# Using Affordances and Constraints to Evaluate the Use of a Formative e-Assessment System in Mathematics Education

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Abstract: e-Assessment systems provide affordances for learning mathematics by means of formative feedback. However, there is a lack of research on affordances of e-assessment systems, and work remains to be done before evaluating their effect on mathematical learning. This paper uses the e-assessment system Numbas and proposes a framework to capture the affordances and constraints of the system at the technological, student, classroom, mathematics subject, and assessment level. The aim of the paper is to explore affordances and constraints that emerge at these levels, and the effect of formative feedback on mathematical learning. Based on the results, some concluding remarks and recommendations for future work are proposed.

## 1 INTRODUCTION

A core component of e-assessment systems involves offering formative feedback to students about the quality and level of their mathematical performance. Formative feedback occurs in the course of mathematical problem-solving and offers information that allows students to change their behaviour and way of thinking (Clark, 2012; Shute, 2008).

The potentialities of formative feedback, which is an essential part of e-assessment systems, to make contributions to mathematical learning are important. However, although there has been great enthusiasm about the potential of e-assessment systems to support learning, there is a lack of research studies on their affordances that might lead to enhanced student mathematical understanding. Although several research studies provide good examples of mathematical learning by means of e-assessment systems (Bokhove, & Drijvers, 2012; Fujita, Jones, & Miyazaki, 2018; Gresalfi, & Barnes, 2016; Hoogland, & Tout, 2018; Olsson, 2018), there has yet to be systematic explorations into how affordances and constraints of the systems might support or hinder student mathematical learning.

This work aims at exploring the impacts of the e-assessment system Numbas on students' mathematical learning drawing on the theoretical background consisting of two central issues: formative feedback, on the one hand and affordances and constraints, on the other hand. It addresses two research questions: a) What are the affordances and constraints that emerge at the technological, student, classroom, mathematical, and assessment level when students interact with Numbas? and b) How do students experience Numbas formative feedback?

The contribution of this work is twofold. Firstly, it applies affordances and constraints to Numbas. Secondly, it assesses the formative feedback of Numbas in terms of affordances and constraints.

## 2 THEORETICAL BACKGOUND

This theoretical background of the work consists of two key elements: formative feedback, and affordances and constraints.

### 2.1 Formative Feedback

Feedback is considered as "information with which a learner can confirm, add to, and overwrite, tune, or restructure information in memory, whether that information is domain knowledge, meta-cognitive knowledge, beliefs about self and tasks, or cognitive tactics and strategies" (Winne, & Butler, 1994, p. 5740). The purpose of feedback is thus to restructure and achieve change in student thinking. Feedback that occurs in problem solving is called formative feedback, in contrast to summative feedback, which



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occurs at the end of an activity and does not normally allow the students to change their thinking. Formative feedback is normally given by a teacher or a peer, but it could be viewed as being the result of the student's interaction with an e-assessment system.

Feedback in e-assessment systems is primarily formative. Shute (2008) identified two main functions of formative feedback: *verification*, that is simple judgement of whether an answer is correct; and *elaboration* that provides relevant cues to guide the student towards the correct answer. Clark (2012) states that the "objective of formative feedback is the deep involvement of students in meta-cognitive strategies such as personal goal-planning, monitoring, and reflection" (p. 210), and, as such, it is related to self-regulated learning. Likewise, Hattie and Timperley (2007) identified two types of feedback: task-based and process feedback. *Task-based feedback* is about a task or product, such as whether a response to a test is correct or incorrect. *Process based feedback* is "information about the processes underlying a task that can act as a cueing mechanism and lead to more effective information search and use of task strategies" (p. 93). Rakoczy et al. (2013, p. 64) found that written process-oriented feedback, that is "suggesting how and when a particular strategy is appropriate" might foster students' mathematical learning. They argue that while task-based feedback may be the least effective form, it can help when the task information is subsequently used for "improving strategy processing or enhancing self-regulation" (pp. 90–91).

## 2.2 Affordances and Constraints

Gibson (1977) developed the concept of affordance to describe the interactions between a goal-oriented actor and an object in the environment in terms of what it "affords" the actor, or in other words in terms of action possibilities for meeting the actor's goal. According to Gibson, affordances are not intrinsic properties of the object. Rather, affordances emerge from the relationship between the object and the actor with which it is interacting. Moreover, affordances are not inherent characteristics of the object and independent of the actor. Rather, affordances are neither objective nor subjective properties: They simply cut across the subjective-objective dichotomy. Finally, affordances are not without constraints. When one thing is afforded, something else is simultaneously constrained. Affordances and constraints are simply not separable, because constraints are complementary and not the opposite of affordances (Brown, Stillman, & Herbert, 2004).

The concept of affordance was introduced to the Human-Computer Interaction community by Norman (1988) to describe the perceived and actual properties of the tool's user interface to determine just how it could possibly be used. Several research studies draw on Gibson's and Norman's work to investigate the concept of affordance in various educational settings. For example, Kirchner et al. (2004) described a three-layer definition of affordance: Technological affordances that cover usability issues, educational affordances that facilitate teaching and learning, and social affordances to foster social interactions. Likewise, Chiappini (2013) applied the notions of perceived, ergonomic, and cultural affordances to Alnuset, a digital tool for high school algebra. Finally, Hadjerrouit (2017) proposed two types of affordances at five different levels in teacher education: Technological affordances at the ergonomic and functional level, and pedagogical affordances at the student, classroom, and subject level. Based on the research literature, the specificities of mathematics education and e-assessment systems, this work proposes a model of affordances and constraints that can emerge at five different levels: Technological level, student level or mathematical task level, classroom level or student-teacher interaction level, mathematics subject level, and assessment level.

Given this background, the following affordances may emerge at the technological level as students interact with Numbas. These are ease-of-use, ease-of-navigation, accessibility of Numbas at any time and place, and accuracy and quick completion of mathematical operations. Moreover, Numbas may help to perform calculations, draw graphs and functions, solve equations, and construct diagrams.

Secondly, several affordances may emerge at the student level or mathematical task level:

- Numbas presents the mathematical content in several ways using text, graphs, symbolic, interactive diagrams, videos
- Numbas helps to transform expressions that support conceptual understanding
- Numbas facilitates mathematical activities such as exercises, multiple choice, quizzes, etc.
- Numbas is congruent with textbook and paper-pencil mathematics
- Numbas offers a flexible way to handle a wide range of assessment questions

Thirdly, several affordances may emerge at the classroom or student-teacher interaction level:

- Numbas enables a high degree of autonomy and help students to work on their own
- Numbas offers multiple levels of difficulty, and can be adapted to different knowledge levels

- Numbas provides opportunities for the teacher to make individual adjustments for students
- Numbas allows to choose the level of difficulty
- Numbas stimulates students to cooperate and share their knowledge

Moreover, several affordances may emerge at the mathematics subject level:

- Numbas offers a high quality of mathematical content
- Numbas questions are useful to foster reflections and higher-level mathematical thinking
- Numbas provides opportunities to exploit the constraints and limitations of the tool to provoke students' mathematical thinking
- Numbas provides opportunities to foster conceptual rather than procedural understanding
- Numbas displays formulas, functions, graphs, numbers, algebraic expressions, and geometrical figures correctly
- Numbas simplifies mathematical expressions so they look as if there are written on paper

Finally, several types of affordances may emerge at the assessment level:

- Numbas provides several assessment tests, e.g. questions, practical exercises, quizzes, etc.
- The order and wording of the assessment questions in Numbas are appropriate
- The questions are relevant to test mathematical knowledge
- Numbas gives immediate feedback
- Numbas provides several types of feedback such as expected answers and advices to the solution, and give hints to problem-solving step by step
- Numbas takes the profile and knowledge level of the student into account and serves up appropriate questions
- Numbas provides an answer to a question, and whether it is correct or not
- Numbas provides a summary of the test, students' answers to questions, what they have done wrong or right, and statistics on students' answers to questions and their performances.

## 3 Numbas

Numbas is an e-assessment system with an emphasis on formative feedback (Perfect, 2015). It is used to create mathematical tasks that help teachers build tests with videos, visualizations, and interactive diagrams that they can use to challenge their students individually. The primary design goal of Numbas is to enable a student to submit a mathematical answer in the form of an algebraic expression. The student selects an option from a list of mathematical tasks designed by the teacher. Numbas provides feedback to the student, and generates information by, for example, drawing graphs according to the student's submitted formulas and expressions. In Numbas, feedback is often provided to students based on their correct or incorrect answer to a mathematical task, either immediately or with a small delay. Numbas can also reveal the solution to the problem.

According to Perfect (2015), the great advantage of Numbas is the large range of marking algorithms and input types, which make it easy to assess a range of answers to mathematical questions that are entered by the students as symbolic expressions or as numbers. Another advantage is that students can access Numbas and produce a test through web browsers without any set-up. Also, the randomisation system, through the definition of question variables and substitution into the question text is particularly powerful compared to other e-assessment systems. Figure 1 shows an example of test in Numbas:

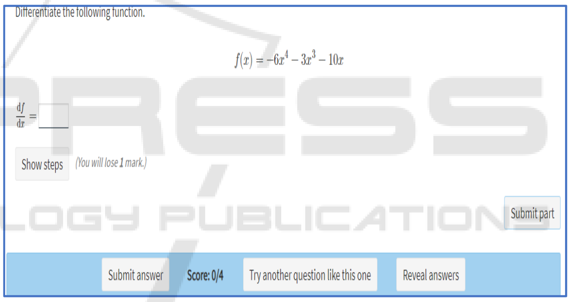


Figure 1: Numbas test: Differentiation of a function.

The main constraint of Numbas is the limited range of mathematical expressions the student can submit, since each input must be automatically marked. It is very difficult to set up a question that gives credit to a student who does a lot of mathematical reasoning while solving a problem, but fails to produce a final result, because it is hard to capture the student's thinking process (Perfect, 2015).

## 4 THE STUDY

### 4.1 Context and Participants

This study was conducted in the context of a master course on the use of digital tools for mathematical learning in teacher education. The participants (*N=15*) were students from one class enrolled in the course in 2018. The students had varied knowledge background in mathematics ranging from arithmetics and algebra to differentiation and derivation. They had also varied experience with digital tools such as Excel, GeoGebra, Khan Academy, etc. In terms of mathematical knowledge, the basic requirement of the course is the completion of a bachelor-degree in teacher or mathematics education. In terms of digital tools, the recommended prerequisites were basic knowledge in digital technologies such as spreadsheets, calculators and Internet. None of the students had any prior experience with Numbas.

## 4.2 Methods

Teaching activities over a period of two weeks were designed. These covered mathematical tasks at the primary, middle and secondary level, which include numbers, fractions, algebra, linear equations, and differentiation.

Both quantitative and qualitative methods were used to answer the research questions described in the introductory section. Firstly, a survey questionnaire with a five-point Likert scale from 1 to 5, and quantitative analysis of the results, where 1 was coded as the highest and 5 as the lowest. Secondly, Students' comments in their own words on each of the items of the survey, and open-ended questions to collect and analyse supplementary information on the use of Numbas. The data collection and analysis methods were guided by the theoretical background in terms of formative feedback, affordances and constraints, and identification of central themes in students' comments to bring to the fore information that was not sufficiently covered by the survey.

# 5 RESULTS

Students' perceptions of affordances and constraints, and their views of formative feedback are presented in the following sections. The results are presented in qualitative rather than quantitative terms due to space restrictions.

## 5.1 Affordances and Constraints at the Technological Level

The survey results show that the vast majority of the students pointed out that Numbas has a user-friendly interface and that it is easy to use, to start and to exit. Numbas has also a ready-made mathematical content that can be extended to include more study material using video lessons, simulations, animations, etc. Technological affordances are reflected in students' comments: "*easy and fine design*"; "*easy to find and navigate through the information*"; "*very positive that we get immediate feedback*". No constraints have been reported. These results show the importance of a user-friendly interface for teachers and students.

## 5.2 Affordances and Constraints at the Student or Mathematical Task Level

The survey results show that Numbas present the mathematical content in several ways by means of text, graphs, symbolic expressions, interactive diagrams, videos, GeoGebra worksheets, etc. Numbas also facilitates various mathematical activities in terms of problem-solving, exercises, multiple choice, quizzes, etc. It can be used to reinforce textbooks mathematics. Likewise, Numbas supports the delivery of mathematical tests outside classroom, and it is flexible to handle a wide range of assessment questions. No constraints have been reported at the student level.

A qualitative analysis of the students' comments indicates three main themes: multiple representations of tasks and variation, feedback with the teacher, and rigidity and constraints of the tool.

Concerning the first theme, it seems that different and multiple representations of the mathematical tasks were highly valued by the students. These are reflected in their comments:

*Many similar technical tasks. Had been interesting if we could enter GeoGebra tasks to increase variation.*

*Good that one can use different representations on the tasks, so that one can test different types of understanding among the students. Good that the students can be tested at home so that they can test themselves how much they can.*

*There is a multi-representation of the mathematical content, which is really important.*

Likewise, students considered Numbas as an alternative tool to traditional testing:

*Can be used as a supplement, but students must also have training in mathematical reasoning.*

*Seems this is a good alternative to traditional testing. Can also be a good tool for testing students who for various reasons cannot be tested at school.*

The third theme is the rigidity and constraints of Numbas in terms of quality of assessment in comparison to human beings. The constraints make teacher assistance necessary:

*Seems to lack assessment skills. A program system is rigid and has trouble seeing if the student is thinking properly.*

*Numbas is designed to be an assessment tool, but since it is a computer program and not a human, it has some obvious limitations, e.g., customized feedback beyond correct/wrong and general hints.*

*Programming errors (….) force students to ask the teacher for assistance.*

### 5.3 Affordances and Constraints at the Student-teacher Interaction Level

Most participants think that Numbas enables a high degree of autonomy for the students to work at their own pace. Numbas also contains multiple levels of difficulty, but it is up to the teacher to adjust the level and make individual adjustments. Students also partly agreed that they can ask the teacher for help, but most of them did not need to use the textbook. Numbas does normally not enable collaborative work. Moreover, many students think that Numbas is not designed to allow them to choose the level of difficulty.

A qualitative analysis of participants' comments reveals four main themes: teacher help, individualization, collaboration, and use of other external resources such as textbooks and internet.

Regarding the first theme, students indicated that they appreciate well the role of the teacher to provide help, design and adapt tasks to their knowledge levels. The constraints of the tool also make teacher help necessary as already mentioned above. Some representative comments are:

*The teacher should adapt the tasks to how the students respond and give easier tasks when the students fail. Good that students can use hints and help themselves.*

*Want to believe that the students will ask for help despite hints and feedback from Numbas.*

*It is the teacher who makes the tasks for the students, (…), and it is positive that they can design more tasks of the same type and several times.*

*The students can work at their own pace, but it is the teacher who decides how far they can proceed. Good that it is not predetermined in Numbas.*

*Teacher help will always be needed when using Numbas, as it has no feedback in terms of syntax errors, especially when a student insists on the correctness of his/her answer. Using a textbook is a choice depending on the students' judgment.*

Regarding the second theme, most students agreed that Numbas has an individual focus and that individualization and adaptation of tasks at different levels are important in the learning process:

*Very individual focus.*

*Very good that Numbas provided the opportunity for hints and feedback underway.*

*Numbas preserves the individuality of the process of practicing.*

*Can provide various tests at different levels so that the students themselves can choose the levels they want to work with, possibly begin at an easy level and move on to more difficult ones. In this way, they can challenge themselves.*

In contrast to the individual focus of Numbas, it seems that students do not think that the tool provides opportunities for collaborative problem-solving and discussion with peers, even though collaboration is considered important for many reasons. The teacher may also play an important role in designing collaborative tasks.

*The assignment can be a good starting point for collaboration where the students can explain how they think.*

*The students can collaborate on certain tasks, but basically Numbas stimulates individual work.*

*Numbas does not facilitate cooperation, but it could provide problem solving tasks to promote discussion.*

*Initially, Numbas seems to be designed for the individual student, (…) but it does obviously not open up for cooperation. That said, the teacher has of course designed the tests/questions so that the students can work together on them.*

*As a teacher, I can decide whether the students will work together or alone.*

The last theme is Numbas as supplementary digital resource in addition to textbooks and other resources available online. Some comments:

*May be wise for the students to have the textbook open. Numbas can be used without teacher help.*

*I use textbooks and the internet as well because there was some topics of the mathematics I can't quite remember.*

### 5.4 Affordances and Constraints at the Mathematics Subject Level

Most students agreed that Numbas provides a high quality of mathematical content, and that the questions and tasks are well-designed and formulated. Likewise, most students found that Numbas displays mathematical notations and expressions correctly, which means Numbas has a high degree of mathematical fidelity. Moreover, Numbas is mathematically correct and it simplifies mathematical expressions. Likewise, many students think that Numbas provides opportunities to foster mathematical thinking through various entry points to Numbas, such as "submit answer", "submit part", "try another question like this one" or "reveal answers", which help the students to decide on their own whether they want to submit an answer or part of it, let Numbas reveal the answers, or just choose another similar question. In contrast to these positive comments, more than the majority answered negatively to issues related to conceptual understanding, even though there is a relatively big variation in their responses. Hence, some work remains to be done to provide tasks that foster conceptual understanding, metacognition, and high-level thinking in mathematics (proving, reasoning), as well as exploit the anomalies and constraints of the tool (machine mathematics). This confirms the designer's view (Perfect, 2015) that it is difficult for Numbas to capture student's thinking and reseaoning processes.

A qualitative analysis of the students' comments reveals three main themes: machine mathematics, congruence of Numbas with paper-pencil techniques, and conceptual understanding.

Machine mathematics is about the way Numbas represents mathematics, e.g., numbers, arithmetic operations or algebraic expressions. The following comments highlight the constraints of machine mathematics versus "ideal" mathematics:

*Can be problematic if you don't write "," but must use a dot for a decimal number. A fraction is also not always mathematically correct if the numbers are very large.*

*Writing fractions such 1/3 can be difficult when the task is written in form of decimal numbers, and it will be wrong if you use it, as the dot is the preferred one. Both parts should be approved. The system is rigid and unable to respond to the wrong answer.*

In contrast to machine mathematics, some students think there is a congruence and complementarity between Numbas and paper-pencil techniques in some situations:

*It was very good that one could enter the formulas in the fields and calculate the answer here.*

*Very good that Numbas writes my answer as you see it on paper even though I write it differently.*

*I use paper to figure out the answer that one can have in different steps and enter, not just the answer.*

*Numbas measures right / wrong and has little focus on process (conceptual understanding) skills, even though one can object that if a student gave the correct answer, he/she might have understood the mathematical concept.*

In terms of conceptual understanding, students think that this issue is dependent on the teacher and his/her knowledge, and the way he/she designs the questions and feedback. Errors in Numbas may also foster reflection.

*Depends on how the questions are asked.*

*Again, it really depends on whether the teacher has designed and programmed the questions correctly. On the other hand, errors in the program can also help to stimulate reflection if they try to understand what has gone wrong.*

*Something I think what is very positive is the given response to answers, the possibility of hints and the possibility of showing calculations. This information can help the students to reinforce their understanding. The teachers have a lot of power to control how this program will affect the student.*

*The degree to which Numbas responds to the criteria in the questions above, is entirely dependent on the teacher who creates the questions, since the program is very flexible in terms of how to create these, as well as has more advanced features as mentioned earlier.*

## 5.5 Affordances and Constraints at the Assessment Level

Most students think that Numbas provides several assessment tests in terms of single questions, exercises, quizzes, and multiple-choice questions as well. Likewise, students think that the order of the questions given to the students is appropriate. The wording of the questions is understandable as well. However, the students pointed out that these issues depend entirely on the teacher who creates the questions, but they also added that Numbas offers the possibility of letting the order of questions be random.

In terms of formative feedback, most students agreed that Numbas gives immediate feedback to a question. It also provides several types of feedback such as expected answers and advices to the solution. For most students, Numbas provides a summary of the test, students' answers to questions, and what they have done wrong or right, and in a lesser degree whether it is correct or not. In contrast, some students did not find that Numbas feedback contains useful information that may help them understand the exercises and answer the questions. Moreover, hints in form of videos to problem-solving step by step were not always useful. Most students also think that Numbas provides statistics on students' answers to questions and their performance and grading. Finally, according to the students, the most important constraint of Numbas is that it does not consider the profile and knowledge level of the student. This confirms the designer's view that Numbas cannot capture students' characteristics.

The most important themes that emerged from the qualitative data analysis and emphasized by the students are the affordances and constraints of Numbas feedback and the role of the teacher in designing the feedback rather than Numbas alone. This confirms somehow the survey results.

*(…) The forms of feedback both to the students and teachers, as far as I can see, are not very good, and therefore should not be based on such tests alone.*

*The fact that the students receive feedback right away is positive, which means that they can make self-assessments to a greater extent. In the event of a difficult test, the result will not come from the teacher.*

*To some extent, it might have been better that Numbas gives more concrete feedback if I had made an obvious mistake as for example, a wrong sign.*

*I feel that the students get a little more control over their own test results as they can choose how much help and support that they want themselves. Again, I think it depends much on the design of individual tests that determine the degree to which feedback satisfies the needs of individual students.*

*Feedback quality depends on pre-programmed solutions.*

*(…) It depends on the teacher who creates the questions, but it can be added that Numbas offers the possibility of letting the order of questions be random. (…) The summaries I have seen are not particularly rich in terms of information and give the teacher little hint about what the student can do.*

## 6 DISCUSSION

The research questions addressed in this work are: a) What are the affordances and constraints that emerge at the technological, student, classroom, mathematical, and assessment level when students interact with Numbas? and b) How do students experience Numbas formative feedback?

Regarding the first question, the study shows that the affordance model was useful to capture and make visible many of the potential affordances described in section 2. Indeed, several affordances and constraints emerged at the technological, student, classroom, mathematics subject, and assessment level when students interact with Numbas.

The technological affordances are ease-of-use, ready-made mathematical content, and extensions to include more study material such as video lessons, simulations, and animations. This is possible, because Numbas has an advanced extension system, which enables the inclusion of a wide range of material and subjects. A user-friendly interface with an understandable language, and usability issues in general are extremely important for both teacher educators and students. At the student level, several affordances emerged. The most important ones are the presentation of the mathematical content in a wide variety of ways and the facilitation of various mathematical activities. The affordances also provide opportunities to reinforce textbook-mathematics and deliver a wide range of tests to the students based on material from textbooks, but this is entirely dependent on the teacher.

Both affordances and constraints emerged at the classroom level. Firstly, Numbas enabled a high degree of autonomy and individualization, and allowed students to work at their own pace, test mathematical tasks, and practice their skills. Moreover, Numbas contains varied mathematical tasks, but it is up to the teacher to design material with multiple level of difficulty to challenge the students and make individual adjustments. Finally, Numbas does not stimulate students to cooperate and share their knowledge, but it is possible for the teacher to design collaborative tasks using Numbas.

At the mathematics subject level, Numbas provided a high level of mathematical content that is correct, sound, and congruent with textbooks and paper-pencil mathematics. Numbas helps to test problem-solving skills, and in a lesser degree conceptual understanding and reasoning such as proofs. Nevertheless, the teacher has the possibility to assess some of these skills indirectly using the available functionalities.

At the assessment level, Numbas provided several assessment tasks to test students' mathematical knowledge, and in particular, the immediate feedback, which was useful in terms of correctness of answers, but it does not take into account the student's profile and knowledge level. This constraint may be considered in future work, even though it is hard to implement.

Regarding the second question, the participants valued the feedback provided by Numbas as this was helpful for mathematical problem-solving, even if it does not automatically promote conceptual understanding. In terms of feedback in comparison to traditional testing, the study shows that the immediate feedback of Numbas is important to many students, but some felt it is limited as it provides mostly wrong/right answers, which do not automatically promote conceptual understanding and higher order-thinking in mathematics as already mentioned above. This is an important constraint that might be considered in future designs and tests. Nevertheless, the feedback function provided help and hint to test a great spectrum of mathematical questions ranging from primary to upper secondary school levels. Clearly, Numbas revealed to be a good formative assessment system for tasks that involve using an algorithm for verifying whether a result is correct or not. Clearly, Numbas feedback made it easy to assess a range of answers to mathematical questions that students submit as algebraic expressions or as numbers. The teacher can also benefit from the ease-of-use of Numbas to create challenging mathematical tasks with different and varied levels of difficulty.

## 7 CONCLUDING REMARKS

The results cannot be generalized due to the limited number of participants (*N=15*). However, some preliminary conclusions can be drawn for the use of Numbas in teacher education.

Firstly, the study confirms that affordances and constraints emerge at the technological, student, classroom, mathematics subject, and assessment level in the context of teacher education, where Numbas was used to test students' mathematical problem-solving skills in a master course on the use of digital tools for mathematical learning. The affordances and constraints reported in this study are specific to the particular context of teacher education.

Secondly, considering the affordances of Numbas that emerged at the assessment level, it appears that a combination of various types of feedback may be the most effective form to support mathematical understanding. The way Numbas shows where a student has gone wrong, giving a full working solution, and not only a right or wrong answer, giving a detailed solution to a task with additional comments on mistakes, and other mathematical misconceptions provide useful information that can make students more confident in their mathematical learning. Thus, Numbas fulfils some of the functions described by Shute (2008) and Hattie and Timperley (2007). Nevertheless, teacher assistance is still important because of the constraints and limitations of Numbas.

Future research will focus on both students' and teachers' perspectives, and a triangulation of their views. It will also include more varied tasks that visualize mathematical concepts, resources such as Geogebra dynamic figures and videos, and the ability to let students make graphs that contribute to more variety, and the opportunity for the teacher to design intrinsically motivating tasks. Students will thus be able to receive information and feedback tailored to their activities, and teachers will receive better feedback on both students' successful and failed solutions and their thinking processes. Finally, collaborative tasks should be addressed in future work as collaboration becomes increasingly important in mathematics education.

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