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TURNING THE PREPARATION FOR A UNIVERSITY TEST INTO A CHANCE TO REFLECT ON MATHEMATICS LEARNING

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In a research conducted within the Italian National project “Scientific degrees”, we attempt to deal with the challenge of transforming the preparation for a university entrance test into an opportunity to learn and reflect on mathematics learning, rather than obsessing students with performance. More specifically, in a series of five lessons, the students engage in tasks by taking on roles that are the cognitive functions that come into play when tackling a math problem. The students work in groups and the roles/cognitive functions are gradually internalized through reflection questions asked at the end of tasks. The results show that the students still focus on performance, but a number of them shift their attention to other dimensions, even considering how they constructed the answer together with their mates.

INTRODUCTION

We focus on a mathematics test administered in a Computer-Supported Collaborative Learning (CSCL) environment to students enrolled at the first year of bachelor studies in STEM programs. It has been acknowledged that assessment in mathematics is a topic of interest for many educators at many levels, as well as for many stakeholders (Suurtamm *et al.*, 2016). Assessment has increasingly been conducted using digital environments. As Weigand *et al.* (2024) note, it is possible to distinguish between assessment *with* and assessment *through* digital technologies. In this paper, we focus on the latter since technology serves as a testing environment itself, as the students interact and communicate using available digital tools, participating in specific discursive activities with the aim of solving tasks and building their skills and knowledge in ways that are possible only through specific technology.

Following Newton (2007), the test under analysis in our study shares a common purpose with large-scale ones, that is making student placements. It is concerned with scores of individual students, in order to establish if they have a sufficient level of preparation in mathematics at the beginning of university, since “successfully completing required mathematics credits is crucial to progress through math-intensive STEM majors” (Kopparlo, 2024, p.107). So, with De Lange (2007), we maintain that this test “reflects the mathematics that is important to learn and the mathematics that is valued” (Suurtamm *et al.*, 2016, p.5).

Traditionally, the main focus of assessment has been on cognitive performance. But, in line with competency models as defined by Klieme *et al.* (2004), cognitive

performance is only one dimension of assessment: it emerges a need to consider further dimensions, for example the social aspects of assessment. Taking into account an iterative process, informed by theory and validated through empirical research in the CSCL context, Weinberger and Fischer (2006) highlighted the need for a holistic approach to knowledge construction that captures the complexity of collaborative learning. This led them to integrate aspects of participation, cognitive engagement in the task, argument construction and social interaction among students. Within this framework, the students' performance and the cognitive demands of the test are part of the epistemic dimension, which is only one out of four dimensions.

In the context of our research, we interpret this as a way to pay attention to both performance and support of students' learning during the preparation to a test. In fact, in a recent literature review on technology, Weigand *et al.* (2024) note that digital environments, as well as software, excel in assessing procedural knowledge, but when it comes to competency assessment, oral interviews and more traditional ways of assessing are still considered the best choice by teachers. Competency assessment is a central but demanding task for digital technologies and some attempts have been made (Weigand *et al.*, 2024). Our contribution can be considered as part of these attempts, in order to overcome the risk, for mathematics education “of focusing too much on assessment of lower order goals, such as the reproduction of procedural, calculation based, knowledge and skills” (Olsher *et al.*, 2023, p.675). We adopt and adapt Weinberger and Fisher's (2006) framework for analysing how the students elicit different ways of experiencing the preparation to a test, thus exploring whether it is possible to shift the students' attention from performance to other dimensions in a course designed to prepare them for an entrance test, and to what extent.

THEORETICAL FRAMEWORK

Weinberger and Fischer (2006) identify four dimensions involved in the process of knowledge construction in CSCL environments. The *epistemic dimension* focuses on how students participate with their contributions, namely how they interact with the content of the tasks, how they perceive the difficulty, what they think they are supposed to do. The *argumentative dimension* focuses on how students justify, qualify or argue, namely how they see and create coherence within the tasks, how they make sense of the structure of the arguments, how they connect the elements. The *participation dimension* focuses on how much students participate, namely how they interact with the elements that are present in the digital environment and whether they exploit its potential. The participation dimension offers two key insights: whether learners are engaging in the activity and whether their participation is balanced and equitable (Weinberger & Fisher, 2006). This dimension is crucial because it provides basic information on the students' involvement in the discourse. The *dimension of social modes of co-construction* focuses on how much students see the value of others in order to reach a correct solution, to what extent students refer to the contributions of their

peers, and whether they indicate the extent to which learners build on their peers' contributions.

In digital environments, it is necessary to pre-structure and regulate the social and cognitive processes in the collaborative phases, as it is not taken for granted that students are able to coordinate and collaborate. This can be done by establishing the roles students are asked to assume and the sequence of activities to be performed (Kollar *et al.*, 2006). In this regard, Albano *et al.* (2021) introduce a model of collaborative problem solving in a digital environment in which the dimensions required to manage the problem solving process are identified and correspond to different cognitive functions, which are: Promoter, Pest, Boss, and Blogger. These functions are speech and thought forms that communicate and their interaction makes the whole process collaborative. Promoter is the function of the explorer and initiator of the process, who seeks an insight or idea that can break an impasse. If they do not succeed on their own, they consult an expert or other sources. Pest is the critical mind, which seeks evidence for conjectures and raises objections and insinuates doubts, questioning what others have produced. Boss is the function of the organiser and regulator of the problem solving process. It acts both on a cognitive level because they hold the threads of the process, move towards the goal, choose the solution strategies. They also act on an affective level in the sense that they seek to reassure, try to restore calm in the case of negative emotions and encourage participation in the resolution process. Blogger is the function that corresponds to the organization in 'fine-copy' of the solution reached. Blogger function is important from a communicative point of view: they produce a text that can be informal, as in communication between colleagues, or formal, according to mathematical standards. Their function is also important from a metacognitive point of view, as 'writing promotes awareness and also supports the processes of checking and revision' (Albano *et al.*, 2021, p. 33). We combine Albano *et al.*'s (2021) framework with the one proposed by Weinberger and Fisher (2006) arguing that Promoter is expected to work at *epistemic dimension*; Pest is expected to work at both *epistemic* and *social modes of co-construction dimensions*; Boss is expected to work at both the *epistemic* and *participation dimension*; Blogger is expected to work at the *argumentative dimension*.

METHODOLOGY

The participants in our study are 65 first-year students enrolled in STEM undergraduate courses at the University of Eastern Piedmont in Italy. They are at the very beginning of the first semester and are attending a bridge mathematics course that helps them recapping the mathematical knowledge that is necessary to pass the entrance test. In this university, the students firstly enrol and then take the entrance test. If they fail, they attend an extra mathematics course and take the test a second time at the end of the first semester. The bridge course is made up of five lessons and the test takes place after them. The course has been designed in a CSCL environment. Students work in groups of four communicating with each other via a chat. Following Albano *et al.*

(2021), the students in each group take turns assuming one of four roles that correspond to the cognitive functions: Promoter, Pest, Boss, and Blogger. Specific tasks were designed for each role: for Promoter, open questions such as “explain your reasoning”, or multiple-choice questions with feedback and suggestions from the platform that acts as an expert; for Boss, tasks regarding the organization of the process, timed questions and open questions such as “Tell one of your mates what the task requires”; for Blogger, open argumentative tasks such as “Justify your answer”, completion questions with word tiles or transitions between representations; for Pest, tasks that can generate doubts, for example open questions such as “Luisa says that.... Do you agree with Luisa? Why?”, or multiple-choice questions with several correct answers.

In each lesson, the students answer a series of math tasks, but also three open reflection questions about the roles played: (i) How well do you think you have played your role? (ii) Why? (iii) How did the features of the role influence your way of dealing with the tasks? To shift the focus of assessment from performance to learning, the lecturers of the course did not consider the scores obtained by students in their math assignments, but only the answers provided to the three reflection questions, giving feedback and considering the dimensions addressed by the students in their answers, that is, the epistemic, the argumentative, the participative and the social modes of co-construction ones (Weinberger & Fisher, 2006).

The students’ answers have been collected on the digital platform and we coded and analysed the written texts marking which dimensions have been addressed. In what follows, we offer some examples for how we proceeded in order to code each student’s written answers to the reflection questions. Then, we aim at answering the research question: does a learning environment of this sort of prompt students to shift from a mere focus on performance (embedded in the epistemic dimension) to considering also participative and argumentative aspects of learning, to even mention social modes of co-construction of learning?

Sofia is playing the role of Promoter in the second lesson, which pivots around a task about percentage. She replies to the three open reflection questions as follows:

I used the feedback, because at my first check whether responses were correct, my answer was only partially correct. I checked through the feedback that my reasoning was correct. Hence, I thought that the problem should have been one of the alternatives that I had not marked as correct. I concentrated only on those and I understood which one of the three remaining was correct, already knowing that it had to be at least one.

Sofia refers to “responses” using the plural because the task required selecting multiple correct options without indicating the number of correct ones. Sofia is asked to say whether she used the feedback, which allows her to feel free to explore and even make mistakes she can correct successively, which is a feature of the role of Promoter. Sofia, in our interpretation, focuses on the task and on getting the job done. She stays within an epistemic dimension, if we look at Weinberger and Fisher (2006), since she refers to how she works on the knowledge construction task she is confronted with. One could

object that the question about whether Sofia used the feedback could have induced her to focus on the epistemic dimension. This may be true, but Sofia provides a different answer when she plays as Blogger after working on a task about the graph of a function. When asked to indicate by what criteria she had chosen the alternative that seemed correct to her (as in this case she had to complete a text with adverbs and/or conjunctions), Sofia provides an answer that focuses on the argumentative dimension, in our interpretation:

In answering the first task, I had to choose the alternative that seemed correct to me so that the sentence would be consistent. However, completing the sentence was not enough, the important thing was to ensure that the speech was coherent and therefore linked by a common thread just like a blogger would do. For this reason I had to use logic and reason to choose the option that in my opinion suited best without stopping at the first choice and thus making hasty decisions, reasoning on every possible alternative.

Sofia mentions her effort to make a coherent and consistent text, referring to a thread and reflecting on how to achieve it. According to Weinberger and Fisher (2006), in knowledge construction learners explore complex problems by developing and weighing arguments to justify potential solutions. They continuously support, refine, or challenge proposed solutions until they reach a conclusion. This general statement about the argumentative dimension is well reflected, in our view, in Sofia's words, especially in the last part of her writing.

Marco is playing the role of Boss, in a different group, in the task on percentages, and he answers to the same questions as follows:

Using my solution to the task, I had to give some information to my classmates through a chat, which helped a lot.

From Marco's writing, we can notice that the focus is still on the task, as he refers to answering it, but to a greater extent it is on teamwork and how he played with the tools at their disposal (i.e., the chat used for communicating within the group) in order to solve the task. This prompts us to code Marco's answer as belonging to a participative dimension. Such a dimension allows us to capture how much the students interact with the elements that are present in the digital environment and whether they exploit its potential.

Gabriele, who is playing the role of Blogger, says:

We were able to collaborate well together and find a solution easily, with my role as a blogger who has to illustrate a production of the work done by the group. This role allowed me to be the final part and illustrate what our group thought to expose the correct answer.

We can notice that the focus of Gabriele's answer is much less on the mathematical content, and much more on how the group collaborated in order to come to a final answer. According to the definition by Weinberger and Fisher (2006), the dimension of social modes of co-construction allows us to focus on how much students see the value of others in order to reach a correct solution and to what extent the students refer

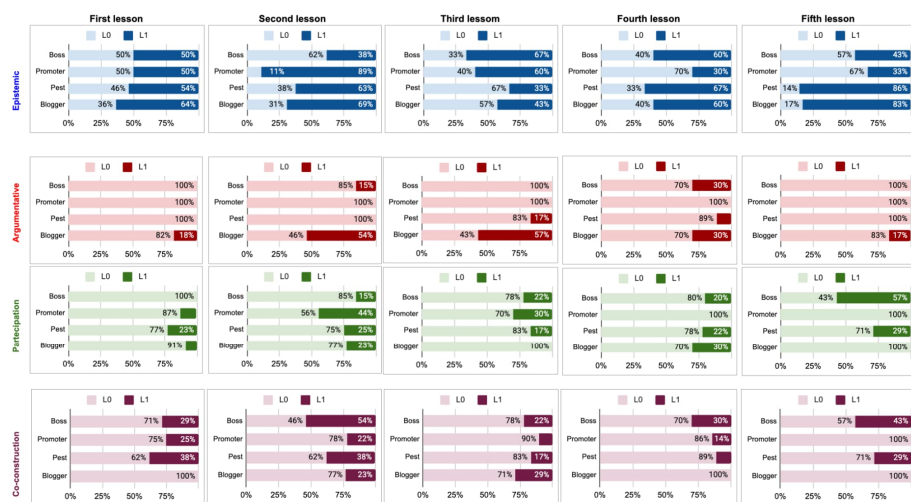
to the contributions of their peers. In Gabriele's response, the reference to group work and the satisfaction in working in a group are present.

After having shown examples of coding, the answers of students having played different roles in different tasks, we try to show how the four dimensions have been elicited by the students in each lesson, and we proceed to data analysis.

DATA ANALYSIS AND RESULTS

Data analysis is centred on a 4x5 table of graphs, shown in Figure 1. The graphs show the percentages of students that mention (L1) or do not mention (L0) each dimension (the four rows: epistemic, argumentative, participation, social modes of co-construction) in answering to the questions (i), (ii), and (iii) for each lesson (the five columnsns).

Figure 1: The percentages of students' responses coded as eliciting each dimension in each one of the five lessons, when asked the questions about the roles played.



If we focus on the first lesson (first column of Figure 1), we can notice that 50% or more of the answers have been coded as belonging to the *epistemic* dimension. The dimension of *social modes of co-construction* emerges in around 30% of the responses across the roles played, whilst the *argumentative* one is substantially not mentioned, and the *participative* one is mentioned by 23% of the students who played the role of Pest, and no or little mentioned by the others. In our opinion, this is not surprising: in the first lesson students focus on epistemic aspects—that is, on what the test requires, since the purpose of the course is to prepare for the test. The students also focus, albeit to a lesser extent, on interactive aspects in the first lesson. If we focus on the other

lessons, we notice immediately that the *epistemic* dimension is always the most present, across roles and across lectures. The *argumentative* dimension attracts a similar percentage of responses in the second and third lessons only for the role of Blogger, which can be interpreted as in line with the features of this role. However, the smallest percentages of Bloggers' responses coded as belonging to the argumentative dimension in the other lessons tell us that it is not given for granted that students playing the role of Blogger focus on the argumentative aspects, and the relatively high percentages of responses, given by students playing the role of Boss and Pest, referring to the argumentative dimension in the third and fourth lessons lead us to say that the argumentative dimension can be elicited by specific roles as well as by specific tasks. The *participative* dimension is present, for the role of Pest, in every lesson. It is also present for the role of Boss, except for the first lesson, and exceeds 50% in the last lesson for the role of Boss. The students playing the role of Pest mention the participative dimension in the first three lessons, and also those who play Blogger mention it in the first, second and fourth lessons. The dimension of *social modes of co-construction* is mentioned often: by all roles but Blogger in the first and fourth lessons, by all the roles in the second and third ones, and by Boss and Pest in the last ones.

DISCUSSION AND CONCLUSIONS

In our research, we aim at exploring if it is possible to shift the students' attention from a merely epistemic dimension of a mathematical test to other dimensions that entail interaction. There is a plea for that even in recent studies (e.g., Olsher *et al.*, 2023; Weigand *et al.*, 2024). Looking at the data from our study, we can say that there is still a great deal of attention paid by students to epistemic aspects. We interpret this as somewhat natural, given the purpose of the specific test under analysis. However, in relatively many cases we notice that considerations emerge regarding other dimensions, especially the argumentative one but also the co-construction one, which have a certain relevance. Some percentages of presence of a dimension in a student's response are low and this may lead us to conclude that the answer to the research question is negative. However, we think that the graphs in Figure 1 need a careful reading and it is crucial to take into consideration the fact that the questions (i), (ii), and (iii) concerned roles. Despite this, there are clear references to the dimensions. Figure 1 shows that, in addition to the epistemic dimension, all other dimensions were involved throughout the lessons. Regarding the argumentative dimension, in addition to Blogger, as expected, Boss and a bit of Pest were also involved. Regarding the participatory dimension, we note that all roles mention it, throughout all the lessons. Regarding the co-construction dimension, we can see that, in addition to Pest, which is the role most characterized by this dimension, the other roles, particularly Boss, also mention this aspect.

The epistemic dimension is certainly the predominant one. However, the students who played the role of Boss were, especially in the second lesson, involved in all

dimensions, primarily co-construction. Except for Blogger in lessons 2 and 3, involvement in the argumentative dimension is low but participation and co-construction are more stable. The students who played the role of Promoter remained fundamentally focused on the epistemic dimension, but they were also involved in participation and co-construction. The students who played the role of Pest engaged in all dimensions, including argumentative, although to a lesser extent. The students who played the role of Blogger focused mainly on the epistemic and the argumentative dimensions but also mention the participation and the co-construction ones. Our study has an explorative nature, and the peculiarities of the context might undermine its generalizability, but it contributes to show that it can be possible to shift the students' attention from scores to other aspects of assessment.

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