to follow their own aptitude and skills, and, finally, they can access to online resources when they prefer, so their learning rhythms are respected.

As for FA processes, it is possible to highlight a continuous activation of FA strategy C (*providing feedback that moves learners forward*), through both the direct *external feedback about the task* given to students, and the *indirect external feedback* that they receive when they are directed to specific tasks. This kind of feedback is on the *processing of the task* and on *self-regulation*, because it is aimed at making students reflect on specific aspects of their knowledge, on their own difficulties and on the role that each hint could play.

In order to collect evidence about students' typical approaches and mistakes, we have designed an open-ended questionnaire, composed of sets of questions to which the students have to answer after the completion of each task (8 questions for each task) and at the end of the learning path (3 questions). Some of the 8 questions focused on the specific mathematical contents to which each task refers and require students to write argumentations *about the processing of the tasks* they faced. The remaining questions focus on metacognitive aspects, such as the difficulties met by students in facing each task, the role of the hints they required, the ways in which each task could support their learning.

The request for argumentation is aimed, on the one hand, to assess students' capability of justifying their own strategies, and, on the other, together with the request for specific reflections, to guide them in monitoring their interactions with the tasks and in making explicit their interpretation of the received *external feedback*. In this way, students could gradually become aware of the possible strategies to face the task and on the reasons behind them, generating their own *internal feedback*. Two other FA strategies are therefore activated through the TT: strategy B (*engineering learning tasks that elicit evidence of students' understanding*) and strategy E (*activating students as the owners of their own learning*).

Research focus and methodology

In this paper, we aim to highlight the effects of students' interaction with the activities we designed to foster individualized learning paths, in terms of: (1) students' development of awareness about their own learning progresses and needs (that is, their awareness about "*where they are"* in their learning and "*where they are going"*); (2) students' declared perception of the impact of the implemented online tasks on their learning (that is their ideas about the role that the tasks could play in making them aware of "*what needs to be done"* to reach the learning objectives).

The activity presented in the previous paragraph was proposed to a group of 15 engineering Master degree students. In this paper we focus on their answers to the following metacognitive questions, which are part of the open-ended questionnaire introduced in the previous paragraph: (1) Did you meet some difficulties in facing the task? (2) Did you use the hints? If yes, what hints did you use? (3) Were the hints useful? (4) Would you have preferred to use additional or different hints? (5) Did the task help you clarify the concepts used from elementary and conditional probability? These questions are aimed at highlighting the *internal feedback* generated by the students' monitoring of their interaction with each task.

We developed a qualitative analysis of the students' answers to the metacognitive questions, referring to our research foci. The analysis the of questions 1-2-3-4 was aimed at detecting evidences of students' awareness about: (a) their difficulties in facing the tasks (possibly connected to their general difficulties in mathematics), (b) the gaps in their learning and (c) the role played by the hints they chose (research focus 1). In particular, we looked for possible categories of students answers in relation to their level of awareness about these aspects (a, b, c).

The analysis of question 5 was aimed at investigating students' perception of the impact of the tasks on their learning (research focus 2). In particular, we focused on the identification of the ways in which the students interpret the hints and the external feedback provided by the TT as supports for their learning.

Each researcher coded the students' answers separately in relation to our research objectives. Afterwards, problematic codes were discussed together so that researchers came to an agreement.

Analysis of students' answers

Referring to the *research focus 1,* we can identify at least three different categories of answers, depending on students' level of awareness about their own learning progresses and needs. The answers belonging to the *first category* show that students are deeply aware of the difficulties they faced in the resolution process, able to explain the reasons behind them and to put them in relation with their typical difficulties with the mathematical topic. Often, this kind of answers is associated to students' capability of recognizing their needs and asking for the suitable hints, when it is necessary. An example is S1 answer to question 1 after the completion of task E1: "*I did not meet many difficulties in facing this task, but it took me some time to understand what kind of probability was given in the text of the problem. Since it is a kind of difficulty that I often have, especially in understanding the distinction between conditional probability and the probability of the intersection of events, I tried to be particularly careful*". This answer represents an evidence of S1's capability of connecting the specific task to her general difficulties (in understanding verbal texts), and of reconstructing both the learning path and the reflections made in facing the activity.

The *second category* of answers is characterized by the fact that students are only partially aware of their difficulties and show an inadequate control of the strategies to be activated to overcome them. An example of answer belonging to this category is the one of S2, who writes that his failure in facing task E1 is due to the fact that he was not able to "*remember the formula for* $P(\bar{B}|\bar{A})$ *and* $P(\bar{B}|A)$", but he asks for hint d (the representation of data through symbolic expressions), which is not useful for him, and answers to question 4 only stating "*I don't know*".

The answers belonging to the *third category* are those that are given by the students who do not recognize their difficulties at all or recognize some difficulties but do not activate adequate strategies to overcome them. The typical approach of these students is, for example, the one of S3, who declares that his usual difficulties are related to the understanding of the data within the verbal text of the problem, but answers to question 2 (after task E1) stating "*I have not considered the hints at all*". The choice of not asking for hints clashes also with the fact that he completed task E1 making more than 3 mistakes.

As regards *research focus 2*, our analysis of question 5 highlighted the students' general appreciation of the TT. The most frequent reasons of this appreciation are connected to the fact that an interaction with a non-human tutor enables students to avoid their fear of being judged, as S4 stresses in his answer: "*Working alone on these online activities was great: not having the pressure of the teacher or a classmate who looks at my work and judges it allowed me to reason calmly, without the fear of making mistakes. It was like being a trapeze artist with the safety net*".

Most of the students seem to not fully understand the advantages of the individualized learning path in which they were involved, but they recognize the TT as a learning resource useful to explore multiple representations and promote transformations between them. The direct *external feedback* given by the software is interpreted as useful support to students' learning. For example, S5, referring to task E1, writes: "*I used the rules to determine the probability of the complementary event and the message that appeared when I inserted the value of* $P(\bar{B}|\bar{A})$ *reminded me that* $\bar{B}|\bar{A}$ *is not the complementary of* $B|A$". Another aspect that is particularly valued by students is the usefulness of the hints. Some students stress the role played by the hint EV (Euler-Venn diagrams) in reinforcing the meaning of the compound events by the graphical representation of events as sets.

Finally, it is interesting to observe that none of the students refers to the aim of passing the examination. They in general consider the TT as a good self-assessment tool and as a way to point out some critical aspects in the theory of elementary and conditional probability. For example, S6 declares: "*Yes, I found this task* (E1) *useful because it is focused on the difference between incompatibility and independence of events. The task has enabled me to clarify that I can consider* $P(A \cap B)$ *to investigate both the concepts, but I have to use it in different ways*…".

Final remarks

In this paper we presented preliminary results from a pilot study developed to investigate university students' perceptions of the impact of individualized online teaching/learning paths designed within a FA frame. In particular, the analysis enabled us to highlight students' elaboration of the external feedback received during their work on the TT, in terms of information about where students are in their learning and what they need to do to reach the learning objectives. The students participating to the pilot study showed different levels of awareness about these aspects: few of them were both aware of their difficulties and capable of activating the necessary strategies to overcome them. A common trend is that students recognize the value of the TT as an effective environment to support their learning, but they do not completely realize the level of individualization provided by the TT. For this reason, we will test a redesign of the methodology of use of TT, characterized by the fact that the individualized activity with the TT will be followed by a collective meta-level discussion during which the university teacher and the students will compare the individual interactions with the online tasks and will reflect on their usefulness.

Most of the students show that they are not used to carry out the kind of reflections that the questionnaire forced them to develop. This suggests the need of re-designing the questionnaire as an integrated part of the TT and as a tool to support self-assessment.

As a future development of this research, we will explore the use of this approach with reference to other knowledge domains of mathematics. Moreover, we will focus on the teachers' perspective, investigating the ways in which the information gathered through this online environment (the track of students' interaction with TT, the hints they ask, the argumentations and reflections they produce…) could represent a useful feedback for university teachers in revealing cognitive and metacognitive difficulties of students and in suggesting suitable re-design of the tasks to better support students in overcoming these difficulties.

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