Students’ instrumentalizations of hints and automated feedback in their task solution process when learning mathematics with a digital curriculum resource

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Automated feedback is a characteristic feature of digital curriculum resources. Recently, there has been a growing interest in students’ perspectives on feedback. Feedback is increasingly regarded as a dialogic process in which learners make sense of information from varied sources and use it to enhance the quality of their work or their learning strategies. This study aims to further contribute to the body of research on the learners’ perspectives on feedback, by investigating for what purpose students make use of hints and automated feedback when learning mathematics with a digital curriculum resource. Students’ use of hints and automated feedback is analyzed through the lens of instrumental genesis. Results from a qualitative study with eight 8th-grade students show which type of hint or feedback is used at what phase for what purpose in the process of solving tasks from a widely available online curriculum resource.

Keywords: automated feedback, hints, user study, students, digital curriculum resources.

Introduction

Automated feedback is a characteristic feature of digital curriculum resources (Choppin et al., 2014; Rezat, 2020). It aims to support students individually in their learning processes. The important role of feedback in learning is widely acknowledged (Hattie & Timperley, 2007). For a long time, feedback was regarded as a unidirectional process in which learners are viewed as receivers of information from an external source that they use to enhance their learning. Consequently, most research on feedback focuses on variables of the feedback message, such as the contents or the timing of when it is provided. Only in the past years, there has been a growing interest in students’ perspectives on feedback (Esterhazy & Damşa, 2019; Molloy & Boud, 2014; Olsson, 2018). Feedback is increasingly regarded as a dialogic process in which learners make sense of information from varied sources and use it to enhance the quality of their work or their learning strategies (Carless 2015). Consequently, the meaning of feedback is not only determined by the feedback message, but by both, the agent and the user (Esterhazy and Damşa, 2019). Accordingly, there is a growing interest in better understanding how students seek, interpret, and use information related to their learning and how programs are designed to foster this (Molloy & Boud, 2014).

Elsewhere, I have shown how feedback can afford or constrain students’ conceptual development (Rezat, 2021) and that the interpretation of signs related to feedback on the artifact level imposes additional challenges on students (Rezat et al., 2021). This study aims to further contribute to the body of research on the learners’ perspective on feedback, by investigating the research question: For what purpose do students make use of hints and automated feedback when learning mathematics with a digital curriculum resource? The focus here is on the purpose of using the supportive information provided by the digital curriculum resource.

Theoretical framework

The instrumental approach (Rabardel, 2002) theorizes cognitive aspects of human interactions with digital artifacts and has proven useful in understanding students' learning of mathematics with Computer-Algebra and Dynamic Geometry Systems. In this paper, hints and feedback are considered artifacts developed to support students individually in their learning of mathematics. To develop a detailed account of how hints and feedback function in the learning process, students' use of these artifacts is analyzed through the lens of the instrumental approach.

Instrumental approach

According to Rabardel (2002) an artifact is transformed into an instrument in use. An instrument is a psychological entity that consists of an artifact component and a scheme component. In using the artifact, the subject attributes functions to the artifact and develops or adjusts utilization schemes that are shaped by both, the artifact and the subject. Attributing functions and the development of utilization schemes are two opposite but intertwined processes, which Rabardel refers to as "instrumentalization" and "instrumentation". In this paper, the focus is on the different functions that students attribute to hints and feedback in their learning process while solving tasks in an online learning platform and thus on their *instrumentalization*. Rabardel (2002, p. 106) defines *instrumentalization* as a "process in which the subject enriches the artifact's properties". Although this process is grounded in the artifact's intrinsic characteristics and properties, it is mainly linked to the subject's goals and conditions for action in a situation.

Hints and feedback

Feedback is widely defined as "information provided by an agent (e.g., teacher, peer, book, parent, self, experience) regarding aspects of one's performance or understanding" (Hattie & Timperley, 2007, p. 81). Therefore, it only relates to information provided to students after they have solved a task and entered a solution into the system. However, many digital curriculum resources also offer information that learners can access on their way to their first solution before they have entered it into the system. This information is widely referred to as hints, cues, prompts, or tips. Referring to conceptualizations of feedback as a dialogic process in which learners make sense of information from varied sources and use it to enhance the quality of their work or their learning strategies (Carless 2015) it makes sense to include this information in the analysis. Therefore, this paper analyzes students' use of supportive information provided by a widely used online curriculum resource that is offered in addition to the task itself before or after students have entered a solution to a task into the system. Consequently, clear conceptualizations of both, hints and feedback are necessary.

Whether a given task is a routine task or a problem does not only depend on task features but also students' knowledge and abilities. If students do not know how to find the solution to a given routine task immediately, the task becomes a problem for students. Zech (2002) suggests a taxonomy of five levels of hints that might support students in their problem-solving process: 1) motivational hints that motivate learners to continue the problem-solving process, 2) feedback that informs learners about the correctness of the selected solution strategy or achieved intermediate steps towards the solution, 3) general strategic hints that suggest a general problem-solving strategy to learners, 4) content specific strategic hints that provide learners with information about the solution strategy for the problem at hand, 5) content related hints provide learners with particular content that is relevant for solving the problem. A comparison between these types of hints and the different types of feedback in the next paragraph will show unmistakable overlaps in their content. Additionally, the digital curriculum resource used in this study sometimes offers the same information before and after entering the solution. Therefore, depending on when the information is presented it would be either considered a hint or elaborated feedback. Consequently, I use the same terminology to distinguish the different types of hints and feedback.

To differentiate different types of feedback offered by digital curriculum resources, the study presented in this paper refers to the classification of feedback according to Shute (2008). Shute distinguishes different types of feedback according to their complexity. The following types are relevant:

1. Knowledge of results feedback (*KR*) informs the learner about the correctness of an answer.
2. Knowledge of correct response (*KCR*) feedback informs the learner about the correct response.
3. Repeat-until-correct (*RUC*) feedback informs the learner about an incorrect response and offers the possibility of a new try to answer the task.
4. Location of mistakes (*LOM*) feedback informs the learner about the location of an error in the solution without giving the correct response.
5. Elaborated feedback (*EF*) offers further information regarding the solution of the task or the solution of the learner.

For the last type (EF), the literature distinguishes many different subtypes. For the study presented in this paper, the following types of *EF* are relevant that Shute (2008, p. 160) subsumes under "topic contingent" and "hints/clues/prompts":

- knowledge about concepts (*kac*),
- knowledge or strategic information on how to proceed (*kohp*),
- a worked example or demonstration (*we*)

Types of hints and feedback in the used digital curriculum resource

As apparent from the theoretical framework, hints and feedback are characterized differently and use different terminology. However, the contents of the messages seem to be equivalent in many cases. Additionally, *bettermarks* shows the same message sometimes as a hint and sometimes as feedback. To develop a clear terminology to denote the information provided by hints or feedback messages, the types of hints according to Zech (2002), types of feedback according to Shute (2008), and the features of the used digital curriculum resource (DCR) that contain these types of hints and feedback are juxtaposed in Table 1. This juxtaposition reveals the overlaps in terms of the content of the feedback message. However, the scope of some of the types is different. On the one hand, the differentiation between general and content-specific strategic hints is not mirrored in different types of feedback, on the other hand, both, elaborated feedback presenting knowledge on how to proceed, or a worked example can be considered content-specific strategic hints. Comparing the types of hints and feedback with the related features in the curriculum resource shows that a single feature may present a variety of different types of hints or feedback. Especially the feature "Tip" may provide knowledge about concepts, knowledge on how to proceed, or a worked example.

Table 1: Juxtaposition of hints, types of feedback, and related features in the used DCR

Type of hint	Type of feedback	Appearance in the DCR
1) motivational hints	-	-
2) hints that provide learners with feedback about the correctness of the selected solution strategy or achieved intermediate steps toward the solution	KR-feedback	KR-feedback after a solution was entered
3) general strategic hints	EF (kohp)	-
4) content specific strategic hints	EF (kohp)	Feature called "Tip" Sometimes shown automatically after entering a wrong solution
	EF (we)	Feature called "Lookup" Feature "Example" sometimes appearing after a wrong solution
5) content related hints	EF (kac)	Feature called "Tip" Linked technical terms in the task

Methodology

This study aims to analyze students' use of hints and feedback from digital curriculum resources in an ecologically valid setting. Therefore, the widely used resource *bettermarks* (www.bettermarks.com) was used. *Bettermarks* offers a wide range of different types of hints and feedback while solving a task. It is licensed in several federal states in Germany by the federal ministries of education and thus offered for free to schools. In this study, eight students in eighth grade were working on a unit on percentages. The unit comprised a set of 17 tasks and problems that students worked through at the end of the unit on percentages as a preparation for a test. The tasks were carefully selected to comprise different kinds of problems covering all the content that was relevant for the test and offering to students possibly all the different kinds of hints and feedback available in *bettermarks* (at that time). The eight students worked on the set of tasks at home in their familiar setting in a video conference with the interviewer on a shared screen. The students were used to working with *bettermarks* at home. Thus, the situation of using *bettermarks* was kept as natural as possible. The only difference was the presence of the interviewer in the video conference.

The recordings of the video conferences provide the data for this study. The videos were analyzed using the qualitative data analysis software MAXQDA. In the first step, each video was coded for the different types of hints and feedback used by the students. In the second step, each episode in which the students used a hint or received feedback was analyzed in terms of the purpose that the students associated with its use. This was done based on the constant comparative method (Corbin & Strauss, 2015) until different *instrumentalizations* could be delineated and defined. As instrumentalizations refer to functions that students attribute to the hints and feedback by their goals and conditions for action in a situation, this was achieved by inferring students' motivations or reasons and their goals for using a hint or feedback from the data. These partly depend on the phase in the solution of the problem, in which students make use of the hint or feedback.

Results

Table 2 provides an overview of the results of the analysis of students' instrumentalizations of the different types of hints and feedback that are offered by *bettermarks*. The left column of Table 2 is organized in chronological order and describes the different phases that students must go through when solving a task from *bettermarks*. These different phases characterize the situations in which hints and feedback are used. As described in the theoretical framework, these influence students' instrumentalization of hints and feedback. The second column contains the different types of hints or feedback that are offered by *bettermarks* in the different phases and were used by the students. In phases 1–3, the types characterize the contents of hints. Starting in phase 4, the types relate to feedback. The third column shows students' *instrumentalizations* of these types of hints and feedback in the respective phase.

Table 2 may be read in the following way: While reading the task (phase 1) *bettermarks* offers hints of *kac*-type. Students instrumentalize these hints to enhance their understanding of technical terms that appear in the tasks. In phase 2, when students aim to find the solution to the task, they have access to three different kinds of hints: They can open *kac*-type or *kohp*-type hints or they can ask for the complete solution of the task (KCR). *Kac*-type and *kohp*-type hints are instrumentalized in two different ways: Students either use them to get support in finding the solution or to resolve uncertainties about the expected input format when entering the solution into the system. KCR is used to understand the expected solution if students do not develop any solution on their own. Starting in phase 4, columns 2 and 3 are divided as there are two possibilities for feedback depending on the correctness of the entered solution. The same applies to the fields in phase 7. Fields shaded in grey denote that no more feedback or hints are accessible at these phases.

Table 2: Cumulated results of students' instrumentalizations of different types of hints and feedback in the different phases of the task solution process

Phase in the solution process	Type of hint / feedback	Instrumentalization
1. Reading task	kac	Enhancing understanding of technical terms in the task
	kac	Getting support to find the solution

2. Finding solution	kohp		Resolving uncertainties about the expected input format	
	KCR		Understanding the expected solution	
3. Entering solution	kac kohp		Confirming that the solution (procedure) is correct before entering	
4. Evaluation of the entered solution	KR feedback: correct	KR feedback: incorrect	Reassurance of own solution	Removing uncertainties about which solution from two alternatives is the correct one
			Resolving uncertainties about the expected input format	
	KCR		Checking own / alternative solution	
5. Rethinking solution		KCR		Understanding the expected solution Understanding own mistakes
		Hints as in phases 2 & 3		*Instrumentalizations as in phases 2 & 3*
6. Entering adjusted solution				
7. Evaluation of solution		KR correct / KR incorrect		*No particular instrumentalization observed*
		KCR (after KR incorrect)		Understanding the expected solution Understanding own mistakes

Discussion

Many of the *instrumentalizations* of hints and feedback can be expected and seem to fit the intended purpose of the type of hint or feedback. This is for example the case for the following hint/feedback/instrumentalization pairs: (*kac*&*kohp*/getting support to find the solution) or

(*KCR*/understanding the expected solution). However, some instrumentalizations are particularly interesting as they indicate difficulties that students have with solving tasks from a DCR. This is especially the case for *instrumentalizations* related to issues with the input format. In these cases, students are not sure, what kind of input or input format (e.g., fraction or decimal, exact or rounded decimal) is expected by the system. They either instrumentalize hints to resolve these uncertainties before entering the solution or the *KR* feedback helps to resolve the uncertainties after entering the solution. Another unexpected instrumentalization is that some students who have found the solution to a task instrumentalize use hints before entering the answer to ensure that their answer is correct instead of simply using the *KR*-feedback for this purpose. However, these utilizations are closely related to the constraints of the DCR. They are mostly not of mathematical relevance. For example, if a number is written as a fraction or a decimal is equivalent from a mathematical point of view, but the DCR only accepts one input as correct.

On the one hand, the results show that different kinds of hints and feedback are instrumentalized for the same purpose. For example, students use *kac* or *kohp* hints or *KR*-feedback to resolve uncertainties about the expected input format. However, as the results give a cumulated overview of the observed instrumentalizations of all participating students, nothing can be said about whether this is the case for one particular student or if this is an observation that only appears between different students. A deeper, case-sensitive analysis is necessary to reveal if a particular student shows a definite *instrumentalization* of a particular type of hint or feedback for a specific purpose. If this is not the case, i.e. if one student uses different types of hints and feedback for the same purpose it may be an indication of an incomplete instrumental genesis. However, it may also be an issue with the system, as it is not always clear what kind of hint is provided by *bettermarks* when students look for support while solving a task especially when they use the feature "Tip". Furthermore, the analysis only focused on what type of hint or feedback was used for a particular purpose. It was not analyzed if the hint or feedback was actually supportive in the sense that it either helped to solve the problem or if students thought that the information was helpful. This would also be a matter of deeper analysis.

On the other hand, the results show that one type of feedback is instrumentalized for different purposes. For example, *KCR*-feedback is instrumentalized for two different purposes: First, for understanding the expected solution before or after entering a solution when students do not have a clue of how to solve the tasks. Second, students also instrumentalize *KCR*-feedback after entering the correct answer to compare their solution with the provided one to check their solution procedure or to see an alternative solution.

In summary, the results show that students instrumentalize the different types of hints and automated feedback offered by the system when solving tasks from a DCR for different purposes and that one type of hint or feedback may be instrumentalized at different phases of the solution process for different purposes. Consequently, these results underline the starting point of the study, namely that "the meaning of feedback is not only determined by the feedback message, but by both, the agent and the user" (Esterhazy and Damşa, 2019). A deeper analysis may reveal how students' instrumentalizations of hints and feedback contribute to a successful solution of the task and their learning of mathematics. These insights could be helpful for the design of hints and automated feedback in DCR as they show students' difficulties and needs during their individual learning processes.

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