The role of peer-review workshops in prospective teacher training

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Abstract
In this paper we present a model for formative assessment based on peer-review workshops on MOODLE, designed by researchers of the University of Salerno and the University of Torino. The model has been implemented in the Mathematics and Mathematics education courses in Primary Education at the University of Torino. The peer-review workshops are intended to pursue the following objectives: (1) strengthening the *argumentative skills* of prospective teachers to direct them towards a *relational* view of mathematics; (2) provide them with models of *formative assessment* rooted in peer-review feedback managed by the University lecturer. We present an example of peer-review that intertwines effective feed-back with a relational understanding of mathematical thinking.
Key words: peer-review; argumentation; formative assessment; feedback; relational thinking; digital technology

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1. Introduction

The aim of this study is to devise a training model for prospective primary school mathematics teachers, focused on the enhancement of argumentation and proof, which has been selected as subject matter knowledge (Ball *et al.*, 2008). The activities carried out in the professional development program also focus on formative assessment in mathematics acting both as a teacher training

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instrument and pedagogical content knowledge (Ball *et al*., 2008). The model is based on peer-review workshops carried out on Moodle learning platform that represents a tool and a resource for teacher collaboration (Borko and Potari, 2020).

We present a work developed as part of the Digimath Group of the Italian Mathematical Union (UMI) (https://umi.dm.unibo.it/gruppi-umi-2/gruppo-digimath/), directed by Giovanna Albano. We describe a model of formative assessment in mathematics, designed by researchers from the University of Salerno and the University of Turin, centered on peer-review workshops (Sabena, Albano and Pierri, 2020) . The model has been implemented in the Mathematics and Mathematics education courses in Primary Education at the University of Torino. The peer-review workshops are intended to pursue the following objectives:

- Strengthening the *argumentative skills* of prospective teachers to direct them towards a relational view of mathematics (Skemp, 1976);
- Provide them with models of *formative assessment* in mathematics to transfer into their teaching practice;
- Actively involve non-attending students in Fundamentals and Didactics of Mathematics courses and support those who are experiencing difficulties with the discipline.

Workshop activities are developed following a framework that involves the performance of mathematical tasks based on argumentation processes, peer-review of papers produced by participants, and finally feedback from the lecturer on optimal and those with common errors. In *itinere*, the lecturer can provide participants with examples of feedback for correction before the peer-review phase. Technology, in the case of the Torino experience, the Moodle platform, plays a key role in building a learning environment that fosters interaction and collaboration among participants, ensures anonymity in peer-review assessment; it allows random distribution of assignments for correction among peers and monitoring and sharing of the students' and lecturer's feedback.

2. Relational thinking for argumentative skills

Skemp (1976), analyzing educational practices at the secondary school level, discusses the multiple meanings that are given to the verb 'to understand' in the mathematics educational context. In particular, he introduces the dichotomy between a *relational understanding* and an *instrumental understanding* in mathematics: "By the first term [relational understanding] I denote what I have always regarded *as understanding*: knowing what to do and why. *Instrumental understanding* [...] is what I have referred to in the past as 'rules without reasons,' without realizing that for many teachers and students the possession of these rules, and the ability to use them, is precisely what they mean by *understanding*" (Skemp, 1976, p. 21).

In Mathematics Education, argumentation is defined as "the discourse or rhetorical means (not necessarily mathematical) used by an individual or group to convince others that a statement is true or false" (Stylianides *et al*., 2016, p. 316). Two components can be distinguished (Hitt and Gonzalez-Martin, 2016):

- A component that seeks to convince (persuade), in the sense of removing all doubt from others.
- A component that seeks to explain (ascertain), in the sense of removing all doubt from oneself, based on reasoning.

"*Relational understanding*" is what is taken as the reference in this workshop because it reinforces the argumentative skills of prospective teachers to direct them toward a relational view of mathematics. In fact, argumentation is intertwined with relational thinking in that it is embedded in the individual's knowledge of what to do and why when accomplishing the abstract and general nature of mathematical thinking.

3. Formative assessment

Educational research singled out a new undersdtandings of asaseesment in higher education focussing on the interplay between assessment, educational design and learning enhanced by the introduction of digital technologies (Ibarra-Sàiz *et al*., 2020). On this note, digital formative ecosystems (Rossi and Pentucci, 2021) allow teaching learning practices that go beyond the space of the classroom and the time of the lecture, rethought to meet training needs and interaction between students and teachers.This enhanced cultural and social space represented by digital educational ecosystems enables the transition from *assessment of learning* to *assessment for learning* and *assessment as learning* (Sambell, McDowell, and Montgomery, 2013; Dann, 2014). The accomplishemtn of the transition from *assessment of learning* to *assessment for learning* and *assessment as learning* rests on the intertwining of formativave assessement and feedback.

Formative assessment is defined as the 'work that a student carries out during a course for which they get feedback to improve their learning, whether marked or not (Higgins, Grant, and Thompson, 2015, p. 4). At the encounter between educational effectiveness and resource efficacy, formative assessment can yield substantial learning gains, where students can monitor their progress, engage in further study, thus increasing their undesrtanting and pursuing meaningful and robust learning. (Higgins, Grant, and Thompson, 2015; Black and William, 2006; McCallum and Milner, 2021). Within digital formative ecosystems, e-assessments foster student engagement and permit early intervention, focussing, besides performances, also on the student's attitudes, belief's and interpretations (McCallum and Milner, 2021).

Feedback is information provided by an agent regarding aspects of one's performance or understanding. There is a body of research (Hattie and Timperlely, 2007; Hattie, 2009; Hattie and Zierer, 2019) on this subject showing its effectiveness in education, especially in a network of digital and non digital resources, for instance in formative ecosystems. The implementation of different forms of feedback (e.g. rubrics, portfolios, e-feedback) allows reflective processes that are carried out in the interplay beteween educators and students and between peers (Winstone and Careless, 2019; Giannanandrea, 2009, 2019; Laici, 2021; Rossi *et al*., 2021). Students, thus, engage in activities in which they themselves request and seek feedback, provide and share feddback with their peers, fully understand its meaning, and are able to use the information about their work or approach to learning in productive and progressive ways over time (Winstone and Carless, 2019). This attitude also holds in the realm of mathematics, where feedback fosters a collaborative environment that allows prospective teachers to encounter mathematics topics such as arguemtation, proof and relational thinking. They interiorize novel forms of rationality with a positive affective attitude towards a subject that is usually perceived "disturbing" by primary school teachers.

The aforementioned findings are acknowledged by mathematics education research that strongly recommends the use of formative assessment. This type of assessment consists of that teaching practice aimed at improving the educational process itself according to a developmental logic (Castoldi, 2012). Formative assessment taks take the form of a true teaching method, in which "evidence about student achievement is collected, interpreted and used by teachers, students and their peers to make decisions about the next steps to be taken in the educational process that may be better, or better founded, than decisions made in the absence of such evidence" (Black and Wiliam, 2009, p. 7).

Typical activities of formative assessment processes are therefore those through which students have the opportunity to check their learning levels, plan and implement, in interaction with the teacher and classmates, the strategies necessary to achieve the set learning objectives (Cusi, Morselli and Sabena, 2017). These types of activities can also support the professional development of teachers because they allow for the structuring of collaboration (Albano, Dello Iacono and Pierri, 2020).

This perspective is also in line with the National Indications (MIUR, 2012), according to which evaluation “precedes, accompanies and follows curricular paths. It activates the actions to be undertaken, promotes the critical evaluation of those carried out. It assumes a prevalent formative function, accompanying learning processes and stimulating continuous improvement” (p. 13).
Black and Wiliam (2009) indicate that formative assessment consists of five key strategies (Fig. 1):
1. clarifying and sharing learning intentions and criteria for success;
2. engineering effective classroom discussions and other learning tasks that elicit evidence of student understanding;
3. providing feedback that moves learners forward;
4. activating students as instructional resources for one another;
5. activating students as the owners of their own learning.

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

Fig. 1 - Aspects of formative assessment (Black and William, 2009, p. 5)

Furthermore, five key strategies for implementing this type of assessment are those elaborated in the theoretical framework of Wiliam and Thompson (2007):
1. Clarifying and sharing learning intentions and success criteria;
2. Design effective discussions to be conducted in the classroom and other learning tasks that highlight students’ understanding;
3. Provide feedback that moves students forward;
4. Enable students to be mutual educational resources;
5. Make students aware of and responsible for their own learning.

In this model, three different actors intervene in Formative Assessment practices: the teacher, the student and his/her peers.

The feedback referred to concerns the information the student receives on his/her performance and is undoubtedly one of the most important tools for building a bridge between actual and expected learning. Following Ramaprasad’s (1983) definition, feedback only becomes formative if the information provided to the student is used in some way to improve his/her performance. It is therefore important that the feedback goes beyond a simple green or red 'traffic light' for the student, which would have the simple task of guiding the student's behaviour. Rather, it is needed to show him what errors, shortcomings, inaccuracies and possibly what they may cause. Based on these reflections, Hattie and Timperley (2007) therefore distinguished four types of feedback:

1. feedback on the task, focusing on the interpretation of the task text or the correctness of the answer given (a kind of feedback on the product);
2. feedback on task performance, in relation to the processes required to understand and deal with the task effectively;
3. feedback on self-regulation, focusing on the individual's ability to self-monitor and consciously direct his or her own actions;
4. feedback on the individual as a person, which concerns issues related to the evaluation of the individual and includes emotional aspects.

Evaluation is addressed by specific criteria defined by the teacher: correctness, completeness and clarity. These categories emerged within the teaching experimentation carried out by the Italian FaSMEd project team (Aldon *et al*., 2017; Cusi *et al*., 2017). The evaluation criteria are detailed below:

- *Correctness*: "Are there errors in the result or in the resolution process? Are all answers provided? Are theoretical references, if any, correct? Are mathematical symbols used correctly?"
- *Completeness*: "Are parts missing or are there jumps in reasoning? Are there unjustified conclusions? Can you find all necessary steps in the reasoning?"
- *Clarity*: "Is the reasoning expressed clearly and unambiguously? Are the sentences comprehensible?"

3. Model of the peer-review workshop

The online formative assessment workshops piloted at the University of Salerno and the University of Turin are characterised by several phases involving the solving of a mathematical problem and the subsequent formative assessment by peers and the teacher. The logistical aspects of this process are simplified and made sustainable, even in large classes, by the use of the special Workshop activity module of the Moodle platform. The module allows problem-solutions to be collected from all students and redistributed randomly and anonymously to a few peers for evaluation, allowing each student to receive one or more evaluations from peers and the trainer to view all resolutions and all evaluations, and thus provide feedback to the class at the end of the process.

More specifically, the trainer has to design and implement the online formative assessment workshop that involves the following four steps (Fig. 2):

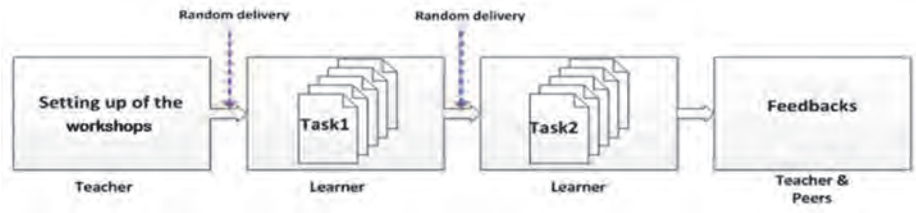

Fig. 2 - The model of the online peer-review workshop

- Workshop set-up: the teacher establishes the structure of the workshop: assigning a time for solving the various tasks; defining the evaluation criteria (correctness, completeness, clarity); distributing a specific number of products for each student.
- Problem-solving (Task 1): all students are given the same mathematical problem to solve and the criteria by which their output will be assessed; then, each student uploads his or her resolution onto the platform.
- Peer assessment (Task 2): each student receives the anonymous productions of three peers, chosen randomly from the Workshop module; he/she then examines them and provides each of them with one or more feedbacks, according to the shared assessment criteria; each student receives the feedbacks produced in the previous step by the peers who examined his/her production.
- Feedback: the trainer makes available on the platform the solutions that he/she considers interesting for the class, chosen from those produced by the students themselves. In particular, the trainer shares examples of optimal solutions and solutions containing common errors with his feedback. The feedback on both types of production (and possibly on the evaluations provided by peers) is finally shared by the trainer within a collective discussion.

Self-assessment workshops require the integration of several resources: knowledge, assignments, assessment criteria and the possibilities offered by the Moodle platform. The correct management of resources makes it possible to build customised pathways that support students' difficulties and enhance their potential. In the case of workshops, the use of the Moodle platform makes it possible to customise both the types of tasks and the feedback offered by the teacher.

3.1 Formative objectives

An online peer review workshop is offered with different learning objectives, identified by the trainer, within a given context. In the context of teacher training, here are some of the most important objectives:

The workshop aims at the development of the mathematical thinking of those who participate in it by leveraging the valuable contribution of the feedback that trainee teachers can receive from peers and that of their own work in reviewing peer products, for the opportunity it offers to reflect on representations and problem-solutions different from their own.

Prospective teachers are also asked to carry out formative evaluation, which can also be understood as a simulation of a practice they will be called upon to implement in their professional lives. In this task they are guided by evaluation criteria provided by the trainer, with possible examples of application: this activity, especially if repeated in the case of peer evaluation workshop cycles, allows the future teachers to develop skills in formative evaluation practice.

Finally, the peer assessment proposal, being accompanied by the introduction of the criteria, can also be used by the trainer to share with the future teachers which assessment criteria will be adopted in the examination, or at least part of them, implicitly communicating also what the trainer considers most valuable in mathematics and its teaching.

3.2 The mathematical problem

The mathematical problem should have the characteristics of an authentic task. The authentic task activates students on open, challenging and meaningful paths. The teacher should construct a problem with multiple possible resolutions and a variety of arguments. The task should be connected to a meaningful mathematical context to activate the students' ability to build connections between different areas of mathematics and beyond. The network of connections built by the student to activate a process of interpretation and reinterpretation that the task authenticates as a dialogue with a challenging context on an epistemological and personal level. An example of a task administered in the workshop, which we will analyse in the next section, is the following:

Consider a natural number. Determine the difference between its square and its preceding square. Repeat the operation for several numbers: what regularities do you observe? Justify your assertion.

A problem like this has several possible solutions that can be obtained by drawing on a variety of arguments. The solution of the task requires a dialogue with the algebraic-arithmetic context in which the problem is set and a game of interpretation and reinterpretation in order to look at the mathematical phenomenon with different meanings by activating semiotic transformations between several registers of representation.

We present below the solution of two different students, with the lecturer's feedback, based on the blending of arithmetical and algebraic thinking.

Student 1

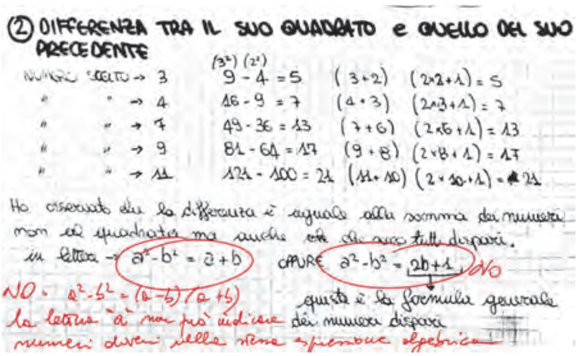

Fig. 3 - Student 1 solution with the teacher's feedback in red

Student 1 embarks on an arithmetical argumentation based on a factual generalization (Radforf, 2003). She grasps the general rule under two possible interpretartions, as the sum of the general number and its preceding one and as the double of the preceding number plus one. When she shifts to the algebraic argumentation via a symbolic generalization (Radford, 2003) she is not able to express a general natural number and its preceding one. She uses the letters a and b that do not express the aforementioned relation between a number and its preceding one, as pointed out by the teacher's feedback.

Also Student's 2 argumentation is trigerred by a factual genersalization in the arithmetical domain, but the core of her proof occurs as a symbolic generalization. Differently from Student 1, she is able to express in symbolic language the relation between a number and its preceding one and thereon her reasoning is sustained by algebraic calculations. From the algebraic expressions, Student 2 interprets the general rule as the sum of the general natural number and its preceding one and as an odd number. She is not able to grasp that the result is the double of the preceding number plus 1 (as highlighted by Student 1) or the preceding of the double of the general natural number as pointed out by the teacher's feedback.

Student 2

Per determinare la differenza tra il suo quadrato e quello del suo precedente voglio partire dagli esempi della tabella che segue.

Numero preso in esame	differenza tra il suo quadrato e quello del suo precedente	Risultato
4	$4^2 - 3^2$	7
5	$5^2 - 4^2$	9
120	$120^2 - 119^2$	239

Possiamo dunque scrivere questa relazione come n^2 - (n-1) ^{2}, dove con n indichiamo un qualsiasi numero naturale.

Osserviamo dagli esempi una particolare proprietà ossia il fatto che il risultato di questa operazione sia la somma tra il numero n ed il suo precedente (prendendo in considerazione il primo esempio: $4^2 - 3^2$ è uguale a 7 che è la somma tra 4 ossia il numero preso come esempio ed il suo precedente); potremmo dunque dire che n^2 - (n-1) ^{2} = n+ (n-1)= 2n-1.

Questo è possibile rappresentarlo dal punto di vista algebrico:

$$n^2 - (n-1)^2 =$$

$$= n^2 - (n^2 - 2n + 1)$$

$$= n^2 - n^2 + 2n - 1$$

$$= \underline{2n-1}$$

Questa formula mi dice quando sto trattando del PRECEDENTE DEL DOPPIO DEL NUMERO di partenza

Da questa dimostrazione ricaviamo anche un'altra proprietà: il risultato sarà sempre e solo DISPARI, in quanto una quantità moltiplicata per un numero pari darà sempre un numero pari, ma se poi gli viene sottratta una quantità sipari, il numero sarà dispari.

Fig. 4 - Student 2 solution with the teacher's feedback in blue

3.3 Formative assessment criteria

In conducting the workshop, the trainer has as a reference point for constructing the workshop and achieving the objectives the formative evaluation according to Black and William's (2009) proposal described above in the paper. We have also seen the five key strategies for implementing such an evaluation according to Wiliam and Thompson's (2007) theoretical framework:

1. Clarifying and sharing learning intentions and success criteria;

2. Designing effective classroom discussions and other learning tasks that highlight students' understanding;
3. Provide feedback that moves students forward;
4. Enable students to be mutual educational resources;
5. Make students aware of and responsible for their own learning.

In the formative assessment workshop, feedback and peer interaction play a key role in the assessment process. They require fine-tuned preparation on the part of the trainer. In fact, the trainer has to set up a series of activities involving the learners in order to clarify and share the learning objectives and the criteria for their achievement. At this point, it makes sense to propose an authentic and challenging task on which the different phases of the workshop are based. To enable learners to be mutual educational resources among peers and make them aware of and responsible for their own learning, the trainer provides learners with operational tools for the formative assessment workshop that is based on the exchange of feedback. Alongside the definition of objectives and success criteria, students receive the mathematical knowledge that enables them to build meaningful conceptual networks, guidelines for recognising a correctly performed task and strategies for sharing effective feedback with peers to support them in acquiring argumentative competences in mathematics. With regard to feedback, the trainer takes care to direct workshop participants towards the production of indications, suggestions and timely explanations that:

1. focus attention on the interpretation of the task text or the correctness of the answer given (a kind of feedback on the product);
2. highlight the fundamental elements for performing the task, in relation to the processes required to understand and deal with the task effectively;
3. support self-regulation, focusing on the individual's ability to self-monitor and consciously direct their own actions;
4. respect the person-centred nature of the workshop and take into account the emotional aspects inherent in assessment processes and the effects they may have on peer motivation.

In the proposed practice example, the trainer chose to share the following evaluation criteria:

- Correctness: 'Are there errors in the outcome or resolution process? Are all answers provided? Are theoretical references, if any, correct? Are mathematical symbols used correctly'?
- Completeness: "Are parts missing or are there jumps in reasoning? Are there unjustified conclusions? Can you find all necessary steps in the reasoning?"
- Clarity: "Is the reasoning expressed clearly and unambiguously? Are the sentences comprehensible?"

Aldon and colleagues (2017) note that the completeness criterion can be misunderstood by students. Often, students associate completeness with the presence of all answers to questions and not with the completeness of the mathematical reasoning expressed through the argumentation, in terms of argumentative steps. The authors emphasise the need to make this explicit from the outset. In order to ensure the success of the workshop, the trainer shares through targeted interventions the three criteria set out above, both for the performance of the task and for the peer assessment process, with a focus on that of completeness.

Aldon and colleagues (2017) also note that two-thirds of the students found the assessment task difficult or very difficult. To support the students in the assessment, the trainer can share tasks that have already been completed to discuss their correctness and experiment with formative assessment strategies together. The experience showed that the students greatly appreciated the opportunity to engage in formative assessment activities in collaboration with the trainer, especially those who had found themselves assessing productions related to a mathematical problem that they themselves found difficult.

4. Example of incorrect solution of the task and excellent feedback from a peer

The following problem was assigned at the peer-review workshop of the University of Torino.

The race to 20 game is played by pairs of players. Each player tries to say "20" first by adding 1 or 2 to the number given by the other. One of the pair starts by saying "1" or "2" (for example, "1"); the other continues by adding 1 or 2 to this number ("2" for example) and saying the result (which would be "3" in this example); the first person then continues by adding 1 or 2 to this number ("1" for example) and saying the result (which would be "4" in this example); and so on. Identify the numbers that make up the winning strategy and explain why it is successful.Which mathematical operation allows you to quickly find the first number to play? Why?

Student's answer:

In the 20-step race of 1 and 2 you win if you play first and know the winning strategy. The strategy is that there are winning numbers and they are 2, 5, 8, 11,14 and 17. Moreover the winning numbers jump from 3 to 3 i.e. the sum of the two steps (1+2=3). If you know the strategy you will therefore start with the number 2 and victory is assured because whichever step your opponent chooses to take you will in any case be able to get to the other subsequent winning numbers and you will win (the opponent after the number 2 can choose whether to say the number 3 or 4 but whichever he answers you will still be able to get to the number 5 and so on). The mathematical operation that allows you to get the first number to play is as follows: you start backwards from the last number and subtract the number obtained from the sum of the steps until you get to the beginning and then to the last number you can say before 0.

Peer's feedback:

The reasoning you have followed is clear and fluent, but it either misses one part completely or leads you to some incorrect solutions.

Pay attention to the wording of the question: why do you win if you start first? Your answer seems more aimed at explaining how to win by starting with a strategy that seems given a priori. The reasoning is stuck at an early stage. It would be useful to try to generalise in order to arrive at quicker and more effective rules than using the subtraction of 3 units from the target number.

Correct reasoning up to the identification of the number series defined as the winning strategy, which however led (perhaps due to haste or carelessness) to an incorrect conclusion. In this case one must NOT start to win! If one considers that the first winning number identified is 5, it is in fact evident that by starting we cannot reach it, as we can only make steps from 1 to 4, and one would leave the opponent with the choice to lead the game.

If we reason in terms of a 'mathematical operation' and consider the request to quickly find the winning strategy, it can be understood that the task requires a more general nature of the answer. If we were in fact in the presence of a 'race at 47 with steps of 1 and 2', it would be complicated to quickly carry out all the necessary subtractions to find out whether it is convenient to start or not and if so with which number. If we divide 20 by 3, we obtain 6 (the numbers that make up the strategy) with a remainder of 2. 2 is then the number from which to start and then, following steps of three, arrive at our goal. We are thus able to start our run at 47, dividing by 3, thus obtaining 15 numbers for our strategy and starting with 2.

The exachange between the two students fosters peer formative assessment that moves the students forward, enables them to be mutual educational resources and make them aware of and responsible for their own learning. The mathematical feedback provided by the peer to an incorrect solution of the task is manifold in that it takes into account the interpretation of the taks, correctness of the answer, the performance in relation to the process required to face the task and accomplish the correct solution. The feedback intertwines to important features of mathematical tasks, i.e., the process and the product as two sides of the same coin. In this specific instance, the peer-review workshop was successful in binding formative assememnt to Skemp's relational understanding when performing mathematical argumentation. The peer's feedback stresses the lack of relational reasoning when he claims that it would be useful to try to generalise in order to arrive at quicker and more effective rules than using the subtraction of 3 units from the target number, prompting the student to an effective strategy that should work also with the race to 47. The feedback meets the criteria of correctness, clarity and completeness, thus providing a positive assessment both of the workshop and the student's mathematical learning.

We remark the collaborative nature of the peer review workshop in the digital formative ecosystem enabled by Moodle learning platform, where students' peer feedback is at the same time mathematically correct and understandable in a communication register suitable for primary school prospective teachers. They are able to use the information shared in the peer review process about their work to learn in a productive and progressive way over time. Moreover, the formative assemment environment based on peer review workshops cuts off anxiety, unease, sense of failure and fear of judgement, especially on the part of the teacher, in their mathermatics learning experience.

5. Concluding remarks

The peer-review workshops aim at providing formative assessment that involve prospective primary school teachers attending university courses in Mathematics and Mathematics education. Formative assessment and its effectiveness stem from to the intertwining of the structure of feedback suggested by Hattie and Timperley with Skemp's relational understanding of mathematics that is at the core of mathematical thinking and learning. Further research is needed to validate quantitatively and qualitatively the strength of the model. Moreover, the model of the workshops needs to be tested in a broad variety of University contexts to single out flaws and the ensuing adaptations and improvements. Nevertheless, peer-review workshops could become a good practice in University courses to pursue the transition form assessment *of* to *for*, and *as* learning.

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