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Meike Böttcher[1], Lara Huethorst[1], Daniel Walter[2], Annabell Gutscher[1], Christoph Selter[1], Andreas Bergmann[3], Tabea Dobbrunz[3] and Andreas Harrer[3]

[1]TU Dortmund University, Germany; meike.boettcher@math.tu-dortmund.de, lara.huethorst@math.tu-dortmund.de, annabell.gutscher@mathematik.tu-dortmund.de, christoph.selter@tu-dortmund.de

[2]University of Münster, Germany; d.walter@uni-muenster.de

[3]Dortmund University of Applied Sciences and Arts, Germany; andreas.bergmann@fh-dortmund.de, tabea.dobbrunz@fh-dortmund.de, andreas.harrer@fh-dortmund.de

This paper illustrates the current status of the design and research of a digital, case-based learning platform (FALEDIA), which is being iteratively (re-)designed and researched to increase the diagnostic skills of pre-service teachers. In an interdisciplinary design team consisting of researchers from mathematics education and computer science, digital learning modules on central topics of arithmetic in primary school are designed and implemented in university courses. The learning modules are characterized in particular by the consideration of potentials of digital media from the mathematics education's point of view, such as multiple external linked representations and informative subject-related feedback systems. In this article, the design approach of FALEDIA learning platform is presented by outlining selected learning modules and insights into first results are given.

Keywords: Digital learning platform, case-based, diagnostic skills, place value understanding, understanding of operations.

Introduction

International assessment studies such as TIMSS (Mullis et al., 2020) indicate that pupils are not sufficiently supported in many countries. This particularly holds true for pupils with difficulties in learning arithmetic. Following these recurring empirical findings, it can be assumed that teaching should be consciously oriented towards the learners' individual learning levels and that diagnosis-based support for children should be practiced (Phelps-Gregory & Spitzer, 2018). Therefore, teachers necessarily need diagnostic skills. In order to support pre-service teachers in increasing their diagnostic skills, digital learning platforms can offer new learning opportunities by including multiple representations and intelligent feedback systems.

First, the theoretical background relevant to the design and research of the learning platform is outlined by addressing diagnostic skills, working with cases, and learning with digital learning platforms. The following two sections address the design of the FALEDIA learning platform and the design of the research study. Finally, the research questions and first results are presented.

Theoretical background

Diagnostic skills

‘Diagnostic skills’ are considered a key skill which all teachers should have in order to be able to provide individual support in (mathematics) lessons (Schulz, 2014). Although there is consensus that diagnostic skills are central to any teaching-learning process, the construct is often conceptualized in different ways. On the one hand, diagnostic skills are understood as adequately assessing pupil characteristics and learning as well as task requirements (*accuracy of assessment*, Karing et al., 2011). On the other hand, they are also understood as validly recording the learning status, difficulties and possible backgrounds on the basis of learners' statements (*diagnostic depth of focus*, Prediger et al., 2013). The latter conceptualization of diagnostic skills is followed in the FALEDIA study, since accuracy of judgement has a focus on performance assessments, whereas diagnostic depth of focus also takes potential causal factors of observable performance into account.

FALEDIA aims at contributing to raising diagnostic skills in central arithmetic topics such as *understanding basic arithmetic operations* (UO) and *place value understanding* (PVU).

Case-based learning

In order to prepare pre-service teachers to diagnose the learning levels of children and, based on this, to take appropriate support measures, case-based learning is of decisive importance (Syring et al., 2016). Cases can be in the form of vignettes – as a video, transcript or teaching/learning related document – and can be an occasion for linking theory and practice by establishing relationships between the general and the specific (Markowitz & Smith, 2008). When analyzing the cases, the pre-service teachers – unlike in classroom practice – are not exposed to any immediate pressure to act. Accordingly, it is possible to repeatedly work through a case and, thus, adopt different perspectives (Krammer et al., 2012). Furthermore, the analysis of cases can help to better cope with the diversity of individual cases without getting lost in the multitude of individual approaches.

Based on the promising experiences with the use of cases outlined above, the FALEDIA learning platform is characterized by a consistent integration of school practice cases.

Learning with digital platforms

Web-based, subject-specific learning with digital learning platforms has become increasingly important. With regard to the degree of student activity within learning systems, two approaches can be distinguished:

- *Worked-examples* (Renkl, 2017): Well-structured examples are presented, largely without learners' self-activity.
- *Problem-based learning* (Koedinger et al., 1997): The learners' own activity is encouraged and accompanied, for example, by intelligent tutorial systems.

Design of the FALEDIA learning platform

To emphasize this distinction, the first FALEDIA learning platform version includes two separate variants of the same content. One variant presents the content with informative elements (*worked-*

examples) only, while the other one includes elements to stimulate exploration (*problem-based learning)*. Each one of these will be briefly presented in the following.

FALEDIA conceptional design

Currently, the FALEDIA platform offers learning opportunities for two different topics – *UO* and *PVU*. The website content for each topic consists of three parts. It is considered fundamental for the pre-service teachers to gain (1) the necessary background knowledge. This forms the sound basis for (2) diagnosis on the one hand and (3) accordingly fostering pupils' learning on the other.

FALEDIA provides the necessary content concerning the three most prominent aspects of each topic at first. For *UO* the three aspects of basic mental model, linking representations and using numerical relations have been identified as the most prominent to know. Examples of competency expectations pre-service teachers should be able to acquire are given in Table 1.

Table 1: Competency expectations towards pre-service teachers

Basic mental models	Linking representations	Using numerical relations
Background knowledge – Pre-service teachers …		
can explain which basic image is addressed by given everyday situations or subjects.	can change and describe representation forms – even in more complex contexts.	can describe which task patterns do (not) suggest usage of a specific mathematical law.
Diagnosis – Pre-service teachers …		
can state in how far a basic image is shown in pupils' documents and name difficulties.	can state in how far a child is able to link representation forms and name difficulties.	can state in how far a child uses task relations und mathematical laws and name difficulties.

Based on these competencies FALEDIA focusses on background knowledge for pre-service teachers and exemplarily diagnosis of primary school pupils' documents. The two different variants are described in the next section.

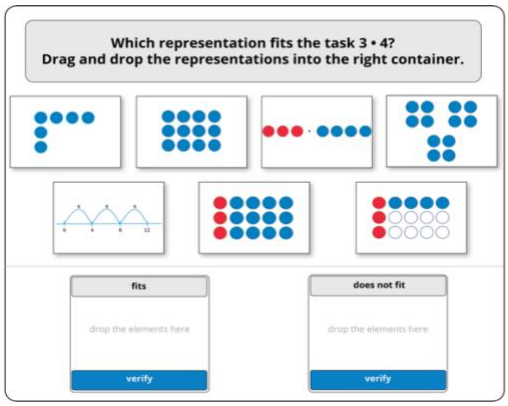
Current FALEDIA variants

The current FALEDIA learning platform includes two variants – one with informative elements only and another one mainly with explorative elements. In order to make a comparison between the two variants, either worked-examples or elements of problem-based learning are offered at the same location of the learning content. The way the learning content is offered should contain the same information and be equally attractive to users. The accompanying text, in both variants, is the same.

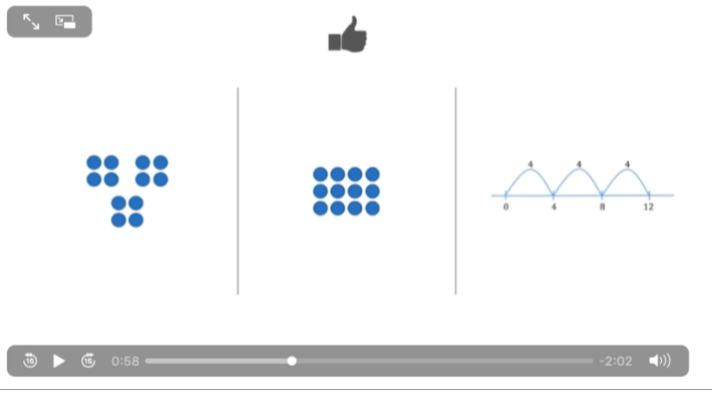
In the following figures, an example of the implementation of the same content from the two different design perspectives is given. Figure 1a shows a problem-based learning element, where users actively group elements by ordering visual representations according to whether or not they fit the multiplication task 3 x 4. The German conventions dictate that multiplicator x multiplicand = product; the multiplicator expresses how many groups there are while the multiplicand defines the quantity of

these groups. A figurative representation shows the quantity of the groups in rows. Users can drag and drop the representations into "fits" and "does not fit" containers. They can click "verify" at any time and receive solution-based feedback.

Figure 1b shows an excerpt from the implementation of the work-example. In this case, the user *is informed* by a video – not as in the example above actively interacting with the platform – about whether or not a representation resembles the task 3 x 4. In each case, a short explanation is given why the respective element was grouped accordingly. This comparison of the examples of the two variants demonstrates that both variants present the same content, but the access to the information differs.



(a) Problem-based learning element



(b) Worked-example

Figure 1: FALEDIA learning modules

The FALEDIA variant with elements of problem-based learning contains various so-called "learning modules"; one of which is the module for "grouping" shown in Figure 1a. To give only a few examples, there is the "slider" in which sequential processes are worked on. At certain important decision points, the pre-service teachers are supposed to choose between three different possible sequels, only one of which is correct. Another activity is "sorting", which is about linear ordering of elements.

The variant with solely worked-examples contains textual and tabular elements; informative videos and audios are integrated. All modules and informative elements are used for various content-related activities and information, both in the background and in the diagnosis.

The following Table 2 illustrates how some contents are realized differently, depending on which variant of the platform they are presented on. Each realization offers learning opportunities – depending on the specific content and its complexity, different accesses might be considered more supportive.

Table 2: Included learning and work-examples only models in comparison

Including interactive modules	Worked examples only

Sorting into groups whether the representation matches a certain task	Explanatory video concerning the connection of different representations
Sorting different contexts to the multiplicative basic mental model which were unknown before	Tabular presentation of the multiplicative basic mental model giving exemplary contexts
Linkage of single-choice tasks concerning an audio file of a pupil explaining her train of thoughts while using mathematical laws	Explanatory audio file including an audio file of a pupil explaining her train of thoughts while using mathematical laws

Design of the FALEDIA research study

The project is designed in a mixed methods design. In the current state, users are offered access to only one of the two pages for each of two topics (PVU and OU). Hence, the pre-service teachers once get access to the variant with worked-examples and once to the one with the problem-based learning, so both variants of access, based on a different topic, are offered. For example, if you see the variant with worked-examples for understanding place value, you see the problem-based variant for operation understanding.

In a next step, the alternative form of access is released for all users in each case, so that access to the information can be chosen freely as required. These multiple representations of the FALEDIA platform are used to gain insights into the perception of the participating pre-service teachers as well as their change in diagnostic tasks.

Research questions

The two following research questions will be addressed in what follows below:

1. Which diagnostic skills do pre-service teachers show before and after using the FALEDIA platform?
2. Which conceptional features and design elements prove to be conductive to learning and in how far are they applicable to other concepts and/or platforms?

Design of the study

To gain insights into the diagnostic skills of pre-service teachers all participating students of a course ($N = 188$) in their third or fifth semester of studying to become a primary school teacher are obligated to participate in two written surveys and use one of the FALEDIA platform versions for self-study purposes to complete another written task. The students were divided into two groups. One group had the variant with the problem-based learning elements and the other group had the worked-examples to PVU. For the OU, access to the other variant was later enabled for the respective group. The two surveys are designed in a pre-post design. The first test was performed. Then the background knowledge of PVU as well as exemplary diagnosis and fostering was elaborated with the help of the FALEDIA platform. Finally, the posttest was conducted. Among other tasks, the pre-service teachers are given a child's solution which reveals weaknesses in understanding basic arithmetic operations, and are supposed to describe the errors and specify possible causes. Additionally, guideline-based

interviews with randomly chosen pre-service teachers (N = 21) were conducted while they used the FALEDIA platform to provide more detailed information which elements of the two different variants pre-service teachers prefer over the other.

Data evaluation

A system of categories – based on a quantitative study by Brandt (in press) – has been developed to quantify the results of the written survey and get an overview of possible differences in results depending on which variant of FALEDIA was used by the participants. In the evaluation, the diagnostic subskills of describing mistakes, analyzing the causes of mistakes, and assessing diagnostic tasks are looked at. In each case, the three central content aspects of the respective topic are included in the evaluation. The correlations and significances were calculated using Anovas (RQ 1).

As important as that, these results are used to merge the current two variants of the FALEDIA platform into one variant that is tailored to the needs of pre-service teachers. For this purpose, the qualitative content analysis according to Mayring (2019) is applied (RQ 2).

Empirical findings

The first results of the surveys are available for both the diagnostic skills and the design elements. In this paper, a subset of the results on understanding basic arithmetic operations, looking at analysis causes of mistakes is focused on. Amongst others, a before-and-after comparison is used to examine whether the pre-service teachers were able to improve their score after working with FALEDIA and whether there are differences depending on which variant of the learning platform they worked with – the one with the worked-examples or the one with the problem-based learning elements.

Diagnostic skills (RQ 1)

For the average value of the scores achieved in the pre- and post-tests, it can be observed that the pre-service teachers improved both in the worked-examples variant and in the problem-based learning variant (Table 3).

Table 3: achieved scores (UO) averages out of max. 6 points

	score before FALEDIA	score after FALEDIA	score difference
worked-examples (N = 94)	1.33	1.60	+ 0,27
problem-based learning (N = 94)	1.32	1.64	+ 0,32

The increase of points for the analysis of causes of mistakes in the *UO* is statistically significant. Which variant of the learning platform the pre-service teachers had, however, is not significant. This means that the FALEDIA learning platform could help pre-service teachers to increase their diagnostic skills in the field of analyzing the causes of mistakes. However, there is no evidence that one variant of the platform can increase the learning success significantly better than the other variant in this area. As noted previously, prior research has found that a learning platform that includes both – work-examples or problem-based learning elements – proved particularly conducive to learning

(Saatz & Kienle, 2013). Qualitative interviews were conducted to determine which criteria should be used to decide whether a learning situation is better served with a worked-example or a problem-based learning element.

Design elements (RQ 2)

The qualitative interviews offer a more detailed insight into the subjectively perceived learning opportunities. In the interviews, various statements could be clustered into categories. Two particularly conclusive categories for the use of worked-examples and problem-based learning, which can be proven on the basis of the students' statements, are listed below.

Worked examples are preferred if…

… the mathematical content is considered rather difficult or new. (“For the videos the increase in value is when it explains an aspect that I've never noticed before.” (Student 1))

… knowledge should be refreshed or presented in an overview. (“If there’s something, where you have some kind of ‘supercategories' and then you have examples in a comparison, where it's not about diagnosing something, but that you get a feeling for what it's based on, I think the table is more appealing.” (Student 1))

Problem-based learning elements are preferred if…

… already acquired knowledge should be verified or deepened. (“This is a good exercise to get more confidence, because you also have to do something yourself […] because you simply have to think more yourself.” (Student 2))

… practical diagnostic skills are to be fostered. (“It was good to work practically, like you’ll do later as a teacher at school. You do it on your own, you can see how to implement [a diagnostic instrument] – not only theoretically.” (Student 3))

These identified categorical differences will be used in the next step to elaborate on the merged site with elements of worked-examples and problem-based learning.

Conclusions

Looking at the insight into the initial survey results provided here, the following can be summarized: for RQ1, there is evidence that pre-service teachers increased their ability to analyze causes of mistakes through the FALEDIA platform. A correlation to the delivery method, i.e. which variant of the platform was used, could not be found significantly. Previous research has demonstrated learning effects for both approaches. However, learning platforms which combine elements of worked-examples and problem-based learning have proven to be particularly beneficial for learning (Saatz & Kienle, 2013). Students' comments from the interviews indicate that both variants are perceived as helpful in certain requirements (e. g. depending on the subject matter and phase in the learning process). Because of this, the final version of the FALEDIA learning platform should not and will not be strictly dedicated to one of the two approaches, but will contain elements of both. For this, with reference to RQ2, categories were worked out in interviews that serve as a basis for decision-making in order to determine which learning opportunity is offered in which variant on the merged

platform. Research on the now emerging merged platform based on the initial results of the surveys will be established across sites in the same study design in the coming semester.

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