A Theory-Based Approach of Feedback in STACK-Based Moodle Quizzes Taking into Account Self-Regulation and Different Proficiency of Learners

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Abstract—Digital assessment systems, such as STACK, nowadays offer various features to provide differentiated and individual feedback to learners. As literature shows, the focus is often on retrospective (error-related) information on the content level. Further aspects beneficial to learning such as self-regulation and consideration of the different capacities of working memory of heterogeneous learners are not yet sufficiently addressed. This article illustrates how feedback in a digital learning environment using the assessment system STACK might be designed to close this gap. According to the feedback model of Hattie and Timperley the discrepancy between current understandings and intended learning goals can be reduced by answering three feedback questions: "Where am I going?" (Feeding Up), "How am I going?" (Feeding Back) and "Where to next?" (Feeding Forward). Within the article it is discussed how these questions can be addressed either on the question level (specific feedback, general feedback) or on the quiz level (overall feedback). Furthermore, following Carless and Boud's concept of feedback literacy, learners are given the opportunity to choose a particular type of feedback. The concept is developed and proven as part of the interdisciplinary project IdeaL at the OTH Amberg-Weiden that is funded by the Stiftung Innovation in der Hochschullehre. A STACK question from a formative assessment on basic properties of functions serves to illustrate the concept.

Keywords—feedback, formative assessment, mathematics, STACK

1 Introduction

At the latest with John Hattie's publication of "Visible Learning" in 2008 [1] the importance of feedback has become a vital element of many educational discussions. Even though Hattie's study focused on school learning similar results have been found for the field of higher education [2], [3]. At the same time, software solutions for digital learning – for instance for interactive videos, web-based training or online assessment – offer increasingly flexible solutions to give differentiated and adaptive feedback to learners. However, these features often are mainly used to inform students what they have done or not yet done correctly on a task [4]. In contrast, Hattie and Timperley [5] point out that feedback is a multidimensional construct that seeks to answer three

questions (*Where am I going? how am I going?* and *where to next?*) on four different levels (task, process, self-regulation and self).

This paper introduces an approach how to implement Hattie and Timperley's model of feedback in a STACK-based self-learning environment for basic university mathematics. STACK is an open-source assessment system for STEM subjects and available as a question type for the learning management system Moodle. The self-learning environment is developed within the third-party funded project IdeaL at the Ostbayerische Technische Hochschule (OTH) Amberg-Weiden, university of applied sciences, in Eastern Bavaria.

Initially section 2 introduces the relevant theoretic foundations for the design of feedback in the self-learning course. Besides Hattie and Timperley's model mentioned above, this also includes the concept of student feedback literacy according to Carless and Boud [6]. Section 3 gives a brief overview on the institutional context at the OTH Amberg-Weiden and describes the Moodle learning environment consisting of so-called adaptive learning modules. Section 4 then pursues the question how the theoretical foundations associated with feedback can be put into practice in these modules using the technical features Moodle and STACK provide. Eventually, in section 5 the approach will be discussed and an outlook to next steps will be given.

2 Theoretical background

First, we provide a brief overview of general findings in feedback research. Afterwards, we outline Hattie and Timperley's feedback model as well as essential aspects of student feedback literacy according to Carless and Boud, both of which we use as a didactic foundation for the concept we present in the subsequent sections.

2.1 The art of feedback

In educational research, feedback has historically been viewed as a process of passing information to the learner in order to change behavior and initiate learning [7]. The positive impact of feedback is often emphasized, in that it correlates with high effect sizes ($d = 0.73$) [1] and can increase learner motivation [8]. However, further research on the topic has shown that the effects of feedback vary widely and may not be exclusively beneficial. Hattie's meta-analysis comparing factors influencing achievement in a school context revealed wide variation regarding the effect sizes of feedback [1]. Thus, as a result of research findings over several years, it has become clear that feedback on its' own does not guarantee learning [10], [11].

Valerie Shute's comprehensive review of feedback literature, in which she collects and structures the results of decades of research, offers various clues for making feedback as effective as possible for learning [7].

There are two types of information that effective feedback conveys: Verification and elaboration [12]. Verification, also known as "knowledge of results" or "knowledge of outcome," contains confirmation of whether an answer is correct or incorrect. Elaboration, on the other hand, contains information designed to enhance the learner's

understanding [13]. The details of elaborative feedback can vary, for example, by addressing the specific errors, addressing general misconceptions, giving examples or providing cues and hints. To avoid cognitive overload [14], elaborative feedback should be broken down into smaller segments and presented one piece of information at a time [15], [16].

Feedback information can be presented immediately or with a time delay, although research findings do not show a clear preference regarding the relationship between feedback timing and learning success. Immediate feedback can help correct errors as quickly as possible, which is particularly effective when training procedural skills [17]. Delayed feedback, on the other hand, promotes transfer learning to a greater extent, especially in the context of concept formation [18], and can create a sense of autonomy in the learner by encouraging active cognitive and metacognitive processing. Shute therefore advises carefully matching timing with variables such as context, task complexity and learner level.

2.2 The feedback model of Hattie and Timperley

Hattie and Timperley's model, which is introduced in the paper "The Power of Feedback", encompasses conditions for effective feedback and takes into account the students' varying learning stages [5].

In essence, Hattie and Timperley consider three aspects regarding feedback: First, the goal of feedback is to reduce the gap between the actual and desired state of the learning process and can be achieved by both teachers (e.g. by providing appropriately challenging learning objectives) and learners (e.g. effort and use of strategies). Second, effective feedback should ideally answer three questions from the learner's perspective: *Where am I going?, How am I going?* and *Where to next?*. Third, as demonstrated in the model, each of these three questions can operate at four levels of feedback: Task, process, self-regulation and self. For this paper, the second and third aspects are particularly relevant. In the following, the three feedback questions and the four feedback levels will be explained in more detail.

Three feedback questions. Effective feedback information seeks to provide answers to three questions: *Where am I going?* (Feed Up) is about defining the learning intention, goals and success criteria against which the learners' performance will be measured. This information creates transparency and clarity, because feedback cannot be used effectively to reduce the discrepancy between current learning and intended learning unless the goal is clearly defined. The question *How am I going?* (Feed Back) directs focus on the learners' current state and progress in relation to the learning goal, a standard solution or in comparison to the learner's own prior performance. Finally, *Where to next?* (Feed Forward) points to the next steps of the learning process: Possibilities for improvement and further development are shown in order to achieve the goal. By guiding the learners to more self-regulation and showing them various strategies and ways of solving problems, a deeper understanding of the learning content can be achieved. These three questions don't work in isolation from each other; rather, the interlocking of the provided insights enables the feedback loop to be closed.

Feedback levels. The aforementioned feedback questions operate at four levels that influence the effectiveness of feedback and should be targeted according to individual students' learning needs. Task level feedback refers to specific requirements of the task and can contain information on whether the task was solved correctly, concrete instructions on how to solve the task and supplementary or missing content. Feedback implementation on this level is relatively easy and is thus used frequently [22]. This level provides the basis for building knowledge at process and self-regulation levels and is therefore essential in everyday teaching. On the other hand, too much task level feedback can lead to a deterioration in performance because it doesn't contribute to strategy development and transfer to other tasks. Feedback at the process level addresses the processes underlying the tasks – including processing methods, strategies for processing information and learning processes that promote an understanding of task completion. Providing feedback at this level instigates a deeper understanding of learning: This includes relationships between concepts and transfer to other, more difficult tasks. Feedback on self-regulation level refers to the ways in which learners observe, regulate and evaluate their learning behavior and align their actions toward the learning intention, e.g. by stimulating the investigation of faulty strategies. Here, more advanced learners take more control over their learning process and may generate their own feedback, thus becoming less dependent on external feedback by their teachers. Finally, self-level feedback typically expresses evaluations about the learners themselves. Since it contains little task-relevant information, it is unlikely to increase learning performance and has even been shown to have a negative impact on learning [1], [9]. Still, it is often used in class situations.

A matrix of feedback for learning. The previously explained model served as a framework for Brooks, Carroll, Gillies and Hattie to further explore which feedback questions and levels are most frequently used in upper primary school [23]. Their results show that in terms of feedback questions, feeding back was most frequently recorded while feeding forward, the information regarding next steps in learning, was the least used. When looking at the four feedback levels, the focus was reported mainly on the task level, with self-regulation level in the last place. These findings are even more relevant as task level feedback is used to build surface knowledge, whereas process and self-regulation level feedback guides deeper and conceptual understanding [24].

Based on the results of the study and Hattie's feedback model, a feedback matrix was created to aid in effectively putting feedback into practice (see Table 1). The different intersections of feedback questions (x-axis) and feedback levels (y-axis) result in a differentiated catalogue of suggested questions and prompts for the respective pairing. The indication of the students' proficiency is a major addition to the matrix, as this is decisive for providing learners with the feedback they require: While novice learners need specific task-related feedback to implement surface learning, proficient and advanced learners reach deeper stages of learning by receiving process-related or self-regulating feedback [5]. As will later be illustrated, the approach introduced in this paper is largely derived from this matrix.

Table 1. A matrix of feedback for learning

Learner Stage	Feedback Level	Feeding Up: Where am I Going?	Feeding Back: How am I Going?	Feeding Forward: What Do I have to do Next?
Novice	**Task**	**Feeding Up Prompts:** Today we are learning … Success in this task will look like (exemplar/model) **Feeding Up Strategies:** Reduce complexity Use exemplars/ models	**Feeding Back Prompts:** You have/haven't met the learning intention by … **Feeding Back Strategies:** Match feedback to success criteria	**Feeding Forward Prompts:** To fully meet the learning intention, you could … Addressing the following success criteria would improve your work … **Feeding Forward Strategies:** Use scaffolding Refer to goals
Proficient	**Process**	**Feeding Up Prompts:** The key ideas/ concepts in this task are … Key questions you could ask about this task are … Strategies you will need in this task are … **Feeding Up Strategies:** Reduce scaffolding Increase complexity Use mastery goals	**Feeding Back Prompts:** Your understanding of the ideas/concepts within this task is … You used … strategies to a … level. **Feeding Back Strategies:** Increase complexity and amount of feeding back Use prompts or cues	**Feeding Forward Prompts:** You could improve your understanding of … concepts by … Thinking further about … could improve your work by … **Feeding Forward Strategies:** Increase complexity and amount of feeding forward Use prompts and cues
Advanced	**Self-Regulatory**	**Feeding Up Prompts:** How could you use the success criteria? Which other ways could you monitor your work? **Feeding Up Strategies:** Reduce emphasis of exemplars	**Feeding Back Prompts:** Are you on track with your work? To which level are you satisfying the success criteria? **Feeding Back Strategies:** Delay feedback	**Feeding Forward Prompts:** How could you deepen your understandings? What is the next step for your learning? **Feeding Forward Strategies:** Delay feedback Reduce teacher reliance

Source: Adapted from [23].

2.3 Feedback literacy

According to Carless and Boud, feedback is fundamentally learner-centered and requires active engagement by the learner to be most effective. To make this possible,

learners need to develop student feedback literacy, which Carless and Boud define as "the ability to read, interpret and then use written feedback. It includes the understandings, capacities and dispositions needed to make sense of information and use it to enhance work or learning strategies" [6].

Carless and Boud propose four interrelated features that serve as a framework for student feedback literacy:

Appreciating feedback. Based on school experience, many learners have become entrenched in the notion that feedback is simply a delivery of information. This may lead to a passive response to feedback. In contrast, appreciating feedback is about learners recognizing the value of feedback as a source for their learning as well as the need for their own active role in the process.

Making judgments. A realistic evaluation of the quality of one's own work and that of others is necessary in order to use feedback processes effectively. Lower-performing learners in particular are often unable to assess their performance because they often mistake effort for quality [19]. With numerous opportunities for self-assessment, learners can improve their judgement skills and learn to autonomously plan, monitor and adjust their work process based on this assessment of their own work quality. Through this monitoring process, learners generate their own internal feedback [20].

Managing affect. Feedback can trigger an affective response that relates to the learner's feelings, emotions and beliefs. Particularly in the face of critical feedback and poor grades, learners are often defensive as they perceive this information as a threat to their identity. Successful engagement with feedback information depends entirely on the learner's ability to maintain emotional balance. Therefore, the aim of feedback literacy is to help learners manage their emotional reactions and focus on the opportunity to improve their performance.

Taking action. It is necessary that learners act upon the feedback they receive – otherwise, the content of the information remains unused and the feedback loop cannot be closed [21]. Accordingly, learners need sufficient opportunity to take action after gaining insight regarding their performance. Teachers should therefore pay attention to how and when feedback is given when designing assessments, so that the information can be applied to the following tasks and work phases as promptly as possible.

The interplay of these four features is illustrated in Figure 1. Learners who are supported in appreciating feedback, self-assessing the quality of their work and managing their emotional reactions to feedback are more likely to engage in translating feedback information into actions [6, p. 1316].

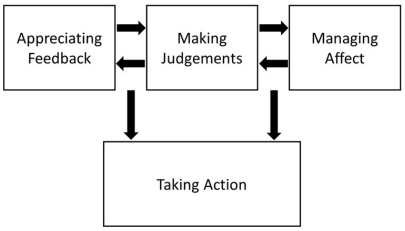

Fig. 1. Features of student feedback literacy

Source: Adapted from [6].

3 Institutional context and learning environment

In the following the main figures of the OTH Amberg-Weiden and the project IdeaL will be described and there will be given a short overview about the essential parts of the learning environment.

3.1 Institutional context

The OTH Amberg-Weiden is a state university of applied sciences with two campus locations in the rural area of eastern Bavaria and approximately 4000 students. The university offers 54 study programs across four faculties, including 29 bachelor's degree programs, 24 master's degree programs and one orientation study program, which make students aware of several technical degree programs. The four faculties are the Department of Electrical Engineering, Media and Computer Science, the Department of Mechanical Engineering/Environmental Technology, the Weiden Business School and the Department of Industrial Engineering and Healthcare (WIG). The predominant start of studies is in winter term. The OTH Amberg-Weiden is characterized by a heterogeneous student body, by many relatively small study programs and by many students from the region, but also by an increasing proportion of international students. Currently, around 20 % of the students are international students.

The OTH Amberg-Weiden is a face-to-face university whose concept for digital learning was significantly expanded in the course of the Corona pandemic. The open-source learning management system Moodle, which is widely used at universities in Germany, is used to maintain online learning. As virtual classrooms, Moodle courses offer the possibility for video lessons, online assessment, the exchange of materials and joint communication and work.

Current efforts aim on the one hand to use the potential of digitalization for the further development of teaching and to implement and establish real teaching innovations, and on the other hand to make teaching more flexible.

3.2 Project content

The project IdeaL is supported by the Stiftung Innovation in der Hochschullehre over the period from 01.08.2021 to 31.07.2024. The project addresses various problems, which are the increasing heterogeneity of students, the growing number of international students, the dropout in engineering sciences which is too high, the teaching in basic STEM subjects often addresses only a restricted spectrum of competencies and university lecturers still have little media-related teaching competence. An innovation network is set up by the project in which learning modules can be used flexibly for adaptive digital teaching. The potential of digitalization can be used by all stakeholders – for example regarding adaptive learning process control, the integration of synchronous learning of technical language and the realization of formative distance examination formats – while at the same time promoting the necessary teaching competencies. In addition to didactic aspects and technical feasibility, it is essential to map subject content in accordance with the demand for high-quality teaching – for

example with respect to adaptive learning process control, the integration of synchronous learning of technical language and the realization of formative distance examination formats – while at the same time promoting the necessary teaching competencies.

It was attempted to meet these requirements in the context of basic topics of engineering pedagogy by the individual use of different didactic elements (see Figure 2).

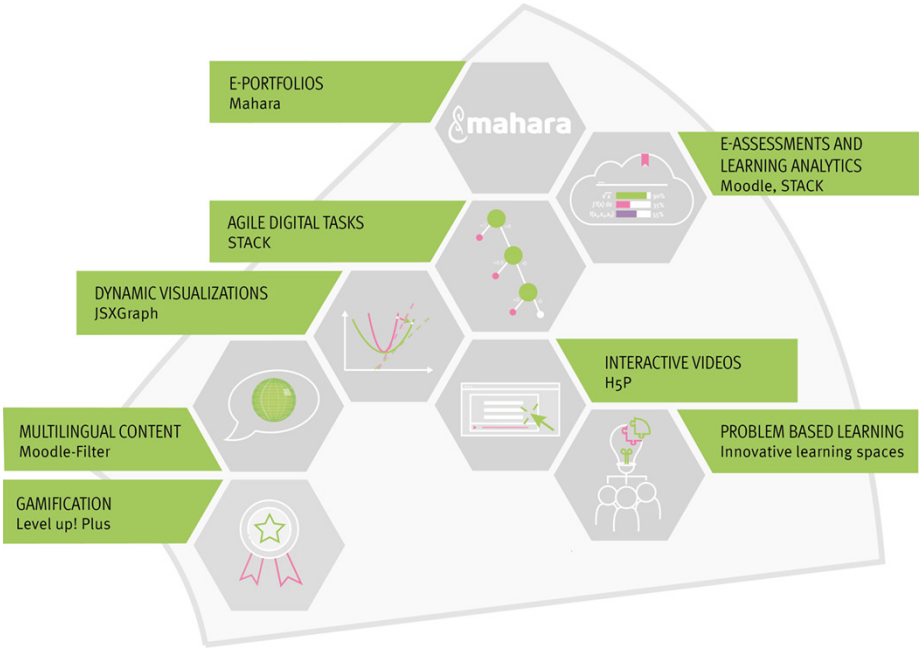

Fig. 2. Didactic elements of an online self-learning course (adaptive learning module)

3.3 Learning environment

Our learning modules are online self-learning courses designed to meet the following didactic guidelines:

- cognitive activation
- orientation towards understanding
- adaptivity and interactivity
- learning control and transparency
- feedback

So far, these courses have implemented mathematical content such as complex numbers, linear algebra or real functions.

In order to create a mathematics course according to the aforementioned didactic guidelines, we use the assessment system STACK.[1] STACK (System for Teaching and

[1] https://stack-assessment.org/

Assessment using a Computer algebra Kernel) is an open-source assessment system for STEM subjects and available as a question type for Moodle quizzes. This assessment system allows the input of mathematical expressions and their evaluation on the basis of the Computer Algebra System (CAS) Maxima. Thus, it creates individualized feedback, possibly with reference to students' misconceptions.

Also, interactive representations (JSXGraph) and interactive explanatory videos and slideshows are implemented in STACK tasks, leading to cognitive activation, comprehension orientation and interactivity. Passive consumption of knowledge is reduced in favor of active participation in the self-directed learning process.

General section: In a general section, there is a topic overview, which is intended to motivate students and provide a first insight into the topic. In addition, the learning objectives are communicated transparently.

Communication: A public and a private channel are provided as communication channels.

Interactive chapters: The area of interactive chapters deals with the preparation and practice of learning content. A close interlinking of self-directed learning and its application lead to the fact that theoretical content is put into context. Thus, deep processing occurs through repetition, creating elaborate and lasting knowledge through application. This part is concluded by completing final questions. There is no limit to the number of attempts. In order to be able to work on the following interactive chapter, a number of correct answers are required.

Exercises: This area contains comprehension questions and control questions, warm-up exercises and exercises for reinforcement. In this area, feedback plays a leading role.

Final quiz: The final quiz is the last activity of the learning module. It is necessary to pass this quiz in order to complete the course successfully.

4 Feedback design in the learning environment

Considering both the importance of feedback for learning and the lack of individual face-to-face feedback in an online self-learning context, great attention has been paid to the design of feedback in the adaptive learning modules described in section 3: How can Hattie and Timperley's model of feedback as well as the idea of feedback literacy be put into practice in a Moodle self-learning course?

After a brief overview of the respective features Moodle and the question type STACK offer, this section will describe how feedback has been designed and implemented in the project IdeaL's learning modules. It will also address advantages and limitations of the tools used and point out questions for further design.

4.1 Feedback features of Moodle and STACK

First, we will briefly describe the features for providing feedback in Moodle and STACK. In essence, a Moodle course contains quizzes which contain questions. This implies three different levels – the course level, the quiz level and the question level – with different possibilities to implement feedback.

Course level: Materials like files or text pages and activities like chats or quizzes can be created and moved between different course sections. For each material or activity a description can be defined, which is a text area that can contain HTML, CSS and JavaScript and thus can be used very flexibly, e.g., for customization of the course page. For instance, using a simple script, a section can be made invisible until some activity is completed by the student. Also, media can be embedded in the descriptions.

Quiz level: The "quiz description" can be enriched with images, videos, applets and scripts, as explained above. During a quiz, text blocks can be shown next to the quiz, for example to provide syntax hints to the students. After submission, there is opportunity to review the quiz (see Figure 3). At the top of the quiz review, the "overall feedback" can be shown. Different feedback messages can be assigned to different percentage ranges of points. In the main review area, all questions of the quiz are shown. They include the students' answers, the number of points, question-level feedback, and optionally other review elements.

Question level: For questions, there are "specific feedback" and "general feedback". The main difference is that specific feedback depends on the student answer, whereas general feedback does not depend on it. In STACK questions, specific feedback is defined using a potential response tree (PRT). A PRT consists of one or more PRT nodes which have at most two child PRT nodes each. Following the PRT algorithm, one or more answers of the student are at first checked on the property defined in the PRT's root node. Depending on the success or failure of this check, evaluation continues in the corresponding child node. The algorithm proceeds recursively until no further child node can be reached. In each node along the evaluation path, partial credit can be added to or subtracted from the score. Moreover, at each node a message can be added to the feedback using information about the student answer. The question author can define multiple PRTs for a question, but there is only one section for general feedback such that every student will see the same general feedback independent from the answer.

4.2 Concept and implementation

After a description of technical possibilities to provide feedback in Moodle and STACK, we will present a concept to integrate feedback into the learning module. Hattie's feedback model (see Section 2.2) and the idea of feedback literacy by Carless and Boud (see Section 2.3) will serve as the didactic foundation. The feedback matrix of Brooks (see Section 2.2) will be used to put the feedback model into practice. Feedback literacy will be implemented using a simple selection element.

In the following, the part of the learning module we will look at in detail will be the final quiz, which was introduced in section 3.3. The final quiz is available after completion of all interactive chapters. It is the first opportunity for the student to test all learning goals of the module comprehensively and in an exam situation. Whereas the interactive chapters and the exercises are optimized for learning and respectively training, the final quiz tests the achievement of the module's learning objectives. Therefore, it is a very natural point to take feedback very much into consideration.

Quiz settings: In the final quiz, the feedback will not be given immediately, but only after submission of the quiz. Time delay can promote a sense of autonomy in the learner

(see Section 2.1), when having to solve questions without knowledge about solutions to previous questions, for instance. In the review of the final quiz (see Figure 3), the overall number of achieved points and the overall feedback is shown. For each question in the review, the number of achieved points, the specific feedback and the general feedback is shown.

Example question: As example question of the final quiz, a STACK-question on basic properties of functions is used (see Figure 3, Question 1). In the task, a function is given which specifies a sum of two square roots of quadratic terms. Students are to give the domain of this function by using interval notation. Hints on the input syntax for intervals are provided in a foldout details tag.

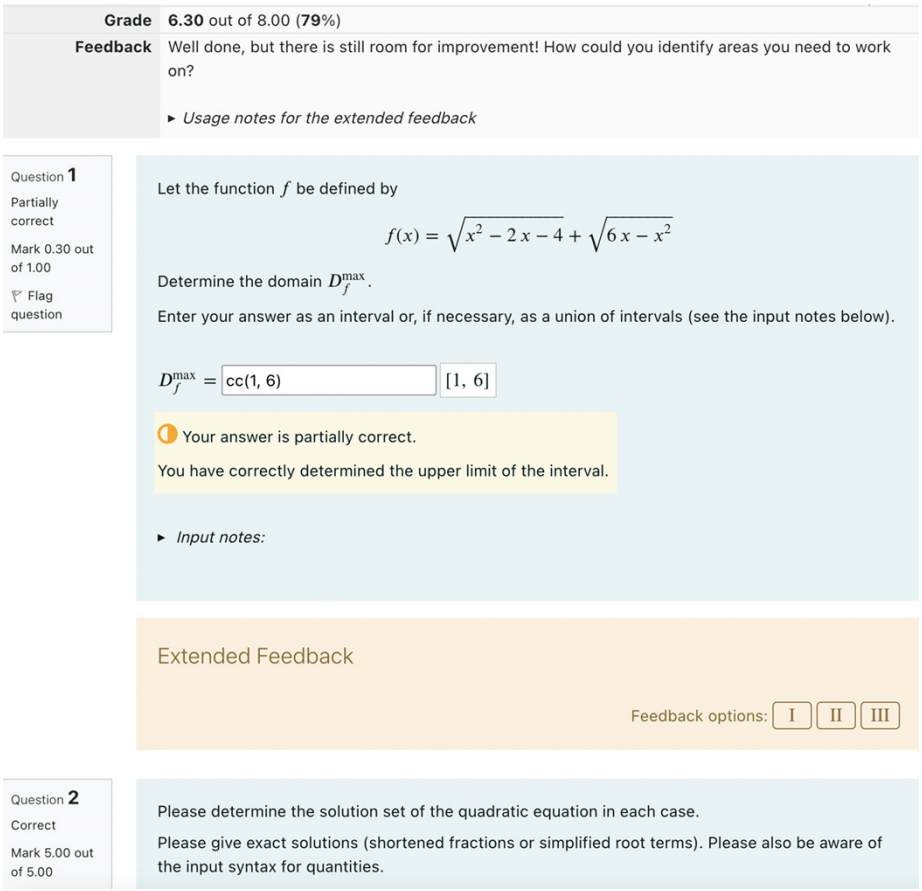

Fig. 3. Example review of a final quiz on real functions. Line 1: Grade for the submitted quiz. Line 2: Overall feedback for the submitted quiz. Question 1: Example STACK-question with question text (blue), specific feedback (yellow, embedded) and general feedback (orange, below). Question 2: Part of a second question of the quiz

Specific feedback: In questions of the final quiz, we use specific feedback to provide brief error-related Feeding Back at the task level, i.e., to show the students how they are going. They can use this information to identify possible mistakes and – if necessary – to prepare for a second attempt on the quiz. Various mathematical properties can be checked for a student answer and feedback can be given adaptively. We decided against the use of Feeding Forward here. Students should actively think about the next step here by themselves or with the help of the general feedback, which will be explained in the following.

General feedback. Extended Feedback: In the general feedback, we propose a new approach that we call "extended feedback". The general feedback area is usually used for a static sample solution. With extended feedback, the area is now intended to provide more differentiated feedback, taking into account learners in different learning stages. This is implemented by designing suitable feedback for each of the three learner stages and offering a selection menu. The selection menu is technically implemented by a tab menu using a small part of CSS and JavaScript. Selecting an option displays the respective content and hides the other two contents. It should be emphasized that the extended feedback is also shown if the answer was correct, which allows for example advanced learners to get more detailed feedback and deepen understanding. Otherwise, correct tasks are often perceived to be checked off prematurely and the opportunity to deepen or correct small details is not taken.

Selection Menu: In the example, the three options of the selection menu are mapped to the learner stages of the feedback matrix (see Section 2.2) as follows: I. Novice, II. Proficient, III. Advanced. Initially, no option is selected (see Figure 3). Unlike specific feedback, which responds adaptively to input, the extended feedback requires the learner to first take action to view it. The learner is given responsibility in the learning process by having to actively choose feedback. Several aspects of feedback literacy can be strengthened as a result. In particular, the learner gets the opportunity to directly follow up on the completion of a task and to take a next step in the specific topic (see Section 2.3, Taking action). In addition, an appropriate choice depends on how well the learner can assess his or her own performance in the task at hand (see Section 2.3, Making judgments). The necessity to consciously choose feedback, may help learners to appreciate having this information (see Section 2.3, Appreciating feedback). Lastly, general feedback is given independent from the student answer, such that students don't have to fear a critical remark to their answer (see Section 2.3, Managing affect). However, related to the same aspect, frustration could arise, when the more advanced options are not understood by novices. This risk can be reduced by including a remark in the usage notes on the extended feedback (see Figure 3), that the advanced contents are not recommended in the early learning stage.

Feedback Option I – Novice: In the example, the first feedback option (see Figure 4) is designed for novice learners. Regarding the feedback matrix (see Table 1), Feeding Up on the task level is used as the main feedback type. It is shown how success in the task will look like using a tutorial-like worked solution of low complexity with verbal explanations and annotations. Contents are presented in a beginner-friendly way (color allocation, explanation of key terms, line-by-line term conversions, illustration on the number line). The content is designed such that it can as well be used by learners in other stages, by using the foldout tags strategically.

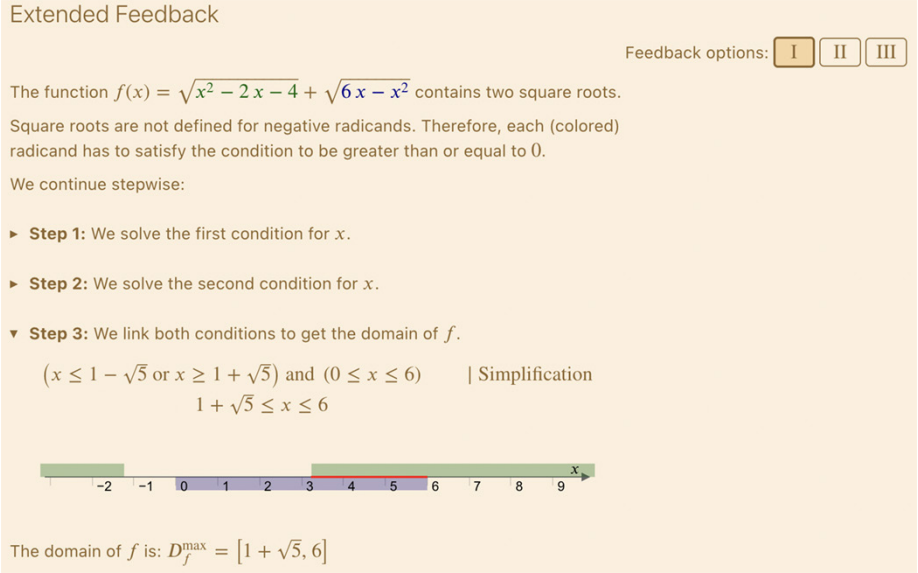

Fig. 4. Feedback option (I) for novice learners

Feedback Option II – Proficient: When choosing the second option (see Figure 5), content is shown which is designed for proficient learners. Referring to the feedback matrix (see Table 1), Feeding Up on the process level is the main feedback type. Now the worked solution is providing no textual explanations and less detailed steps. This way the proficient learner should be able to check his answer quickly and concentrate on the most important steps. The learner should be able to handle the transformations or use this as a challenge. Furthermore, at least one alternative solution type is outlined in addition to the standard solution. The proficient learner can use this as another challenge to think about and solve the problem from another perspective.

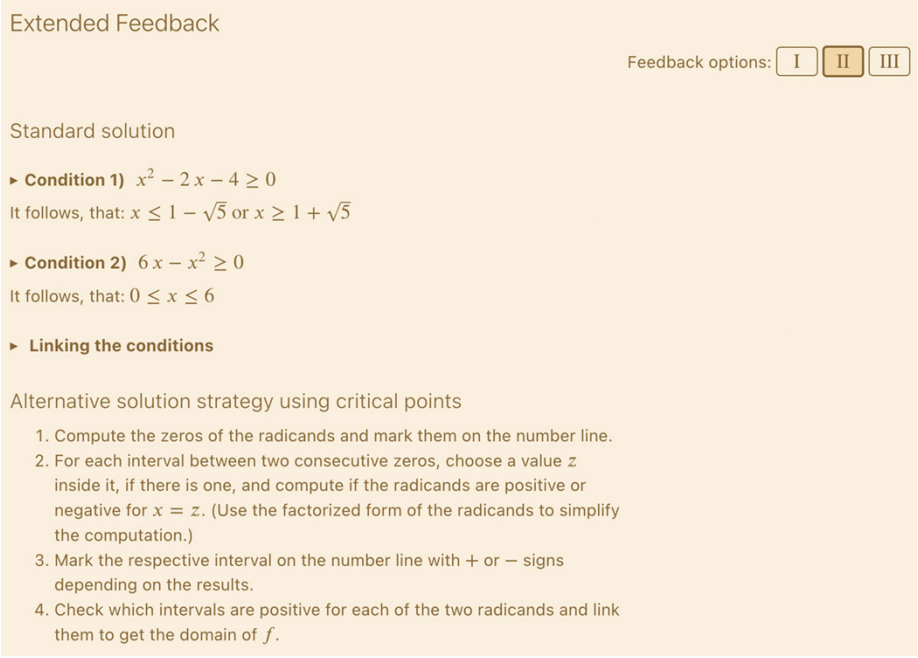

Fig. 5. Feedback option (II) for proficient learners

Feedback Option III – Advanced: The content of the third option (see Figure 6) is intended for advanced learners who want to delve deeper into the topic of the question and benefit less from being given a worked example or an alternative strategy because they already mastered the process needed to solve the task. The main feedback type used is also Feeding Up on the process level by further increasing the complexity and reducing the scaffold. In comparison to the previous option, the additional strategy to reduce emphasis of exemplars is used, also providing elements of self-regulatory Feeding Up. The small assignments are formulated in a way that requires a higher level of self-regulation from the learner. Taking responsibility for the learning process, the learner should first solve the task on a piece of paper and only in a second step activate the corresponding checkbox to show the solution. This way learners have an opportunity to deepen their understanding, which can lead to higher appreciation for feedback. In this example, linking graphical and symbolic representations is promoted, which can be the next step in learning.

Overall feedback. The overall feedback in the quiz review contains usage notes for the extended feedback, explaining that feedback for different learner stages can be selected by the learner. The location of the notes on the same page with all feedback can be used by the learner flexibly by scrolling up while using the extended feedback of selected questions. Feeding Forward information is given on the self-regulation level. According to the feedback matrix, Feeding Forward strategies for this level are to delay the feedback and reduce teacher reliance. In this case, the feedback is shown after the whole quiz is submitted and not immediately after submitting a question.

Also, the students have access to much feedback, but, apart from usage notes, need to learn using it to their benefit by themselves. So, the final quiz is an opportunity for students to develop self-regulation for example by evaluation of their learning behavior through investigation of faulty strategies.

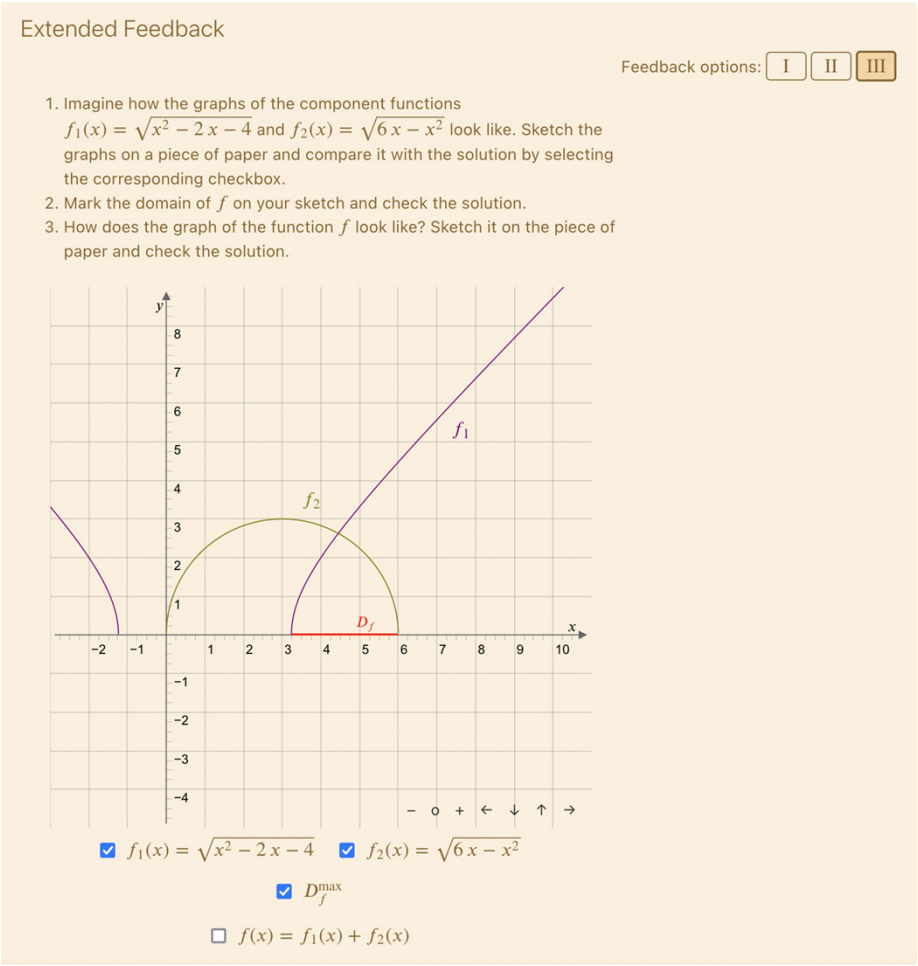

Fig. 6. Feedback option (III) for advanced learners

4.3 Summary

STACK based Moodle quizzes are offering a great variety of features that can be used to implement far more than just knowledge of result and correct answer. The question type STACK in particular supports detailed, error-based information in the specific feedback. In the extended feedback this question type allows for flexibly integrating randomized variables which is great for STEM subjects. However, the basic concept of the extended feedback is only using a Moodle core feature (the general feedback) plus

some additional JavaScript. Therefore, it could also be implemented in any Moodle question type. Of course, it takes a lot of resources to design and to implement such an extended feedback and it is important to choose specific points in the course of the learning process to provide it.

5 Discussion and outlook

This paper outlines the components of the learning environment for basic university mathematics developed within the framework of the third-party funded project IdeaL. The development of the learning environment is based on the institutional conditions of the OTH Amberg-Weiden and in particular on the demand for an adaptive learning environment resulting from the increasing heterogeneity and diversity of students, which can be used by students in self-study independent of time and place and the associated course (see section 3). In order to support the work in self-study, special emphasis was placed on the design of the digital learning modules with integrated quizzes, (1) to promote the feedback literacy of the students by means of a multidimensional feedback and thus to achieve a high effect size of the implemented feedback based on the feedback model of Hattie and Timperley and (2) to support self-regulated learning on the one hand and to adapt the cognitive load induced by feedback to the prerequisites of the learners on the other hand (see section 2). The realization of the quizzes with multidimensional feedback just described is done in STACK in combination with JSXGraph. The feedback is generated automatically and adaptively, and can be controlled by learners (see section 4).

The IdeaL project is now in the middle of its three-year duration. At this point, it can be stated that the technical development of Moodle, STACK and JSXGraph has progressed to the point that, with in-depth knowledge of JavaScript, complex feedback models such as those of Hattie and Timperley as well as advanced didactic feedback concepts such as feedback literacy can be implemented in a digital self-learning environment.

In the next phase of the project, in addition to motivational aspects, the learning effectiveness of the digital learning environment will be examined by comparing two cohorts of students with the aim to find out whether students who only work with the digital learning environment achieve comparable, better or worse results than students who attended face-to-face classes. Implications for teaching are to be derived from the results, for example whether the digital learning environment is already suitable for use in exam preparation at times when no face-to-face lectures are available.

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