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► To cite this version:

Sebastian Rezat. Students' utilizations of feedback provided by an interactive mathematics e-textbook for primary level. CERME 10, Feb 2017, Dublin, Ireland. hal-01950495

HAL Id: hal-01950495

<https://hal.science/hal-01950495>

Submitted on 10 Dec 2018

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Students' utilizations of feedback provided by an interactive mathematics e-textbook for primary level

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Feedback is acknowledged as an important influential factor on learning and achievement. An affordance of digital learning tools is that they provide different kinds of feedback to students. Research on the effectiveness of feedback has mainly focused on different forms of feedback and its timing assuming that different students react homogeneously to feedback. This paper provides a qualitative in-depth analysis of two third grade students' responses to feedback in an interactive e-textbook environment. Students responses to feedback are conceptualized in terms of utilization schemes within an instrumental approach. Results indicate that students utilize feedback differently, which has consequences for the effectiveness of the feedback.

Keywords: Feedback, e-textbook, instrumental genesis.

Introduction

Feedback is widely acknowledged as an important influential factor on learning and achievement (Hattie & Timperley, 2007). The fact that interactive digital learning tools constantly provide feedback to the learners' actions with the contents is indeed one of the most emphasized advantages of learning with digital tools (e.g. Mason & Bruning, 2001). In fact, an outstanding defining aspect of interactivity is that users get immediate feedback to their actions with the tool.

According to Hattie and Timperley (2007, p. 81) feedback is understood as “information provided by an agent (e.g., teacher, peer, book, parent, self, experience) regarding aspects of one's performance or understanding“. The goal of feedback is to support understanding and/or performance. In line with this, Shute (2008, p. 154) defines formative feedback as “information communicated to the learner that is intended to modify his or her thinking or behavior for the purpose of improving learning“. According to Hattie and Timperley (2007, p. 87) effective feedback has to address three questions: “Where am I going? How am I going? Where to next?”.

Research related to feedback aims at identifying features of feedback that increase its efficiency. Two aspects seem to be important for effective feedback: 1) the information provided by feedback and 2) the timing of feedback. Mory (2004, p. 753) distinguishes five categories of feedback regarding information complexity: “1. No feedback means the learner is presented a question and is required to respond, but no indication is provided as to the correctness of the learner's response. 2. Simple verification feedback or knowledge of results (KR) informs the learner of a correct or incorrect response. 3. Correct response feedback or knowledge of correct response (KCR) informs the learner what the correct response should be. 4. Elaborated feedback provides an explanation for why the learner's response is correct or incorrect or allows the learner to review part of the instruction. 5. Try-again feedback informs the learner when an incorrect response and allows the learner to one or more additional attempts to try again.”

Research has shown that both, the wrong form of feedback and the wrong timing might even have negative effects on learning and achievement (Fyfe & Rittle-Johnson, 2016a; Hattie & Timperley,

2007). The majority of studies in this context quantitatively measures effect sizes of different forms or timings of feedback in order to draw conclusions regarding the effectiveness of feedback. The underlying assumption in these settings is that students will react consistently to the respective form or timing of feedback. While different conditions of providing feedback that might influence its effectiveness have been studied, e.g. prior knowledge (Fyfe & Rittle-Johnson, 2016b) or feedback specificity (c.f. Shute, 2008) students' individual ways of responding to and making use of feedback have scarcely been studied in mathematics education. Bokhove (2010) presents an exception. He reports from a study where student inquiry about desired feedback was used in order to develop a feedback design of a digital tool to learn algebra. He concludes that "asking students when to use what feedback can improve a digital tool" (Bokhove, 2010, p. 125). Most of the research on feedback is based on experimental testing (Shute, 2008, p. 156). Shute (2008, p. 156) summarizes that „the specific mechanisms relating feedback to learning are still mostly murky, with very few (if any) general conclusions“. The aim of this paper is to contribute to the understanding of the mechanisms relating feedback to learning. In particular, the focus is on two research questions: 1) How do students individually utilize feedback in order to improve their understanding and performance?; 2) What are the consequences of students' individual utilizations of feedback with regard to the efficiency of feedback?

Theoretical framework and methodology

In this paper, feedback is regarded as an artifact, which is developed in order to improve students' learning and achievement. 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 with particular intentions the subject develops and adjusts utilization schemes, which are shaped by both, the artifact and the subject. This process is referred to as "instrumental genesis" (Rabardel, 2002). According to Vergnaud (1998, p. 167) a scheme is "the invariant organization of behavior for a certain class of situations". Vergnaud (1998) suggests that schemes are in particular characterized by two operational invariants, which refer to the knowledge included in schemes: theorems-in-action and concepts-in-action. The difference between both operational invariants is that of relevance and truth. While "concepts-in-action are relevant, or not relevant, or more or less relevant, to identifying and selecting information", "theorems-in-action can be true or false" (Vergnaud, 1998, p. 173).

With regard to research question 1, students' utilization of feedback is conceptualized in terms of their concepts-in-action and theorems-in-action, which guide their utilization schemes of the feedback. The situation that the scheme refers to is defined by the type of task with respective feedback.

Methods

The study presented in this paper is part of a larger study, which aims at understanding students' learning with interactive e-textbooks at primary level. Therefore, we used an interactive e-textbook that is available on the German market. The e-textbook "Denken und Rechnen interaktiv 3"¹ was the only interactive textbook for primary level that was available on the German market when the study

¹ <http://www.denken-und-rechnen-interaktiv.de>

was carried out. The e-textbook was not developed for the sake of this investigation, but by one of the leading German publishing companies for textbooks. Consequently, the design principles for the feedback are not known and do not necessarily take into account the current state of research in this field.

In this paper, a case study with altogether 12 cases is presented. All students were at the end of third grade with an age between 8 and 9 years. Each case works on a tablet in experimental conditions on tasks from one unit of a beta-version of the web based interactive mathematics e-textbook. During data collection the students encountered the interactive e-textbook for the first time. The students were asked to verbalize their thoughts (thinking aloud). Additionally, the interviewer asks questions in order to understand the students' actions and thoughts. The interviewer also gives hints in order to assist students' instrumental genesis. The work of the students was video recorded. Data was transcribed and analyzed in terms of concepts-in-action and theorems-in-action. As the name of these concepts indicates, these are mainly inferred from students' actions. Only sometimes students explicate the concepts and theorems guiding their actions verbally. Concepts-in-action were inferred from the data by constantly asking 'what are the concepts / relevant categories / notions guiding the student's action?'. Accordingly, theorems-in-action were inferred from the data by asking 'what assertions / beliefs assumed as true by the student guides the student's action?'

Since utilization schemes are defined as "invariant organization of behavior" (Vergnaud, 1998) it might seem questionable to investigate them with children that encounter an e-textbook for the first time. However, utilization schemes do not develop from scratch, but can be understood as adjustments (accommodation) of existing schemes. In fact, this experimental setting allows for analyzing the instrumental genesis in terms of accommodation of existing schemes.

Analysis

Analysis of the artifact

An analysis of the task and related feedback is a prerequisite in order to understand students' utilization schemes of the feedback, because they are influenced by the affordances and constraints of the artifact in the instrumentation process (Rabardel, 2002). Task no. 2 on page no. 73 and related feedback is analyzed for the scope of this paper. It is depicted in figure 1. The task is to find solids in the picture ("Which solid shapes do you find?"²) and to enter their names into the empty fields. After pressing the OK-button on lower right corner of the screen the software provides knowledge of results (KR) feedback. Correct inputs are shown in green color with a green frame, wrong inputs stay as they were entered for a few seconds. Afterwards they disappear and the empty fields are shown again (figure 2). Correct answers stay on the screen and the student can enter new inputs into the empty fields. Students get the opportunity to correct their wrong inputs twice. After their third try knowledge of correct response (KCR) feedback is provided by showing all the correct answers in green color. The ones that were entered correctly by the student are framed. An answer is evaluated as correct if

² This was the task in the beta-version of the interactive textbook. In the latest online-version of the textbook the task was changed to "Enter befittingly sphere, cube, cylinder or pyramid".

the student entered the correct name of the solid in the correct spelling. The feedback does not differentiate between incorrect spelling mistakes or incorrect solid names.



Figure 1: Task

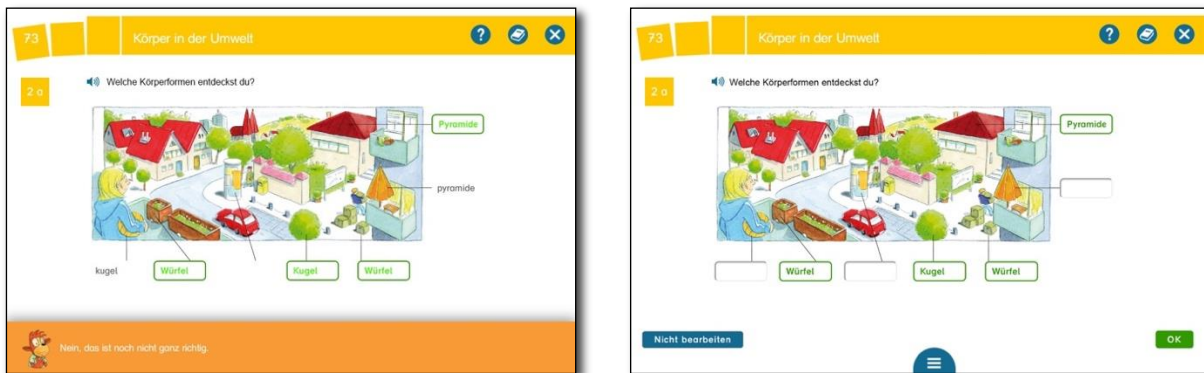


Figure 2: Task-level-feedback (KR) and screen for second try

Analysis of students' utilization schemes of the feedback

In this section data of two cases will be analyzed. The analysis of both cases starts at the moment, when the students have filled in most of or all empty fields and press the OK-button at the lower right corner of the screen. After pressing the OK-button the KR-feedback appears on the screen.

Case 1: Farrell

On Farrell's feedback screen four out of seven answers are depicted in green color and with a frame and stay on the screen while three of his answers remain as they were entered and disappear after a few seconds. He gets the feedback "Sorry, wrong".

- 13'03" Interviewer What happened?
- 13'08" Farrell Correct answers are green and what is gone now was wrong
- 13'18" Interviewer Ok. And do you have an idea why it was wrong?
- 13'22" Farrell Wrong spelling? And wrong entry.
- 13'30" Interviewer Could be. ... Think about it. What else could you write or how could you write it differently if you think it also might be because of the spelling
- 13'35" Farrell *Tips into an empty field and starts typing 'Cube' in correct spelling.*
- 13'54" Interviewer Uhum, now you say it's a cube. What did you enter before?
- 13'56" Farrell Square.

- 13'57" Interviewer And why do you think it is the cube now?
- 13'58" Farrell Because, before, the square is not an object, no symmetrical figure
- 14'12" Interviewer Ah, ok, and now you believe it's the cube.
- 14'15" Farrell Yes, because the square can only be seen and not touched
- 14'19" Interviewer Ah, ok.
- 14'35" Farrell *Types 'cuboid' in one empty field in the same wrong spelling as the first time.*
- 14'08" Interviewer Which form could that be?
- 15'12" Interviewer Can the book help you somehow?
- 15'21" Farrell *Presses the '?'-button and choses "help" (the help screen appears). He reads the help screen.*
- 15'45" Interviewer Does that help you somehow? What do you see?
- 15'52" Farrell There is everything that could give me a hint.
- 15'56" Interviewer Hmm, ok. ... And does that help you for the task?
- 16'02" Farrell No.
- 16'04" Interviewer No. Is there maybe another function that could help you?
- 16'09" Farrell I will check. *Presses the '?'-button and points on the option 'Lexikon'. Lexikon.*
- 16'13" Interviewer Yeah, click it.
Farrell explores the lexicon. The interviewer asks questions, which are related to the use of the lexicon. He looks for 'form' and "solid".
- 18'43" Farrell I believe it starts with a 'Q'. *At the same time, he opens the letter 'Q' in the lexicon and looks at the entries.*
- 18'58" Farrell No, but I found something different.
- 19'02" Interviewer Ok. What did you find?
- 19'04" Farrell The cuboid (in German: *Quader*) *Returns to the screen/tab with the task and tips into the field with the entry "Qader".*
- 19'09" Interviewer You already wrote cuboid there. So what did you find?
- 19'12" Farrell That in-between the Q and the A there is a U.
- 19'18" Interviewer Ah, that means the lexicon helped you a little.
- 19'28" Farrell *After completing to type the word 'cuboid' he presses the OK-button. All his entries are shown in green color with a frame. He gets the feedback "No, not correct yet."*
- 19'30" Interviewer And, what now?
- 19'31" Farrell I looked if what I wrote now is already correct.
- 19'38" Interviewer And, how does it look?
- 19'38" Farrell Correct.

The relevant concepts that guide Farrell's revision of his answers are verbalized in the beginning of the episode: Farrell verbalizes his interpretation of the feedback at 13'08" and also explicates two concepts of possible mistakes at 13'22". Accordingly, Farrell's utilization scheme of the feedback is guided by two concepts-in-action: 1) Correct answers are shown in green; wrong answers are shown in red (not explicit, but likely) and disappear (13'08"); 2) His concept-in-action of mistakes indicates that two kinds of mistakes are possible: Wrong names of the solids or wrong spelling of the names

(13'22"). The latter concept-in-action is supported by his way of proceeding with the task. On the one hand he thinks about different entries (13'35") and on the other hand he is sensitive about the spelling (18'58"-19'12").

Case 2: Edda

Edda gets the feedback "No, that it not quite correct". On the screen, the fields around her entries disappear and all her entries stay on the screen. An analysis of her answers reveals that five of her answers (from left to right and bottom to top: 1, 3, 4, 5, 7) named the solid correctly but were spelled wrong with no capital first letter, while two of her answers (2, 6) also contained a wrong name of the solid.

- 23'51" Edda It says that it is all not quite correct. *Looks at the screen*
- 23'55" Edda All (wrong) entries disappear. All fields are displayed empty again. Ah, boy!
- 24'02" Edda Looks at the screen. Hm.
- 24'07" Edda But this must be a sphere.
- 24'12" Interviewer Do you have an idea what may could have been wrong? ...
- 24'16" Edda Yes, this and this (*points at the two empty fields at the right side of the picture*)
- 24'20" Interviewer ... because everything disappeared.
- 24'27" Edda Well, this can't be a cone. ... Then I simply do again ... It's a sphere, definitely. *Types 'sphere' in the same (wrong) spelling as before in the empty field.*
- 25'00" Edda Hm, it's bad, now I don't know what was wrong and now one cannot ...
- 25'10" Interviewer What is it that you can't?
- 25'12" Edda ... ehm, know what is wrong, I know ... ehm ... I have to do everything from scratch ... (not understandable) this and this was wrong (*points at the two empty fields at the right side of the picture*)

Edda's feedback screen shows all her entries in the way that she typed them. She seems frustrated that all her entries disappear from the screen (23'55"). Her answer to the interviewer's question at 24'12" reveals that she does not infer from the feedback that all her answers were wrong, but has her own beliefs about her wrong answers (24'16"). Her belief that her two answers on the right side of the picture were wrong seems to be stable throughout the episode (25'12"). However, these beliefs are not congruent with her actual performance on the task. At 25'00" it becomes apparent that she does not have the concepts available to make sense of the feedback given by the tool.

Although she does not say it explicitly, her actions seem to be guided by the concept-in-action that she has to enter the correct names of the solids. There is no indication of her being aware that it is not only the name of the solid that is relevant, but that correct spelling is also a relevant aspect of the name related to this task.

Discussion

The analysis of students' utilization schemes of feedback shows that both students do not activate the same concepts-in-action when they utilize the software's feedback (research question 1). While Farrell's utilization scheme is guided by the two relevant concepts-in-action "name of the solid" and "spelling of the name", Edda's interpretation only refers to the "name of the solid". Edda seems surprised and disappointed that all her entries disappear on the screen and her belief that only two of

her entries were wrong seems to be stable. This indicates that she does not seem to have relevant concepts available in order to utilize the feedback.

However, it is important to note that the different utilization schemes of Farrell and Edda appear under different conditions. The intended interpretation of the feedback occurs in a situation when the student has got correct and wrong answers. In the case of Edda, it becomes apparent that she has difficulties to utilize the feedback. This is supported by findings from other cases in the study that have got all answers wrong in their first attempt. Two hypotheses can be inferred from this observation (research question 2): 1) In order to make effective use of the feedback it is important that students have both, correct and incorrect answers. If all answers are wrong it is more difficult to utilize the feedback, because it is more difficult to make sense of the feedback. 2) On the other hand, the findings might hint at an overall connection between the mathematical ability of the students and their ability to utilize the feedback effectively. Students who need the feedback most in order to improve their mathematical performance, because they have got many answers wrong in their first attempt have the most difficulties to utilize the feedback for improvement.

Conclusions

The analysis of two cases' utilization-schemes of feedback in an interactive mathematics e-textbook, which was used for the first time, is too limited in order to draw far reaching conclusions. However, the results show that the feedback of this task can be optimized. For some students it seems to be important to get more detailed feedback about the kind of mistake they made, especially if mistakes from different domains such as mathematics and language are relevant for the evaluation of the solutions. Altogether, the results support the call for adaptive feedback systems in digital learning systems (Vasilyeva, Puuronen, Pechenizkiy, & Räsänen, 2007).

The fact, that the feedback of the software is not sensitive to different kinds of mistakes can in fact be appraised differently depending on the pedagogic perspective. From the perspective of concept development, it is a constraint of the feedback that it is not sensitive to the kind of mistake, because it does not provide detailed information related to the question "Where to next?", i.e. detailed information about "what is and what is not understood" (Hattie & Timperley, 2007, p. 90). Research has shown that "that feedback is significantly more effective when it provides details of how to improve the answer rather than just indicating whether the student's work is correct or not" (Shute, 2008, p. 157). From the perspective of integrated mathematics and language learning it might even be an affordance that the name and the spelling of the name of the solid have to be correct in order to be evaluated as a correct answer.

On the other hand, the reconstructed concepts-in-action and theorems-in-action that guide students' utilization schemes of feedback indicate that students interpret feedback differently. Therefore, the efficiency of feedback is not only a question of the features of the feedback, but also a question of students' utilization-schemes of feedback. Like with any other artifact, students have to instrumentalize and develop utilization-schemes of the feedback so that it becomes an instrument for improving understanding and performance.

Acknowledgement

This investigation was supported by the Westermann Group by providing tablets and a beta-version of the interactive mathematics textbook used in the study.

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