Digital resources to promote individualization processes at university level: the role played by the integration between automatic scaffolding and expert scaffolding

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Abstract. This paper reports the results of a study focused on the use of a digital resource designed to promote individualization processes at the university level. The aim of the study was to investigate the interaction between a group of university students enrolled in the first year of a Master's Degree in Management Engineering and the digital resource, with the support of an expert tutor. Specifically, these interactions were analyzed to examine the integration and interplay between the automatic digital scaffolding provided by the digital resource and the scaffolding provided by the expert to help the students overcome the moments of impasse they encountered while solving a series of tasks focused on probability. The analysis we conducted allowed us to highlight the key role of the expert in reinforcing the individualization tools provided by the digital resource.
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1. Introduction

The crucial role that digital environments could play in fostering individualized and personalized teaching-learning at the university level has been widely recognized through different studies developed in the last decade that testify the impact that these tools and environments could have on cognitive, metacognitive and affective levels of learning [7, 1, 2, 10].

Within this line of research, we have developed a design-based research to investigate the design and implementation of learning paths within digital environments to promote individualized teaching at the university level [4, 11, 12]. In

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particular, in [11, 12] we presented two educational experiments focused on the design of online teaching-learning paths for first-year Engineering students at the Università Politecnica delle Marche (Italy). Both studies highlighted students' insufficient awareness of their difficulties with mathematical topics and of their needs, a widespread lack of students' metacognitive control, and students' lack of awareness of the individualization of the path in which they are involved. As a result of these deficiencies, students are not able to activate adequate strategies to overcome their difficulties while working in digital environments. For example, they do not use the necessary information to perform tasks, they fail to interpret the feedback provided, or they do not identify appropriate cues that digital environments could provide to scaffold their work.

In this paper we present the results of a study developed from a redesign of one of the tasks of the teaching-learning path presented in [11], aimed at enabling students to activate themselves at the metacognitive level by providing them with feedback that supports their use of digital hints to scaffold their work. The study, which involved a group of university students enrolled in the first year of the Master's program in Management Engineering, aims to investigate the role of the integration between digital scaffolding and expert scaffolding in supporting students to make the most of the individualization tools provided by the digital learning environment.

2. Theoretical background

2.1 The role of scaffolding in promoting individualization at the university level through digital technologies

In the context of university teaching and learning, digital environments have an important role to play in supporting educational processes, both for teachers and students, at different levels. In particular, they allow the promotion of teaching and learning activities tailored to individual needs [3, 7, 20, 25]. Teachers can keep track of students' work in order to characterize their approach in relation to their typical difficulties and learning approaches; students have the possibility to access the resources whenever and wherever they prefer, to deepen mathematical concepts according to multiple representations, and to monitor their own preparation through self-assessment tools.

The present study is framed within a broader research focused on the individualization of teaching-learning paths at the university level [4, 11, 12, 26]. We refer to Baldacci's [5] definition of individualization as the act of differentiating didactic paths in order to enable all students to reach common goals. Individualization is particularly relevant at the university level, where students need to overcome knowledge gaps due to the heterogeneity of their backgrounds and often feel a sense of massification due to a detached relationship with the teacher and classmates [7, 14]. According to Buttler [9], since academic success is based on students' ability to implement strategic approaches and their development of a positive self-perception, the best way to support students is to provide them with calibrated support that takes into account their existing knowledge, skills, and specific difficulties.

This consideration suggests a shift in focus to the role of scaffolding in supporting the individualization of teaching and learning. Holton and Clarke [16] define scaffolding as "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" (p.131).

Types of scaffolding have been identified in terms of the agents that provide it [16]: expert scaffolding (provided by an expert), reciprocal scaffolding (provided by peers), and self-scaffolding (provided by an individual to herself). Holton and Clarke [16] note that the step from expert to self-scaffolding involves a change in the locus of authority, from external to the learner to internal.

Metacognition is an essential element in students' use of the scaffolding provided and their subsequent development of awareness of the role of scaffolding [16]. This concept is defined by Wilson and Clarke [27] as the awareness that individuals have of their own thinking, their evaluation of that thinking, and their regulation of that thinking. It is important to specify that this definition does not aim to focus on issues that inform metacognitive decision making, but on acts of thinking - acts of metacognition - that operate on cognitive thoughts to assist in the process of learning or solving a problem. According to Wilson and Clarke [27], scaffolding and metacognition rely on the same set of actions: "The outward signs that we see of scaffolding in a learning environment are equivalent to those used by the individual when engaging in metacognition. The external dialogue of scaffolding becomes the inner dialogue of metacognition" (p.141). Meijer et al [18] introduced different categories of metacognitive activities that could support the analysis of the effects of the scaffolding provided to students, particularly in the area of problem solving:

- Orientating refers to utterances focused on identifying prior knowledge to refer to, reflecting on task demands, and sharing feelings about the task;
- Planning refers to utterances that focus on identifying strategies for tackling a particular task;
- Executing refers to utterances focused on carrying out action plans;
- Monitoring refers to utterances related to checking progress in facing and understanding the task;
- Evaluation refers to utterances aimed at evaluating the way the task has been performed;
- Elaboration refers to utterances focused on elaborating on the learning process.

In this study, we focus on computer-based scaffolding [19], which is the "computer-based support that helps students engage in and gain skill at tasks that are beyond their unassisted abilities" (p.26). Belland [8] introduces a number of scaffolding functions that can be activated in digital environments: conceptual scaffolding, strategic scaffolding, metacognitive scaffolding, and motivational scaffolding. In particular, he notes that while conceptual scaffolding guides students in making sense of the data and information they encounter and in identifying things to consider when solving problems, strategic scaffolding aims to get students to develop a strategy for solving problems. Providing this type of scaffolding could produce what Reiser [22] refers to as the fundamental mechanism that digital tools could support, i.e., problematizing aspects of the subject matter rather than simplifying the task, helping students see something as requiring attention and decision making that they might overlook, and getting them to engage with important ideas or processes.

The key-role of metacognitive aspects in guiding the design of scaffolding is emphasized in digital technology-enhanced environments because students' effective use of the digital scaffolding provided and their subsequent development of awareness about the role of scaffolding requires that they activate themselves at the metacognitive level. Indeed, Sharma and Hannafin [24], in their discussion of the implementation of scaffolding in digital technology-enhanced environments, state that a strength of effective software scaffolding is that it provides consistent support and clarification about basic procedural and metacognitive aspects of a learning task.

2.2 The role of the expert in making digital automatic scaffolding more responsive

The actions of scaffolding are closely related to the notion of responsiveness. In fact, Koole and Elbers [17] suggest that "We argue that the question whether a particular action or utterance by the teacher is an instance of scaffolding cannot be answered in general terms. Scaffolding actions are responsive actions that take the competence the student demonstrates into account. Only by finding out whether a teacher is responsive to previous contributions by the student can we establish if he or she provides the kind of support that can be called scaffolding." (p.58)

Our previous studies have allowed us to reflect on the importance of focusing on the role that the expert can play in enabling the level of responsiveness of a digital environment. This is in line with Pea's [23] suggestions that a teacher or other facilitator should support learners through forms of metacognitive scaffolding in selecting appropriate supports when working in digital environments. This requires a balance between the fixed hard scaffolding provided by digital environments and the negotiable soft scaffolding provided by the expert [23].

In line with these ideas, Bakker, Smit and Wegerif [6] note that since intelligent tutoring systems cannot be responsive in the sense that humans can be, it is crucial to focus not only on the digital tools and their ways of scaffolding students' learning processes, but also on the "whole system in which these tools function as scaffolds" (p.1050).

We therefore adopt the perspective suggested by Reiser [22], who emphasizes that "Scaffolding Requires a System: A final caution to be discussed in exploring models of scaffolding in software tools is that learners, tools, and teachers work together as a system, and it is an over-simplification to consider how tools can scaffold learners without considering the other aspects of this system." (p.298) Therefore, studying the use of computer-based scaffolding in digital environments requires considering the whole system, which consists of three elements: the learner, the digital environment, and the expert who supports the learner's interaction with the digital environment.

Butler [9] suggests that in order to truly support the individualization of learning processes, the expert should design calibrated scaffolding that takes into account students' current levels of performance and what they could achieve with assistance, and also aims to deconstruct supportive scaffolds as students become more independent.

In their analysis of the process by which an expert supports a learner's performance of a particular task, Wood et al. [28] identify six main functions of scaffolding: recruitment (gaining the learner's interest and compliance with the requirements of the task), reduction in degrees of freedom (simplifying the task by reducing the number of constituent acts required to achieve the solution), direction maintenance (keeping the learner on track), marking critical features (highlighting relevant features or parts of the activity), frustration control (reducing the learner's stress without creating too much dependence on the tutor), and demonstration (modeling solutions to a task).

3. Research context and the digital resource used in this study

The context of the research is a Probability and Mathematical Statistics course for Engineering Master's Degree students, taught in the first semester of 2019-20 academic year. Approximately 30 students participated in the course, and 10 of them agreed to participate in our study as volunteers. The study involved the students' individual work with a digital resource within a computer lab, in the presence of an expert, one of the authors, who was in the lab to help the students in case of technical problems or moments of impasse. The students' work with the resource was followed by a semi-structured interview with each of them. These students were familiar with resources similar to the one implemented in the study, although this resource was used by them for the first time during the study.

The digital resource with which the students interacted is the result of a first cycle of design-based research. It consists of a GeoGebra applet designed mainly by exploiting one of its specific features, the conditioned visualization functionality associated with check boxes and insert fields. The choice to use such functionality is aimed at making the applet provide different feedback and hints according to students' answers.

The redesign of the digital resource was developed on the basis of some critical issues that emerged in a previous study [11], in particular in relation to the students' lack of metacognitive awareness, both in terms of their ability to monitor their processes and their flexibility in using multiple representations. The analysis of the data collected during these studies allowed us to identify a set of criteria for the redesign of the resource [13], which aimed to scaffold students' work at the metacognitive level in order to (a) guide them in the use of the hints provided; (b) support their work by organizing the tasks into subtasks; (c) promote their flexible handling of different representations.

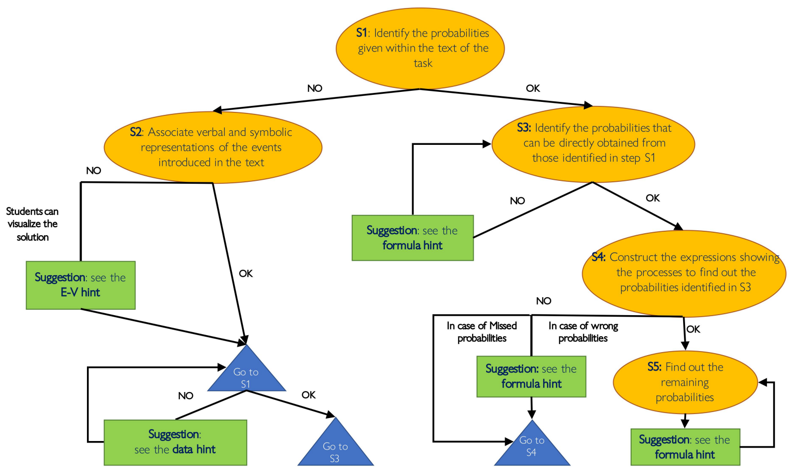

Figure 1: The structure of the digital resource used during the study

The structure of the digital resource is shown in Figure 1. The task that the students have to solve through the resource is to fill in six input fields with elementary, compound and conditional probabilities depending on two events A and B. The digital resource supports the students in solving the task by guiding them through five sub-tasks (corresponding to different steps).

At the beginning (Step S1), a text is provided in verbal language. The text contains three of the six required probabilities. The orange ovals correspond to subtasks that help students fill in the boxes. Students should be able to recognize from the text what the given probabilities are (Step S1) and use probability rules and the definition of conditional probability to find the other probabilities (Steps S3, S4, S5). If the student does not recognize what the given probabilities are, he/she is asked to associate verbal and symbolic representations of the events presented in the text (Step S2).

The arrows and the blue triangles highlight the Steps to which students are addressed according to their answers. The green boxes contain suggestions that are automatically given to students when they fail to complete certain Steps.

Students have five hints available as possible automatic scaffolding for their interaction with the task: a summary of the probabilities given in the text (data hint, suggested when students make mistakes in step S1, after their work on step S2), Eulero-Venn diagrams of compound events (EV hint, suggested in step S2, in case of mistakes), a list of useful formulas (formula hint, suggested in steps S3, S4, and S5, in case of mistakes). In addition, response-specific feedback and scaffolding messages guide students in selecting useful hints and understanding how to use them when they encounter specific difficulties. A screenshot of the digital resource, showing the suggestion given to students when they fail Step S3 (that is to ask for the formula hint) is shown in Figure 2.

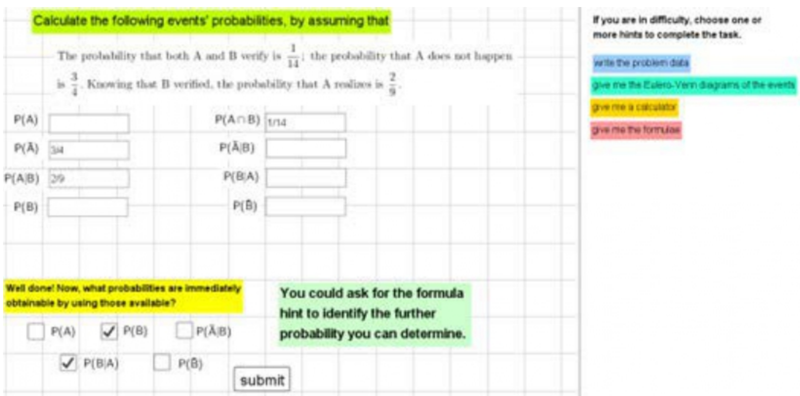

Figure 2: A screenshot of the digital resource

4. Research questions and research method

As mentioned above, the aim of the study documented in this paper is to investigate the ways in which the expert could integrate his/her scaffolding with the automatic scaffolding provided by the digital resource presented in the previous section, especially at the metacognitive level, in order to make this scaffolding more responsive for the students. The researcher who played the role of expert in this study, as the designer of the digital resource, knows the scaffolding elements it provides. At the same time, she is aware of the risk of the automatic scaffolding being unresponsive. However, she had deliberately not defined a priori a set of interventions to scaffold students' work in order to investigate the expert's in-the-moment spontaneous support to students.

We interpret the integration between the expert's and the automatic scaffolding within the scaffolding dynamics, i.e. the interactions within the system constituted by the digital resource, the student and the expert, in terms of co-action [15], which means that two of these actors - the digital resource and the student - alternately play the roles of actors and re-actors during their interaction, while the expert intervenes to support the student's re-reactions when he/she is in a moment of *impasse*. We use the term *impasse* to refer to those moments when the student is presented with a suggestion to use a particular hint, but gets stuck and may ask for the expert's help.

We investigate both the integration of the expert's scaffolding into the scaffolding provided by the digital resource, with the goal of making this scaffolding more responsive, and the effects of this integration by addressing the following research questions:

1. What kind of difficulties do the students face when they have to react, at the metacognitive level, to the scaffolding provided by the digital resource? What kind of moments of impasse could be observed, during the interaction between the students and the digital resource, in relation to this issue?

2. How does the expert integrate his/her scaffolding with the scaffolding provided by the digital resource in order to help students overcome these moments of impasse? How does the expert's scaffolding take into account the students' specific difficulties at the metacognitive level when carrying out this integration?

As mentioned above, the experiment conducted in this study included the students' individual work with the digital resource and a subsequent a-posteriori interview in which the students were asked to reflect on their interaction with the digital resource and with a tutor (who played the role of expert) who was present in the computer lab to assist the students.

We collected video-recordings of students' screens as they interacted with the digital resource. In addition, to develop an in-depth analysis of students' use of the scaffolding provided by the digital resource, we asked students to think aloud as they completed the tasks, and we audio-recorded their speech. During their interviews, students were shown some excerpts from the video- and audio-recordings of their interaction with the digital resource, asked to read the transcripts of the audio recordings and to reflect on the difficulties they had encountered and on the scaffolding they had received from the digital resource and from the expert.

The data that we analyzed were: the video-recordings of the students' screens, the transcripts of the audio-recordings of the students' work with the digital resource and their a-posteriori interviews. The data analysis was developed in three successive phases.

In the *first phase*, we analyzed the data to identify moments of impasse in their use of the provided scaffolding (suggestion to use specific hints).

In the *second phase*, we focused on each moment of impasse and analyzed the video- and audio-recordings of the students' interaction with the digital resource and with expert to highlight:

a) the characteristics of the impasses in student's use of the scaffolding provided by the digital resource (to answer research question 1);

b) the characteristics of the scaffolding provided by the expert to help students overcome their impasse (to answer to research question 2); and

c) the effects of this scaffolding at the metacognitive level (to answer research question 2).

The characteristics of the impasses in students' use of the scaffolding provided by the digital resource (a) were highlighted by analyzing the data according to the categories of metacognitive activities introduced by Mejier et al. [18] to highlight the interrelationship between specific impasses and the metacognitive activities that were not activated due to the impasses.

The characteristics of the expert's scaffolding (b) and its effects (c) were investigated by analyzing his/her intervention according to both the categories of functions of scaffolding introduced by Wood et al. [28] – to highlight the roles he/she plays – and the categories of metacognitive activities – to highlight the intentions behind his/her interventions and their effects on the students' interaction with the digital resource.

The object of the third phase of analysis were the transcripts of the a-posteriori interviews with students, which were analyzed to find evidence for the results of the previous phase of analysis.

5. Data analysis

In this section we present the results of the data analysis focusing on two students who participated in the study: Maria and Luigi. We chose to focus on these two students because their approaches to using the digital resource and the difficulties they demonstrated were at the extremes of the range of approaches observed.

Each of the following sub-sections focuses on moments of impasse in Maria and Luigi's use of the scaffolding provided by the digital resource in relation to different metacognitive activities:

- scaffolding to support the orientating metacognitive activity (first sub-section);
- scaffolding to support the planning and the executing metacognitive activities (second sub-section);
- scaffolding to support the monitoring metacognitive activity (third sub-section).

In each sub-section, we will present the analysis of excerpts that document the interaction between the students, the digital resource and the tutor. The analysis will be carried out, according to the methodology presented in the previous section, in order to reflect on the ways in which the expert (the tutor) integrates the scaffolding provided by the digital resource to bridge its lack of responsiveness to the specific needs of the students.

The students' comments from the a-posteriori interview will be included in the analysis presented in each sub-section as evidence of the coherence between the results of the analysis and the students' interpretation of the data.

5.1 Moments of impasse related to the scaffolding aimed at supporting the orientating metacognitive activity

5.1.1 Impasse at the orientating level in Maria's interaction with the digital resource

In the following excerpt, Maria is facing S1 (identify the probabilities given in the text of the task), after failing S1 once and then trying to face S2 (associate verbal and symbolic representations of the events introduced in the text of the task).

1. Maria: I try... enter, and then?
2. Tutor: It is recommended to ask for the "data" hint. [Maria clicks on data hint]
3. Tutor: ... uhm, what about it?
4. Maria: It is 4/9... so the first one is wrong... probability that A and B verify... ah, it is not a conditional probability, but the intersection; the second one is ok. The third one... conditional probability... first A than B, instead I put first B than A...
5. Tutor: Well, what do we do? These is the data... how could we interpret it [the data hint]? [Silence]
6. Tutor: Some of the probabilities given are the ones that are required: $P(A \cap B)$ is required... insert the correct value...
7. Maria: Should I correct it?
8. Tutor: Yes, of course
9. Maria: Should I erase here?

The impasse that Maria faces is related to her inability to identify the effective ways to use the data hint that the digital resource automatically suggested to her. In fact, Maria initially focuses only on the need to correct the mistakes she made in S2 when converting from verbal to symbolic representations. The automatic scaffolding provided by the digital resource (consisting of both the suggestion to ask for the data hint and the information contained in the data hint itself) acts at the orientating level, inducing the establishment of task demands and the identification of important information. However, this automatic scaffolding is not responsive enough for Maria, whose metacognitive activity is blocked at the orientating level. The tutor's scaffolding integrates the one provided by the digital resource through a reformulation of the request in S1 (lines 5 and 6), aiming to suggest how to use the automatic scaffolding to perform this step of the task correctly. This scaffolding turns out to be more responsive for Maria, as can be seen from her a-posteriori interview, in which, referring to this moment, she explains

"I was unsure about how to write in symbols what was in the text...when the tutor intervened, I was more...before I was unsure".

With her intervention, the tutor activates a "direction maintenance" scaffolding function that makes Maria reflect on the role of the data hint; and a "recruitment" scaffolding function that explicitly redirects Maria's attention to the request in S1. Only after the tutor's intervention, which clarifies how to use the automatic scaffolding, does Maria identify, with some difficulty, the first steps she needs to take to complete the task.

5.1.2 Impasse at the orientating level in Luigi's interaction with the digital resource

The excerpt is from the first phase of the activity, when Luigi is facing S1 (identify the probabilities given in the text of the task). The student has inserted some answers that were not requested, so an error message has appeared. Thanks to the a-posteriori reconstruction of Luigi's interaction with subtask S1, we have highlighted that his impasse is due to the fact that he did not read the text of the task carefully:

"I didn't understand what to do, probably I didn't read the task requirement".

1. Luigi: The Bayes' theorem? [Luigi asks the tutor for the Bayes theorem's formula]
2. Tutor: The message says "Are you ready? Let's start! Click here" … You should click here. [Luigi clicks]
3. Tutor: Now [the tutor reads the message], "What probabilities are given in the text?", so not all of them are required.
4. Luigi: Ok [Luigi deletes some of the answers he entered earlier]
5. Tutor: … those given in the text, ok.
6. Luigi: And these?
7. Tutor: No, if you want, you can write the probabilities that are not given in the text in a sheet, they can be useful later. Here you can write only the probabilities given in the text. Then you should click "Enter". [Luigi remains silent for a few seconds]

8. Tutor: You should leave here only the probabilities given in the text and delete the others.

9. Luigi: So, I will also delete the probability of the complementary event. . . ok.

The tutor's interventions act at the orientating level, aiming to focus the student's attention on the requirement of the sub-task. In this case, the problem is that Luigi does not really use the feedback provided because he has not read it. The tutor's interventions (lines 2, 3, 5), aimed at activating the "recruitment" scaffolding function by guiding the careful reading and interpretation of the text, support the orientating metacognitive activity. In this way, the expert scaffolding intervenes and integrates the automatic scaffolding, making it more responsive for Luigi. In his interview, Luigi explains that the tutor's intervention (mainly her suggestion in line 7) was essential to overcome his impasse. In fact, the automatic scaffolding could not support the missed or unfocused reading of the task requirement. In this case, the expert scaffolding integrates the automatic scaffolding in a fruitful way to get the student out of his impasse.

5.2 Moments of impasse related to the scaffolding aimed at supporting the planning and the executing metacognitive activities

5.2.1 Impasse at the planning and executing level in Maria's interaction with the digital resource

The following excerpt refers to the moment when Maria, facing S3 (identify the probabilities that can be directly obtained from those identified in Step S1), receives from the digital resource the suggestion to ask for the formula hint and she decides to follow this suggestion.

1. Maria: . . . Well, give me the formula hint. . . [Silence]

2. Tutor: Well, what can be useful for us?

3. Maria: . . . the formula hint?...

4. Tutor: What formula in particular? [Silence]

5. Tutor: For example, how might we calculate $P(A)$?

6. Maria: Is this one? [Maria points to a not useful formula]

7. Tutor: Well, you know $P(\neg A)$. . . is there a formula that could help you to determine $P(A)$ from $P(\neg A)$?

8. Maria: Is this one? [She indicates the formula for the probability of the complementary event, which is the useful one] [Silence]

9. Tutor: Ok! How can you use this formula? [Silence. Maria selects the box where she should enter $P(A)$. Then, she is blocked again]

10. Tutor: Is there another probability that can be calculated directly? From this formula [She points to the second one] ... You can calculate $P(B)$ from the second formula, right? And then? [Maria is blocked again.]

11. Tutor: $P(B)$ could be calculated from $P(A \cap B)$, so... if you invert this formula, you can find $P(B)$.

Although Maria has asked for the formula hint, she is unable to proceed because she cannot effectively use the hint to identify which probabilities can be obtained directly from the data. Therefore, the tutor's scaffolding is needed to activate the planning metacognitive activity. Indeed, the tutor intervenes by suggesting that Maria focus on one of the probabilities to be found (line 5), then on one of the data available (line 7) and asks Maria to identify a formula that connects them. The tutor's scaffolding aims to "reduce the degree of freedom" of the student's interaction within the resource by identifying a sub-goal with respect to the request in S3. The tutor's intervention also aims to activate the "marking critical features" scaffolding function, allowing Maria to focus on a specific formula for a specific goal. In her a-posteriori reconstruction of this episode, Maria recognizes the key role of the integration of the tutor's scaffolding with the automatic scaffolding, making it more responsive for her:

"I tried to look at all the required probabilities and to compare them with the formulas... the tutor allowed me to overcome my difficulty... the formulas alone were not enough".

5.2.2 Impasse at the planning and executing level in Luigi's interaction with the digital resource

The following excerpt refers to Luigi's work on the sub-task S2 (associate verbal and symbolic representations of the events introduced in the text of the task).

1. Luigi: I do not know $P(B)$, nor $P(\neg B)$, can I find $P(B \mid A)$? [Then Luigi clicks on "Enter" and a message appears: "To find the probabilities that you need, you could ask for the formula hint to understand which probabilities you can calculate using the ones you have". However, he has already asked for the formula hint.]

2. Luigi [read the message again]: To find the probabilities that you need, you could ask for the formula hint to understand which probabilities you can calculate using the ones you have...

3. Luigi: ... to understand what probabilities you can calculate using the ones you have... so I write $P(A \mid B)$ is equal to $P(B \mid A)$...$P(B \mid A)$ which is... [the tutor walks nearby and Luigi stops her] Can I ask?

4. Tutor: Of course
5. Luigi: What is the formula? I do not remember... $P(B \mid A)$ ...
6. Tutor: Well, ... what is written here is enough for you... what is your doubt? [She reads the probabilities that Luigi has inserted]. There is another probability that you can easily find.
7. Luigi: I think it is $P(B)$, but I cannot remember the formula.
8. Tutor: You think $P(B)$...well, what can you use to find $P(B)$?
9. Luigi: Bayes' theorem.
10. Tutor: This is easier. The formula, the definition of conditional probability.
11. Luigi: Uh...
12. Tutor: Which of the formulas in the list can be useful? [Luigi silently reads the list of formulas.]
13. Luigi: The third one is about conditional probability... but I cannot find $P(B)$...
14. Tutor: Exactly. There the conditional probability appears, but you cannot find the probability you are looking for... what is it instead that you can use to calculate $P(B)$?

Luigi explicitly asks for the tutor's help (line 3) after asking for the formula hint. During the a-posteriori interview he explains that he was blocked because he could not remember the formula to use (lines 5, 7). Luigi is therefore blocked at the level of the planning metacognitive activity. According to his a-posteriori reconstruction of his experience, his difficulty was due to a lack of familiarity with the formulas:

> "The problem here was that I didn't know the formula... even if I had it [the formula of Bayes' theorem], I might not recognize it immediately".

This lack of familiarity determines that the automatic scaffolding provided by the digital resource is not responsive enough for him. In order to help him overcome this block, the tutor intervenes by "marking critical features", since she suggests looking for a link between the available information, the given formulas and the goal of the sub-task (lines 6, 8, 12, 14). Moreover, when the tutor suggests Luigi to use the conditional probability formula (line 10), she activates the "demonstration" scaffolding function. After the tutor's intervention, Luigi quickly overcomes the impasse and performs sub-task S2 correctly. In this sense, the expert scaffolding makes the automatic scaffolding more responsive for Luigi, as explained by the student in his a-posteriori interview, where he stresses the crucial role of both the automatic meta-scaffolding provided by the digital resource (on the hints to be required) and the tutor's intervention in helping him to make fruitful use of the hints provided:

> "I would be more confused if the suggestions about the hints to ask for were not available"

> "If the tutor had not told me that there was an easier way to find the conditional probability I was looking for, I would have spent much more time".

5.3 Moments of impasse related to the scaffolding aimed at supporting the monitoring metacognitive activity

5.3.1 Impasse at the monitoring level in Luigi's interaction with the digital resource

The following excerpt refers to Luigi's work on sub-task S5 (find the probabilities that were not determined in the previous Steps). Luigi has inserted an incorrect expression for the conditional probability $P(B \mid A)$, so an automatic feedback appears in the form of an error message. However, the student is not able to recognize his mistake and asks the tutor for help.

1. Luigi: A message told me that these ones are wrong [Luigi indicates the probabilities $P(B \mid A)$ and $P(A \cap B)$ he has inserted in the input fields]... I don't know... maybe I made a mistake here... maybe I wrote a wrong expression.
2. Tutor: Maybe... maybe some brackets are needed.
3. Luigi: I can try. [Silence] [The tutor talks to another student. Luigi works on the expression of $P(B \mid A)$, but the error message does not disappear. Then he deletes the expression he has written.]
4. Luigi [reading the expression to find $P(\neg B)$]: One minus...
5. Tutor: Do you need some parentheses? ... Check carefully! There is no division...
6. Luigi [reading]: The product?
7. Tutor: "The product"?
8. Luigi: I should write...?
9. Tutor: Well... how do you find $P(\neg B)$ if you know $P(B)$?
10. Luigi: One minus $P(B)$.

11. Tutor: Well… in the expression of $P(B)$ there is a division… you have to write it.

12. Luigi: Ah, ok. $P(B \mid A)$ is equal to $P(A \mid B)$, 10/17, multiplied by … in the list of formulas I find the Bayes theorem … for $P(A)$. $P(A)$ is one minus 2/3. Everything should be divided by $P(B)$. $P(B)$ is … [But the message error does not disappear.]

13. Luigi [asking to the tutor]: Is this the correct formula, isn't it? $P(B)$ in the numerator?

14. Tutor: Yes, it is correct. But what is the numerator? What is it equal to?

15. Tutor: … but it is right [The tutor leaves.]. [Luigi does not follow the tutor's suggestion because his attention was focused on another formula.]

16. Tutor [She approaches Luigi again]: If you look at the list of formulas, what is $P(A \mid B)$ multiplied by $P(B)$?

17. Luigi: It is… the probability of the intersection of A and B

18. Tutor: Well, ok. It's faster and clearer, isn't it?

The tutor intervenes to help Luigi interpret the feedback provided by the digital resource (lines 2, 5). In particular, she "marks critical features" in order to help Luigi to effectively activate the metacognitive activity of monitoring by making him direct his monitoring focus either to conceptual errors and to possible syntactic errors (lines 2, 5, 9, 11). Finally (lines 14 and 16), the tutor guides the student's monitoring process by trying to help him identify his error by simplifying an expression he has written. When Luigi understands the tutor's suggestion (line 17), he is able to correct his mistake and overcome his impasse.

The student's a-posteriori reconstruction of the episode supports our interpretation, since he declares: "Uhm, at first I didn't understand if I missed the division or the product between the brackets… instead there was a typo... I erased and rewrote several times. I did not know which formula to use, and I wrote it wrong… I did not understand what was wrong, so I tried many times. When the tutor helped me to find the correct formula, I saw the mistake."

6. Results and final discussion

In this paper we have analyzed the interaction of two students with a digital resource in order to highlight, on the one hand, the students' difficulties in effectively re-acting to the scaffolding provided by the digital resource at the metacognitive level and, on the other hand, the ways in which the expert (the tutor) integrates her scaffolding with the automatic one in order to support the students in overcoming their moments of impasse.

Our analysis of Maria and Luigi's interactions with the digital resource has allowed us to identify three main categories of moments of impasse related to different metacognitive activities. Moreover, the analysis has highlighted the key role played by the tutor's interventions to reinforce or clarify the automatic feedback provided by the digital resource. These interventions are strongly related to the goals of the expert scaffolding that the tutor wants to provide: sometimes her scaffolding is mainly aimed at supporting effective interactions with the digital resource (see section 5.1.2), sometimes the support provided is mainly conceptual (when the student's block is related to unforeseen gaps, as in sections 5. 2.2 and 5.3.1), sometimes the scaffolding is aimed at balancing the conceptual level and the level of interaction with the digital resource (for example, when the student needs support to make effective use of the hint received, as in sections 5.1.1 and 5.2.1). Each scaffolding function is primarily associated with one of these goals. For example, while the recruitment function is mainly associated with the goal of supporting the student's interaction with the resource, the demonstration function, when the tutor shows how to use formulas or develop reasoning, is less focused on the level of interaction with the resource.

Despite the identification of these common elements that characterize the interaction within the system constituted by the student, the digital resource and the tutor, our analysis has shown that although some of the impasses that the two students face are similar from a macroscopic point of view (that is, at the level of the whole interaction that characterizes each moment of impasse), their ways of re-acting to the scaffolding provided by the digital resource are different due to their different metacognitive competences. This leads the tutor to re-act to their impasses from a microscopic point of view (i.e. at the level of specific interventions or of short excerpts) by providing them with different forms of scaffolding.

The analysis of the two excerpts in section 5.1, focusing on Maria's and Luigi's impasses at the orientating level, has shown that the tutor's reactions to these impasses are different. This is due to the fact that Maria's impasse is related to her inability to effectively use one of the hints provided, while Luigi's impasse is mainly due to the fact that he did not read carefully the task's request. In fact, the tutor reacts to these impasses in different ways: while she has to activate both the "recruitment" and the "direction maintenance" scaffolding functions to support Maria, she only needs to activate the recruitment function to support Luigi.

The analysis of the two excerpts in Section 5.2, which focus on Maria's and Luigi's impasse at the planning and executing levels, has shown that the tutor's approaches are different because, while Maria again has difficulties in using the provided hint effectively, Luigi's impasse is mainly due to his lack of knowledge about a specific formula. The tutor, therefore, reacts by supporting the two students in different ways. In fact, although in both cases she activates the "marking critical features" scaffolding function to make the students focus on a specific formula to achieve their goals, she supports Maria by activating the "reduction in degrees of freedom" scaffolding function because the student needs a more structured support, while she activates the "demonstration" scaffolding function to support Luigi because in this case the tutor wants to quickly promote the fading of the scaffolding.

The fact that we have included only one excerpt in section 5.3, related to Luigi's interaction with the digital resource at the monitoring level, testifies to a further difference between Maria's and Luigi's metacognitive competences, since Maria never activated herself at this level. Luigi is supported in overcoming his impasse at the monitoring level by the tutor's activation of the "marking critical features" scaffolding function.

The results of our analysis highlight the role that expert scaffolding plays in integrating automatic scaffolding for low-achieving students who have serious difficulties at the metacognitive level, especially in interpreting the feedback provided to them (as in Maria's case). The expert scaffolding also proves to be particularly useful in the case of students who are more competent at the metacognitive level (as in Luigi's case), when the type of impasse they face requires them to be provided with types of feedback that digital tools alone cannot easily provide.

These reflections suggest that a third cycle of research should be developed with the aim of systematically categorizing the tutor's interventions in relation to different types of impasse and to different student difficulties at the metacognitive level. This categorization could, in the future, serve as a professional development tool to assist teachers in identifying the most effective expert scaffolding that they could provide to their students in order to make automatic scaffolding more responsive for them.

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