Re-design of digital tasks: the role of automatic and expert scaffolding at university level

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In this study we present the re-design of a digital task for university students attending to a probability course. The re-design, directed toward the overcoming of specific critical issues highlighted in previous studies, is mainly aimed at providing students (in particular low achievers) with hints and feedback as tools of scaffolding and meta-scaffolding. Thanks to the analysis of a low achiever's interaction with the re-designed task, we investigated the limits of the automatic scaffolding and the key- role of expert's interventions in fostering students' overcoming of possible impasses.

Keywords: digital scaffolding, task design, university level, role of the expert

INTRODUCTION

The research presented in this paper is part of a wider study focused on the individualization of teaching-learning paths at university level (Alessio, Demeio & Telloni 2019, Cusi & Telloni 2019a, Cusi & Telloni 2019b). In particular, in Cusi & Telloni (2019a, 2019b) we presented two teaching experiments, focused on the design of online teaching-learning paths, developed with formative assessment purposes, involving groups of engineering students of the Polytechnic University of Ancona (Marche, Italy), attending to Calculus and Probability courses. Both studies highlighted students' inadequate awareness about their difficulties with mathematical topics and about their needs and a widespread lack of metacognitive control. As a result of these lacks, students are not able to activate appropriate strategies to overcome their difficulties while they work within digital environments. Starting from these results, here we propose a re-design of one of the digital tasks of the teaching-learning path presented in Cusi and Telloni (2019a). This re-design aims at creating a digital environment that could enable students to activate themselves at the metacognitive level, offering them feedback that support their use of hints to scaffold their work. Moreover, we propose the analysis of the interaction of a low achiever with the re-designed task to reflect on further difficulties that could arise and on the key-role that the expert plays in supporting students' overcoming of these difficulties.

THEORETICAL FRAMEWORK

In our design of individualised teaching-learning paths, we refer to Baldacci's (2006) definition of *individualization* as the act of differentiating the didactical paths in order to enable all the students to reach common objectives. This is particularly relevant at university level, where students need to overcome gaps of knowledge due to the heterogeneity of their background. A possible way of realizing individualization at this level is focusing on the use of digital environments, where a fundamental formative assessment process can be flexibly activated: *providing feedback* (Hattie & Timperley, 2007). Giving feedback could be also conceived as a possible means to realize *scaffolding*, that is the "act of teaching that (i) supports the immediate construction of knowledge by the learner; and (ii) provides the basis for the future independent learning of the individual" (Holton and Clarke, 2007, p.131). When scaffolding is realized within digital environments, the focus is on *computer-based scaffolding* (Belland, 2017), that is the "computer-based support that helps students engage in and gain skill at tasks that are beyond their unassisted abilities" (p.26).

Research in mathematics education has distinguished different scaffolding domains. Holton and Clarke (2007), for example, introduce two domains: (a) *conceptual scaffolding*, which relates to specific contents; and (b) *heuristic scaffolding*, which relates to the development of heuristics for learning or problem solving. Types of scaffolding could be also identified in relation to the agents that provide it (Holton and Clarke, 2007): *expert scaffolding* (provided by an expert), *reciprocal scaffolding* (provided by peers), and *self-scaffolding* (provided by an individual to himself). This last type of scaffolding plays a key-role in fostering the following *fading*, that is the appropriation of the scaffolding by the learner (Shvarts & Bakker, 2019).

Students' effective use of the provided scaffolding and subsequent development of awareness about the role of scaffolding requires that they activate themselves at the *metacognitive level* (Holton & Clarke, 2007). The fundamental role of metacognitive aspects is stressed also within digital environments, where a good balance between procedural and metacognitive-scaffolding is needed (Sharma & Hannafin, 2007).

Research has highlighted that, within digital environments, the support provided by facilitators (teachers, tutors or, more in general, human experts) in activating meta-scaffolding is particularly crucial (Pea, 2004). To analyze this role, we refer to Wood, Bruner and Ross' (1976) main scaffolding functions: *recruitment* (enlisting learner's interest and the adherence to the requirements of the task), *reduction in degrees of freedom* (simplifying the task by reducing the number of constituent acts required to reach the solution), *direction maintenance* (keeping learners in pursuit of a particular objective), *marking critical features* (accentuating relevant features or parts of the activity), *frustration control* (reducing learners' stress, without creating too much dependency on the tutor) and *demonstration* (modelling solutions to a task).

RESEARCH QUESTIONS AND RESEARCH METHOD

The analysis developed in Cusi & Telloni (2019a, 2019b) highlighted some critical issues that prevent students from fruitfully exploiting the hints provided by digital environments to scaffold their work. This study is aimed at facing two main research questions: (1) What criteria can guide a re-design of digital tasks to overcome these critical issues and foster an effective scaffolding of students' work? (2) When a digital task is re-designed according to these criteria, what factors inhibit the overcoming of the critical issues that have been highlighted? In case of students' impasses due to these inhibiting factors, what kind of support could be provided by the expert scaffolding to effectively integrate the digital automatic scaffolding?

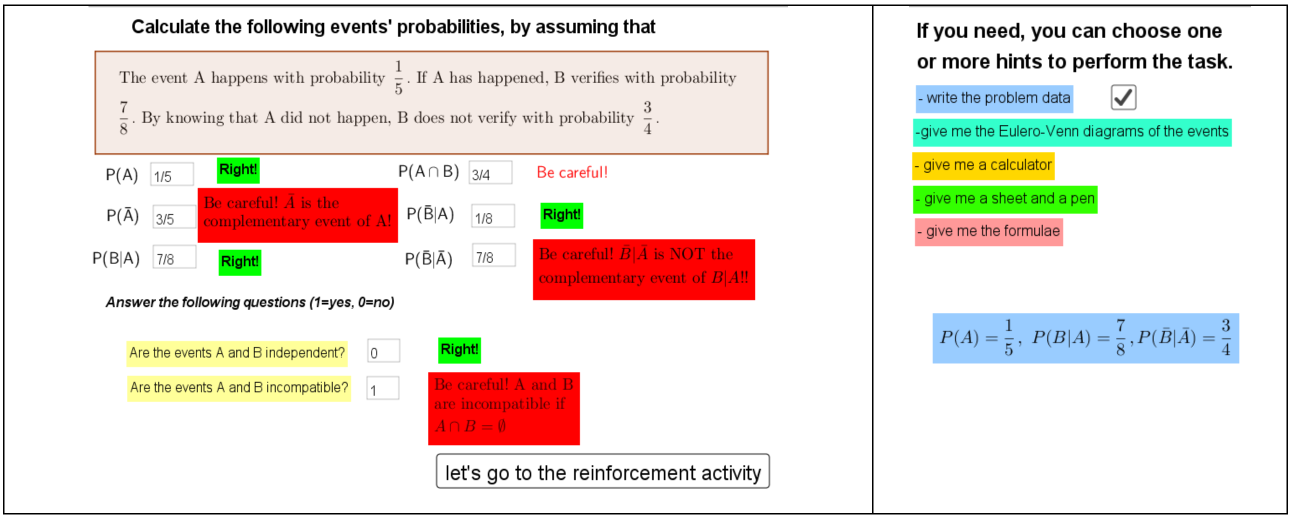
The reflections developed to answer to question 1 enabled us to identify three main criteria, that guided our re-design of one of the digital tasks belonging to the teaching-learning path presented in Cusi and Telloni (2019a). These criteria and their use in re-designing the task will be presented in the next section.

To investigate the aspects connected to question 2, we developed a teaching experiment, with a group of ten first year master-degree engineering students, enrolled on voluntary basis. The students, who were attending to a mini course focused on probability (in the period September-December 2019), in the middle of the course (November 2019) were asked to work on the re-designed version of the digital task, within a laboratorial activity. We collected the video-recordings of students' screens while facing the task. To develop an in-depth analysis of students' use of feedback and hints provided within the digital environment to scaffold their work, we asked them to think at loud while facing the tasks, and audio-recorded their speeches. A tutor (the teacher of the course, one of the authors) was in the computer lab to provide support to students in case of problems.

In this paper, we will focus on the analysis of the interaction of a low achieving student, Maria, with the re-designed task, through the tutor's support. Maria was selected because she displayed, from the very beginning of her work on the task, her awareness about her lack of knowledge. This analysis was developed in two subsequent phases. In the first phase, we identified key-moments, during which the student faced difficulties in her work on the task. In the second phase, we developed an analysis of the interactions between Maria, the digital environment and the tutor to identify: (a) impasses in the student's use of hints to scaffold the development of the resolution process; (b) factors that create impasses; (c) specific roles of the tutor in fostering the overcoming of these impasses.

ANALYSIS OF THE TASK RE-DESIGN

In this section we focus on the re-design of the digital task presented in Table 1.



A text in verbal language introducing some events and their probabilities (their values are random) appears on the screen. The students are required to fill six input fields by inserting the probabilities of some events: three of them are those given in the text and the remaining can be obtained applying probability rules (complementary events, conditional probability). When the six input fields are correctly filled, other two questions (yellow boxes) appear on the screen, concerning the independency and the incompatibility of events. For each answer given by the student, the program reacts by a feedback (red and green boxes).	During the interaction with the task, students can ask for different kinds of hints. We mention, in particular: a summary of the data given in the text (*data hint*), Eulero-Venn diagrams of elementary and compound events (*E-V hint*), a list of useful formulae (*formula hint*).

Table 1: The first version of the task [1]

Thanks to our previous studies (Cusi & Telloni, 2019a, 2019b), we identified three main critical issues and their effects in negatively influencing students' work on digital tasks. The identification of these critical issues suggested us three main criteria that could guide task re-design. These aspects are summarised in table 2.

Critical issues	Negative effects	Criteria for the re-design
Students' lack of awareness or partial awareness about their difficulties/weaknesses and their learning needs.	Students are not able to identify useful hints to scaffold their work on the tasks.	(1) Add explicit written feedback in which possible hints to be used are highlighted.
Students' lack of metacognitive control in monitoring their problem-solving processes.	Students are not able to exploit the provided hints to effectively scaffold their work on the tasks.	(2) Re-structure the tasks in order to guide students in identifying the fundamental steps to solve the tasks. Provide students with explicit feedback by a tutor to enable them to become aware about possible ways of using hints.
Insufficient flexibility in the use and interpretation of different representations (graphical, symbolic, verbal…)	Students are blocked in the interpretation of hints and in the use of hints to face the tasks.	(3) Provide students with multiple representations and explicit feedback to stimulate a flexible use of these representations (written feedback or feedback given by a tutor)

Table 2: Critical issues, their negative effects and criteria for the task re-design

The identified criteria led our re-design of the task, aimed at scaffolding students' work by guiding them into 5 sub-steps that characterize an effective resolution process. The structure of the re-designed task is summarized in Figure 1.

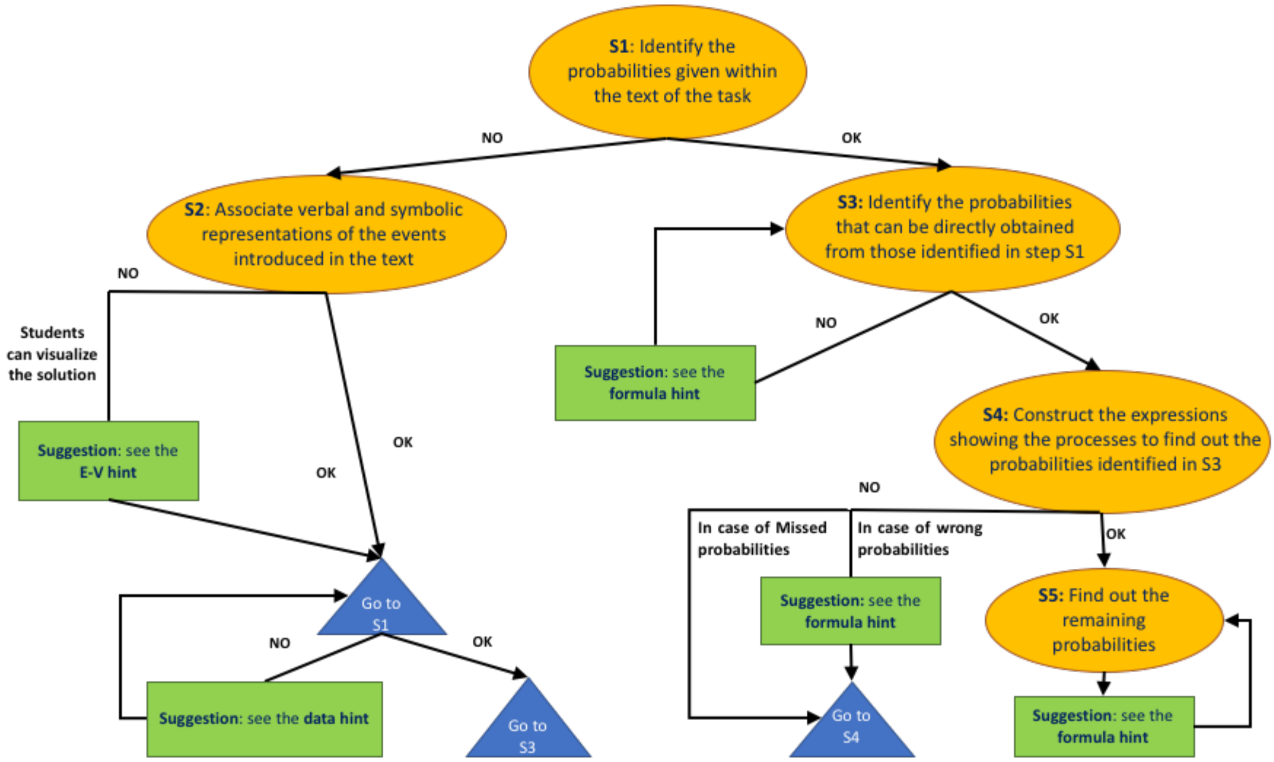


Figure 1: The structure of the re-designed task

The orange rounds in Fig. 1 represent the 5 steps that characterize a possible effective approach to the resolution of the problem. We referred to these steps to organize the scaffolding of students' work on the task (criterion 2), since each step corresponds to a sub-task, whose completion enables the students to progress in their work. In this way, the scaffolding functions *reduction of the degree of freedom* and *marking critical features* (Wood et al., 1976) can be activated.

The individualization of students' paths when facing the task is highlighted by the arrows and the blue triangles, which show the steps to which students are addressed according to their answers, and by the green boxes, which contain suggestions automatically given to students if they fail in specific steps. These suggestions are new elements introduced in the re-design process to scaffold students' work at a meta-level, guiding their choice of the hints, conceived as possible effective tools for conceptual scaffolding (criterion 1). Another element of individualization is the fact that students are free to accept or not the suggestions of asking for specific hints.

The design of the questions in S1 (involving interpretation of verbal texts) and S2 (requiring conversions from verbal to symbolic representations) and our choice of the hints on which scaffolding is focused are aimed at fostering students' flexible use of different representations (criterion 3). This flexible use is also required in S4, where students are asked to represent, through suitable numerical expressions, the processes that lead to determining the required probabilities starting from the known ones.

ANALYSIS OF A LOW ACHIEVER'S INTERACTION WITH THE RE-DESIGNED TASK

In this section we analyze Maria's interaction with the re-designed task. We identified three key-moments that highlight Maria's difficulties in effectively referring to the provided hints to scaffold her work. Because of space limitations, we summarize the main results of our analysis in table 3, in which each key-moment is analyzed in terms of: impasse that is shown, factors creating the impasse, roles played by the tutor to foster the overcoming of the impasse.

Key-moment 1: impasse due to a lack of focus in developing a strategy	
Position of the key-moment within Maria's path	After having failed S1, faced S2 and visualized S2's solution, Maria is facing again S1.
Kind of impasse	Maria is not able to use the data hint to correctly complete S1.
Factors creating the impasse	Maria is confused because her main focus is on her mistakes in S2 in converting from verbal to symbolic representations.
Roles played by the tutor to foster the overcoming of the impasse	The tutor reformulates the request in S1, making Maria observe that the data hint directly shows how to complete this step. In this way, the tutor activates: a *direction maintenance* scaffolding function, making Maria reflect on the role of the data hint; and a *recruitment* scaffolding function, explicitly re-focusing Maria's attention on the request in S1.
Key-moment 2: impasse due to an inadequate strategic use of provided hints	
Position of the key-moment within Maria's path	While Maria is facing S3, she follows the suggestion of using formula hint.
Kind of impasse	Maria is blocked: she is not able to use the formula hint to identify the probabilities that can be directly obtained.
Factors creating the impasse	Maria is not able to activate a strategic approach in identifying formulas that can be used to determine other probabilities.
Roles played by the tutor to foster the overcoming of the impasse	The tutor suggests Maria to focus on one of the probabilities that have to be found, then on one of the data and asks Maria to identify a formula that relates them. In this way, Maria is guided in setting a sub-goal with respect to the request in S3, and the *reduction in degrees of freedom* scaffolding function is activated. The tutor's intervention aims also to activate the *marking critical features* scaffolding function, enabling Maria to focus on a specific formula towards a specific goal.
Key-moment 3: impasse due to difficulties in handling multiple representations	

Position of the key-moment within Maria's path	Maria is working on S4, when she explicitly asks for the tutor's support.
Kind of impasse	Maria does not know what strategic approach she can activate to find out one of the required probabilities.
Factors creating the impasse	Maria refers to the right formula, but she is not able to find out the inverse formula to determine the required probability, because of her lacks in manipulation and interpretation of algebraic formulae.
Roles played by the tutor to foster the overcoming of the impasse	The tutor models an effective strategic approach, activating the *demonstration* scaffolding function to guide Maria in obtaining the right inverse formula, and in understanding how the known probabilities should be substituted in the formula itself. This scaffolding also involves metacognitive aspects, since it regards the use of the hints to perform this step of the task.

Table 3: Key-moments in Maria's interaction with the re-designed task

FINAL REMARKS

The re-design process presented in this paper has been developed considering three criteria, which proved to be effective, especially in the case of average and high achievers, in stimulating students at a metacognitive level, fostering a scaffolding focused on solution processes that require flexibility in making reference to conceptual knowledge and in effectively using it.

The analysis of Maria's interaction with the re-designed task enabled us to highlight that the activated scaffolding is sometimes not effective, especially in the case of low achievers, who, because of their lack in metacognitive control, are often not able in correctly interpreting the given feedback and in autonomously using the hints provided within digital environments. Through our analysis, we showed that the role of the expert (the tutor) becomes crucial in supporting low-achievers in overcoming moments of impasse connected to specific factors, such as lack of focus in developing a strategy, inadequate strategic use of provided tools, difficulties in interpreting mathematical representations and in using multiple representations.

Through our analysis, we identified specific roles that could characterize, also in other contexts, the expert's approach in case there is the need of integrating the automatic scaffolding provided by the digital environment: (a) making the students reflect on the role and use of specific hints; (b) re-focusing students' attention on the task's requirements; (c) focusing students' attention on conceptual aspects; (d) setting sub-goals that could guide students' resolution process; (e) highlighting connections between specific goals and tools to achieve them; (f) modeling effective strategic approaches, focusing on syntactic and semantic control of these processes. In table 3 we also show how these roles can be connected to an effective activation of specific scaffolding functions (Wood et al, 1976).

As an ongoing development of this research, we are focusing on a further tool to scaffold students' learning and to activate them at metacognitive level: the use of the diagram in Fig.1 to support students' a-posteriori reconstruction of their own learning path and consequent reflections on their use of digital tools and hints.

NOTES

1. The task, presented in Cusi&Telloni (2019a), has been designed using the software GeoGebra.

REFERENCES

Alessio, F., Demeio, L. & Telloni, A.I. (2019). A formative path in tertiary education through GeoGebra supporting the students' learning assessment and awareness, *International Journal for Technology in Mathematics Education*, *26*(4), 191-203.

Baldacci, M. (2006). *Personalizzazione o individualizzazione?* Roma: Erickson.

Belland, B. (2017). *Instructional Scaffolding in STEM Education*, Cham: Springer.

Cusi, A. & Telloni, A.I., (2019a). The role of formative assessment in fostering individualized teaching at university level. In U.T. Jankvist, M. Van den Heuvel-Panhuizen & M. Veldhuis (Eds.). *Proceedings of CERME 11* (pp. 4129-4126) Utrecht: Freudenthal Group & Institute, Utrecht University and ERME.

Cusi, A. & Telloni, A.I., (2019b). Students' use of digital scaffolding at university level: emergence of utilization schemes. In B. Barzel et al. (Eds.), *Proceedings of ICTMT 14* (pp. 271-278). Duisburg-Essen Publications online.

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

Holton, D., & Clarke, D. (2007). Scaffolding and metacognition. *International Journal of Mathematics Education in Science and Technology*, 37(2), 127-143.

Pea, R. (2004). The social and technological dimensions of scaffolding and related theoretical concepts for learning, education, and human activity. *Journal of the Learning Sciences*, *13*, 423-451.

Sharma, P. & Hannafin, M.J. (2007). Scaffolding in technology-enhanced learning environments, *Interactive Learning Environments*, *15*(1), 27-46.

Shvarts, A. & Bakker, B. (2019). The early history of the scaffolding metaphor: Bernstein, Luria, Vygotsky, and before, *Mind, Culture and Activity*, *26*(1), 4-23.

Wood, D., Bruner, J. & Ross, G. (1976). The role of tutoring in problem solving. *The Journal of Child Psychology and Psychiatry*, *17*, 89-100.