Special Issue Paper

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Promotion of self-regulated learning in a digital learning environment with the help of learning transparency

https://doi.org/10.1515/cti-2025-0011
Received January 31, 2025; accepted August 3, 2025; published online September 9, 2025

Abstract: This study examines the relationship between self-regulated learning (SRL) and learning transparency in digital learning environments. Using a digital learning environment on the topic of chemical equilibrium as an example, the study examines how to promote the planning, execution, and self-reflection of learning processes in line with Zimmerman's SRL model by making the learning objectives explicit to secondary school students. The aim is to support learners in SRL within digital learning environments, on the one hand, and with complex chemistry topics, on the other hand, as both pose significant demands on (meta-)cognitive abilities. An initial practicality check with first-year primary school teacher trainees showed that structured learning objectives can help learners organize themselves and assess their own learning. At the same time, potential for optimization was identified concerning the design of the learning environment and its functionality. The results highlight the potential of learning objectives as a central tool for fostering metacognitive, cognitive, and motivational strategies in digital chemistry education. In the next step, the study will be conducted with a larger sample of students to comprehensively evaluate the effects of the learning objectives.

Keywords: self-regulated learning; digital learning environment; learning transparency; chemical equilibrium; learning objectives; ECRICE 2024

1 Introduction

Transparency in the learning process is a theoretical construct that can help learners in applying SRL skills within digital learning environments. The ability to learn in a self-regulated way is considered a key competence in modern society[1] and an important requirement for lifelong learning.[2] To foster these skills, it is essential to support students in developing and applying cognitive, motivational, and metacognitive strategies. However, upper secondary school students often struggle with setting their own goals and maintaining motivation.[3] At the same time, teachers at this level rarely promote SRL.[4]

Two central aspects arise in the context of SRL with digital learning environments: On the one hand, there is the potential to promote SRL through digital learning environments; on the other hand, the learning environment also place high demands on learners.[5,6] One challenge that learners face when using digital learning environments is, for example, to select suitable cognitive or metacognitive strategies.[5–7] In the context of learning with digital learning environments, aspects of time management, effort regulation, or metacognitive strategies (e.g.

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self-monitoring, self-management, planning) are particularly relevant. Therefore, promoting these skills in digital learning environments is important for more effective digital learning.[8–11] In addition to its importance for digital learning, promoting SRL is especially crucial in chemistry education. The content of this subject is often cognitively demanding. Topics such as chemical equilibrium require a high degree of SRL skills.[12] Integrating learning transparency within SRL environments offers an opportunity to provide targeted support to students.[13] To address this problem and support secondary school students in chemistry, a digital learning environment for chemical equilibrium was developed that includes learning objectives, questions for self-reflection and a transparent design (for example, about the sequence of the learning environment). These measures are intended to create transparency in learning in order to make it clear to learners what demands or expectations are placed on them within the learning process, what knowledge is required of them and what the goals are.[13,14]

2 Theoretical background

2.1 Self-regulated learning

Self-regulated learners are able to activate, change and maintain cognitions, affects and behaviors that are designed to achieve their own learning goals.[15–18] The (meta-)cognitive, emotional and motivational dimensions of learning are critical components of SRL.[19] SRL is influenced by a variety of regulatory mechanisms and regulatory judgments, such as self-efficacy, knowledge of cognitive and metacognitive strategies, or the ability to reflect.[19,20] In recent decades, a large number of models of SRL have been developed.[19] Zimmerman's[17,18] model is one of the most important models and is therefore considered the basis for this study due to its processual nature. Zimmerman[17,18] distinguishes between the forethough, performance and self-reflection phases. In the forethough phase, tasks are analyzed, for example by selecting appropriate strategies or setting goals. At the same time, motivational aspects play an important role. The performance phase focuses on metacognitive strategies such as self-monitoring and self-observation. These are used to carry out the planned steps, monitor the learning process and make adjustments when necessary. Finally, in the self-reflection phase, learners evaluate both their goal achievement and overall learning process. This evaluation helps them draw conclusions that can inform future learning endeavors.[17,18] For this reason, it is important that learners acquire knowledge about motivational, metacognitive and cognitive strategies[20] and are also enabled to apply this knowledge in a meaningful way.[21–23] Measures to promote (meta-)cognitive skills, for example, can improve academic performance.[20,24–27] Another way to promote aspects of sSRL (e.g., goal setting, planning, monitoring),[28–32] as well as academic performance, is assessment.[28,33] In this context, the way in which teachers organize the assessment measure is an important factor, but the exact conditions are not yet entirely clear.[21,28,34] SRL has also already been investigated in the context of chemistry lessons. Feldman-Maggor et al.[35] and Feldman-Maggor[36] showed through their research that integrating SRL skills into the classroom is important, for example by giving learners choices. However, teachers should also focus on promoting learning strategies. Additionally, metacognitive support tools can facilitate self-regulated problem-solving in chemistry lessons.[37] The use of multi-touch experiment instructions also has the potential to promote SRL indirectly.[38]

2.2 Transparency of learning

The second theoretical construct is learning transparency. The "Transparency in Learning and Teaching" (TILT) framework provides a helpful foundation for the conceptual categorization of learning transparency. Even before the learning process begins, this framework emphasizes three central steps that are clearly defined by a structured approach and specifically support the processing of tasks:[13]

(1) Learners should know the purpose of the task and be informed about the actual benefit of the task before working on it.

(2) It should be made clear to learners in the task design what they are supposed to do and how they are supposed to do it.
(3) Learners should know the criteria that make a task successful.

The aim of these steps is to support teachers in the design of tasks and to encourage learners on a metacognitive level when working on the tasks.[13] However, not only tasks are important in the context of teaching, for example, communication with the learners also plays a role.

Veenman[39] addresses metacognitive processes with his *WWW&H rule*. In this rule, he emphasizes that it is important that learners are guided and trained to answer the questions '*What* to do *when*, *why* is it necessary and *how* to do it?'. Both approaches, Winkelmes' and Veenman's, offer solutions to the problem that learners often face in school of not using the best strategies in the right places.[2,3,39] Therefore, students should be supported, for example with support programs that focus on metacognitive skills[24,25] even before they work on the tasks.

In order to implement a broad concept of learning transparency, it is also relevant to include aspects of assessment research. Black and William[40] make it clear in their theory of formative assessment that it is important to gain insights into student performance so that the next steps in teaching/learning can be planned. In the context of SRL, however, the focus is particularly on the learners and their own learning process, which can and should be supported by the teachers in the context of formative assessment.[21] By making learning intentions and learning criteria transparent, teachers can ensure that learners take responsibility for their own learning process.[32,40,41] The assumption of responsibility can also be promoted through self-assessment by the learners.[28,42,43] This encourages learners to actively reflect and evaluate their own learning process so that they can better assess the quality of their work.[43] The promotion of these skills is particularly important in the context of SRL.[17,44] On this basis, it is logical to link SRL with formative and self-assessment, as learners can be supported explicitly in the forethough and self-reflection phase and implicitly in the performance phase through transparent learning intentions, learning criteria and self-reflection.

In the concepts presented so far, a direct method for the actual realization of learning transparency has not played a role. Learning objectives are one way of linking all concepts together. Learning objectives are statements that use an operator to communicate the purpose of the lesson, the expected performance and the conditions under which the performance is to be achieved.[14,45–48] Three central aspects are attributed to them:[14,46–48]
– Behavior: Learning objectives should reflect an observable action, be measurable and specific, and have appropriate action verbs.
– Conditions: Learning objectives should describe the circumstances under which learners are expected to demonstrate the behavior.
– Criterion: Learning objectives should specify the benchmark or standard that learners must meet in order to demonstrate acceptable performance.

Orr et al.[14] found that there is much literature on learners perceiving learning objectives as useful for their learning, but there is little literature on their effectiveness on, for example, achievement. Furthermore, the results of studies on learning objectives are inconsistent.[14,49–52] Some studies show that learning objectives that are too specific have lower effects on performance than non-specific ones,[50] while Wirth et al.[52] found no differences in specificity with general learning objectives. Some studies have also found that transparent learning objectives can help learners to better organize their time and effort,[53] but learners may also have difficulties in assessing the expected depth of learning.[54] For this reason, it is even more important that learners receive clear instructions on the use of learning objectives and the benefits of their use.[27,39,51] These results show that learning objectives can be suitable for promoting more effective learning and also aspects of SRL. However, it is clear that it is necessary to make transparent to learners what is expected of them and how learning objectives can be used.

Based on these research approaches, we have developed a definition for transparency of learning to clarify which aspects teachers should consider when planning lessons in order to support learners in initiating, implementing and reflecting on their learning processes:[55]

Learning transparency includes all measures that a teacher can take to design learning situations in such a way that learners know

… why they are learning something and how they can use the knowledge they have acquired to achieve situation-specific goals that go beyond the learning situation.
… what they have to work on and what demands are placed on them.
… how they can adequately assess their own learning achievements.

Compared to existing approaches, the definition of learning transparency presented here goes beyond the previous focus on particular elements, such as task processing[13] and formative assessment.[40] These facets all contribute to metacognitive skills and can promote SRL. Our definition emphasizes a comprehensive, process-oriented approach. This approach integrates task and learning objective transparency, linking them to the overarching goal of enabling learners to actively shape, control, and critically reflect on their learning processes. Thus, the definition provides teachers with a structured guide for incorporating learning transparency as a holistic concept into lesson planning and implementation.

3 Interaction of SRL and learning transparency in digital learning environments

Digital learning environments present a number of challenges for learners. Students often find it difficult to cope with the particular autonomy of such learning environments.[6] A common challenge is the non-linear structure of digital learning environments,[5,56] which often require learners to navigate multiple media formats and complex organizational structures. This complexity demands constant self-monitoring.[56] Additionally, learners must make numerous decisions within such environments, necessitating skills like goal setting and effective coordination of their learning processes.[5,10,56–58] Metacognitive, cognitive and motivational strategies are necessary to deal with these demands.[5,6,10,58] As studies show that learners who are equipped with better SRL skills are also more able to cope with such learning environments. Consequently, SRL is widely regarded as an effective approach to support learning in such contexts.[6,56] The literature identifies two main ways to promote SRL:[6,59,60]

- *Direct support* by integrating measures to teach learners SRL skills strategies through training.
- *Indirect support* by creating a learning environment that requires learners to apply SRL skills that they already know.

Digital learning environments not only place high demands on learners in terms of applying SRL, but conversely, they can also be used to promote SRL.[6] At this point, therefore, we will focus on the indirect promotion of SRL through a digital learning environment. However, it should be noted that studies have shown no or even negative effects when using only indirect support.[60] In order to indirectly promote SRL, it is useful to design a learning environment that includes complex, challenging learning tasks, clear learning objectives and at the same time encourages learners to self-assess.[61] For this reason, we combine the indirect promotion of SRL with the implementation of learning transparency measures in order to meet the challenges and potentials mentioned. We are guided by Zimmerman's[17] process model and combine this with suitable support measures:

- In the forethought phase, learners are made aware of why, what and how they can learn in relation to the task analysis through appropriate measures (for example, learning objectives; explanations of functions). This enables them to decide on relevant strategies and sub-goals.[13] Learners are also encouraged to actively extend their knowledge by applying their prior knowledge. In addition, learners are given transparent learning objectives and criteria.[60]

- In the performance phase, learners are supported in their metacognitive perception of their own learning process (for example, scaffolding or step-by-step exploration of the learning environment). Equally important, learners have the opportunity to navigate the learning environment relatively freely.[60,62] However, learners are also free to decide how fast they work and what level of support they need.[63]
- In the self-reflection phase, learners can check themselves using sample solutions and actively reflect on their learning progress using self-assessment sheets. Learners can then decide whether they need to explore the topic more deeply, for example by choosing more in-depth tasks.

There is already some research on the effects of transparency of learning in the context of SRL. For example, the use of learning objectives or assessment guidelines can be relevant on several levels, as learners can be supported in the forethought phase in organizing their learning and selecting adequate learning strategies.[51,53,64] On the other hand, it can also be useful to use them as a self-assessment tool in the self-reflection phase.[51,53] Most research in this area deals with higher education rather than secondary school students and digital learning environments.[10,65]

4 Research goal and design

The overarching goal of this study is to investigate how SRL can be promoted through learning transparency in digital learning environments. To this end, we have developed a digital learning environment for secondary school students that contains transparent learning objectives. Before the learning environment can be evaluated quantitatively and qualitatively in the pilot and main study, the materials must first be tested in a practical check. During the practicality check, we address the following questions:

Q1: How do learners use the learning environment, the functions of the learning environment, the learning objectives and the self-assessment?

Q2: How do learners evaluate the learning environment, the functions of the learning environment, the learning objectives and the self-assessment?

The practicality check was carried out with first-year primary school teacher trainees. These students were chosen because they are similar to 11th grade school students in terms of age and prior knowledge and can therefore be used to determine whether the learning objectives and support measures in the learning environment are helpful. The primary school teacher trainees worked on a part of the learning environment for 60 min. Their work on the tablets was recorded using screen capture software. Finally, the students were interviewed to gain a more detailed insight into their attitude toward the presented approach.

Before presenting the results, the learning environment will be described below.

5 The digital learning environment

5.1 Structure and content

The basis for the indirect promotion of SRL is a digital learning environment on chemical equilibrium. The digital learning environment was created using *genially*.[66] The environment is organized into three different modules, each with the same structure but different content. The first module focuses on chemical equilibrium and the law of mass action, the second module focuses on Le Chatelier's principle and the last module focuses on applying what has been learnt in the context of the environment and industry.

In addition, there will be three different treatment groups (Figure 1). Students will either receive learning objectives at the beginning and at the end (G1), only at the beginning (G2) or none at all (G3).

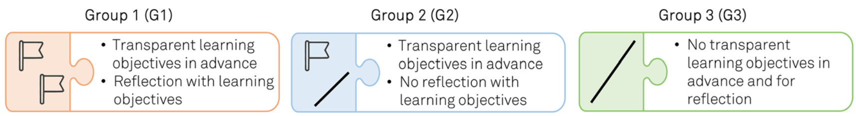

Figure 1: Overview of the groups.

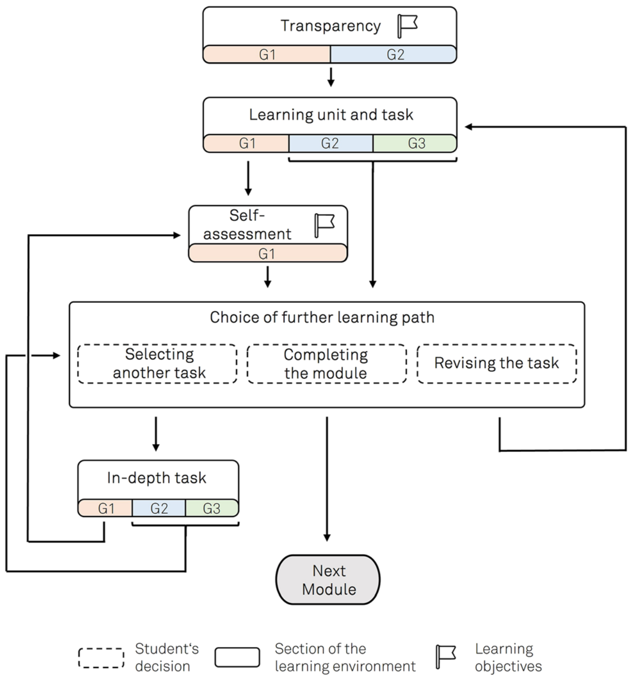

Figure 2: Procedure of the digital learning environment.

Figure 2 shows the process of the digital learning environment for each module. First, all groups receive an explanation of how the learning environment works. Two groups (G1 and G2) are then given learning objectives to help them plan their learning process before working on the tasks. G3 does not receive any further support before they complete the tasks. This is followed by the learning unit using text, experimental videos and models (see Figure 3 for an example). At the same time, the learners should apply the acquired knowledge with the help of learning tasks. After the learners in G 1 have worked through all the learning units and tasks and compared their solutions with the sample solution, they carry out a self-assessment based on the learning objectives. The learners can then decide whether to repeat the tasks, choose more in-depth tasks or move on to the next module. In the next module, the cycle starts all over again. The aim of this modularization, in addition to the division into parts, is to find out whether the learners in the learning environment approach the topics differently in the course of their learning process and therefore apply different learning strategies.

Figure 3 gives an insight into an example page of the digital learning environment. At the beginning, the learners are given the learning objective and are then asked to click through the learning environment step by step. Several experiment videos and a model are integrated on this page. Additional explanations of specialist terms are provided in some places. At the end, learners are given a learning task to apply the knowledge they have acquired on this page. The aim is to provide a clearly structured learning environment that also offers enough freedom to make independent decisions.

5.2 Formulating of transparent learning objectives

It can be assumed that the use of learning objectives is an effective way to implement learning transparency in the classroom while promoting SRL in the context of digital learning. Orr et al.[67] rightly point out that it is not yet clear

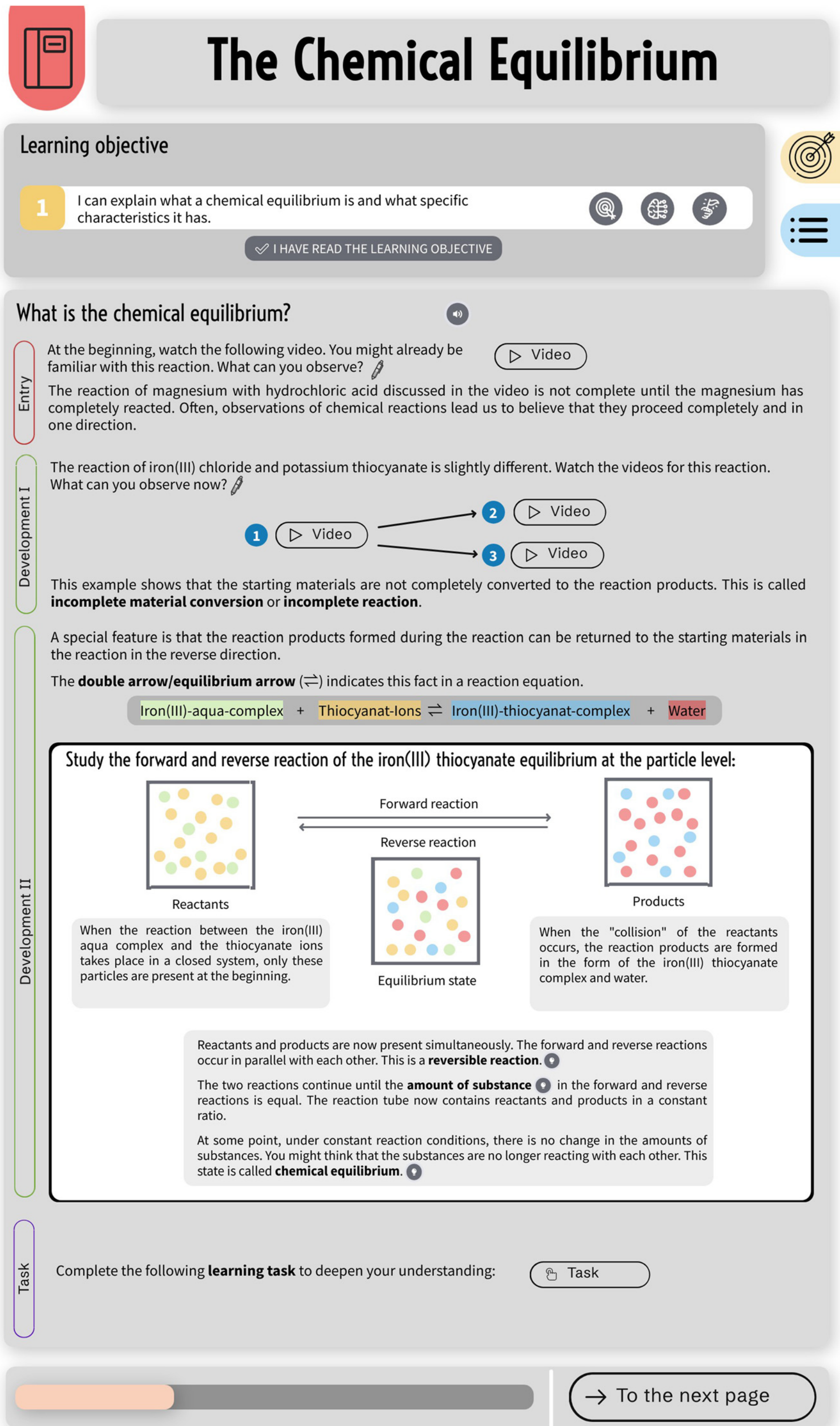

Figure 3: Example page for chemical equilibrium.

how teachers can help their students to better understand their performance, the conditions and criteria of learning objectives to enable effective learning. For this reason, we present an approach that makes learning objectives transparent to help secondary school students understand them.

When formulating transparent learning objectives, we focus on the three central attributes (behavior, condition and criterion) of learning objectives. In addition, suggestions for the formulation of learning objectives are made in the literature. Accordingly, learning objectives should be adapted to the students' prior knowledge,[68]

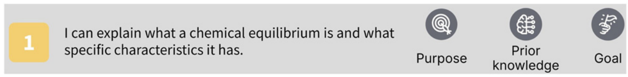

Figure 4: Structure of the learning objective with icons for purpose, prior knowledge and goal.

be clear, understandable and concrete[14,68,69] and clarify the purpose of the learning objective.[51,64] However, they should also have a clearly describable, observable behaviour,[14,47,70] clear actionverbs[14,45] and be linked to tasks.[47] Last but not least, it is important that they are realistic, challenging[47,71] and measurable,[47,48,69] make the time limits transparent[69] and are universally accessible.[47,71]

Our approach attempts to include these components in order to support learners in understanding the learning objectives. The example in Figure 4 illustrates how this approach is structured.

At the centre of the approach is the learning objective, which relates to a thematic focus in the learning environment and can therefore be linked to explicit tasks. In this example it is:

> *"I can explain what a chemical equilibrium is and what specific characteristics it has."*

This learning objective covers the understanding of chemical equilibrium and the characteristics behind it. Learners should be able to explain these aspects after they worked in the learning environment. Our aim was to make the objective as understandable, clear, and concrete as possible. However, we suppose that this was not enough for learners to really understand what is expected of them, especially if they have never had the topic before. At this point, we thought it was important to give the learners additional explanations. The first thing we did was to add the purpose component:

> *"Expand your knowledge of chemical reactions here."*

With these measures, we wanted to address the learners directly and clarify the purpose of this knowledge and the context in which it is needed. Secondly, we focused on linking the learning objective to the students' prior knowledge:

> *"So far, you can explain that chemical reactions have certain characteristics (for example, that chemical reactions are associated with energy conversion). Chemical equilibriums also have specific characteristics."*

In this case, this refers explicitly to the content of chemistry lessons, but to some extent we also make references to mathematics lessons. Here, all learners have already dealt with chemical reactions and know that chemical reactions have specific characteristics. Our aim is to break down barriers by helping learners to remember what they already know and plan their learning at the same time. Finally, we wanted to give them a goal to work towards:

> *"At the end of this module, you will be able to explain why this is a chemical equilibrium based on the reaction shown."*

In this example, learners are shown a video of a chemical reaction that illustrates the influence of a chemical equilibrium. Here, learners are given a time frame ("At the end of this module") and prepared for what to expect so they can choose appropriate learning strategies. At the beginning of each module, but also in parallel with the completion of the tasks, learners are given these learning objectives.

6 Checking the practicality

The sample group for the practicality check comprises three female university students. The first results are presented below. In this context, the two research questions Q1 and Q2 are answered. Because the sample size is small, the results should be treated with caution. Nevertheless, the findings offer valuable insights into the practical suitability of the learning environment and how well it is accepted by students.

a) Screen recordings

The screen recordings provided a more detailed insight into the use of the learning environment (Q1) to understand which of the implemented features were actually being used. The students needed about 60 min each to complete the first module. With this in mind, it seems reasonable for us to plan around 90 min per module in the pilot study, as not all tasks were fully completed by the students.

The data indicate that students accessed all the basic pages of the learning environment; however, only one student attempted the more in-depth tasks. The student completed one of the three tasks completely, one partially and the third not at all. In the context of SRL, this demonstrates that the student may have worked on the tasks according to her individual needs. In particular, the in-depth task was carried out with great care. Furthermore, we could see that all the students made full use of the presented approach and not only read the four learning objectives, but also looked at the purpose, prior knowledge and goal aspects. However, we suppose that these aspects were still not emphasized enough, especially for secondary school students. We therefore decided that learners could only move on to the next learning objective if they had read all three aspects.

Some of the tasks, such as the observation tasks for the implemented experiment videos and the task of adjusting the chemical equilibrium, were completed correctly and thoroughly by all students. This suggests that the content is suitable for the pilot study. However, the tasks for calculating the equilibrium constants require revision, because none of the students completed them correctly and in full. Based on the video recordings, it can be concluded that the students had difficulty working through the task. Additional support elements and minor changes to the task design will therefore be implemented for the pilot study.

Certain features demonstrated higher levels of usage than others. However, the implemented help for individual technical terms was used regularly by all students, whereas the buttons for the outline and learning objectives of the module were not used by any of the students. It would therefore seem sensible to review the frequency of use of these features in the pilot study to avoid an overload of features. Some tip cards also need to be revised because they were used by learners but aren't providing as much support as hoped. The option to use the results with the sample solution was also used only sporadically. For this reason, the relevance of using the sample solution should be emphasized more strongly in the pilot study.

Finally, self-assessment questions at the end of each module were completed in full by all learners. Two students reported achieving two of the four learning objectives. One student reported not achieving any of the learning objectives. All students agreed that they had difficulty understanding the content related to the law of mass action and the equilibrium constant. The analysis of the screen recording confirms this self-assessment. First, it is encouraging that all students used the self-assessment, and that our analysis and the students' self-assessments are consistent. Based on these findings, no changes are necessary for the subsequent pilot study.

The screen recordings provided a more detailed insight into the students' approach than interviews or completed tasks alone would have. Based on this, it is possible to provide an answer to the first research question, as the students basically used the learning environment as expected. At the same time, the functions used appear to be useful, though minor changes are necessary for more effective learning. The extensive and sensible use of learning objectives and self-assessments is positive. However, it remains to be seen how effective these measures are.

b) Interviews

The interviews provided a more focused understanding of learners' attitudes towards the digital learning environment (Q2). Learners particularly praised the structure and presentation of the learning environment ("I thought it was very well prepared. Everything was easy to read and it was well-structured. I liked that very much."). They appreciated that it was consistently clear "what I have to be able to do at the end". At the same time, learners highlighted the usefulness of the help cards, which they only needed at the end of the module. They said that they were helpful because "you could look at them if you weren't quite sure". It also seems to make sense to emphasize the tasks more when introducing them, as one of the students stated that she had problems with this. On the other hand, everything worked on a technical level. This is a good basis, given the complexity of the digital learning environment. As observed in the screen recordings and confirmed during interviews, some features were not utilized by students. For example, learners stated that they did not need the outline button in the learning environment ("I think I pressed that at the end for the demanding tasks. I didn't need that."). Due to the small sample size, we will wait for the results of the pilot study before making any modifications to the features.

Learners found the learning objectives themselves clear and comprehensible and appreciated their structured design, as it clarified what was expected of them. One student found the three-part structure of the learning objectives helpful, because it showed how they built on each other. This structure also showed her that she needed to understand one objective before moving to the next. Another student said that she understood better what was expected of her because of the three-part structure ("The first learning objective seemed easy at first, but then I saw it again with the second learning objective and thought, 'Okay, you really have to make sure that you check that.' I thought that was quite good."). However, two learners noted that the procedure for working with the learning objectives was not entirely clear at the beginning of the module. They remarked that these objectives did not significantly impact their approach to work ("I just paid more attention to the fact that this is important right now. I didn't plan in advance that this is exactly what I have to do now."). For this reason, we will do even more to explain how the learning objectives are structured (purpose, prior knowledge, goals) and how they work so that learners can actually utilize them to their full potential. In addition, one learner stated that they would prefer more learning objectives within university courses, "because then I can see what we've covered, mark it as complete, and that helps me." Another student added that having more learning objectives helps them "categorize the content more quickly and have a better overview, which makes it a bit more networked".

Regarding the self-assessment, the learners stated that they would like to have a third button and not just 'I have achieved' and 'I have not yet achieved' ("Well, it helped me, but I would have liked to have had another button in the middle."). Another student replied, however, that she believed that if a third button were added, many children would be more likely to say, 'Yes, I'm in the middle.' We will not pursue this idea in the pilot study as we are concerned that learners will only use the middle option. So, it seems reasonable to us to wait for the pilot study. However, the learners also said that the self-assessment helped them to assess their knowledge better, as they were "honest with themselves." One student added that the self-assessment made her realize that she needs to take a closer look at the math problems. Finally, the learners stated that they would like to have more of these digital learning environments in the classroom as they were able to learn at their own pace and revisit some of the content several times. One student said that this had helped her in school, as all her chemistry lessons had been frontal, which she found boring and did not learn much from ("I think something like that would have given me a different approach. So, hey, you really can't do it now, or I can do it, and I want to do it again.").

The interviews made it possible to gain learners' impressions of the digital learning environment and the implemented functions. This made it possible to provide an answer to Q2. It became clear that the learners were satisfied overall and that the learning objectives and self-assessment in particular were perceived as positive by the learners. However, it also became clear that individual functions in the learning environment are not even necessary and may only overload the learning environment.

7 Conclusion and outlook

Within this paper, our aim was to show learning transparency as a way to indirectly promote SRL in a digital learning environment. Furthermore, with our approach to transparent learning objectives, we want to offer a possible answer to the question of how teachers can better clarify the performance, the conditions and criteria of learning objectives to their students.[64]

In this first practicality check, with primary school teacher trainees, of the learning environment and the presented approach to learning transparency, we were able to gain helpful insights into the use and evaluation of the digital learning environment. Initial results from the practicality check with teacher trainees highlight that learning objectives can effectively support learners' organization and self-assessment. For example, learners found the learning objectives helpful in organizing their learning and were better able to assess whether they had learned something through the self-assessment measures. These points show that the implementation of learning objectives as part of the forethought and self-reflection phase can be a useful way of stimulating processes of SRL.

At the same time, opportunities for improvement in the design and functionality of the digital learning environment were identified. The learning environment will be slightly revised before piloting in schools: The learning objectives themselves have proven to be understandable and helpful, but it should be made even clearer at the beginning of the learning environment how to work with them. Due to the low usage of the sample solution, it makes sense to better emphasize the positive aspects. On the other hand, we have decided not to remove some functions, which have little use by students, such as the outline button. We will wait for the pilot study in secondary schools and then decide whether to remove them. However, we will make small changes to the learning environment to better support learners. For example, we will provide additional support when working on math problems to help learners understand how to complete a task.

It is important to note that in the context of this check, only the first module and only one treatment group was tested. For this reason, the use of the second and third modules in particular needs to be examined in more detail as part of the pilot study. The next step is a pilot study with around 60 students. Our aim here is to examine the use of the learning objectives and how the learning environment works in detail with the help of screen recordings. In addition, the developed and used test instruments will be implemented for the first time and possibly optimized.

This will be followed by a larger main study. This study will examine how the learning objectives affect content knowledge, cognitive load and the use of SRL strategies. In addition, screen recordings will be made of the individual actions of the students on the tablets.

Acknowledgments: We would like to thank the students who participated in the practicality test.
Research ethics: Not applicable.
Informed consent: The students provided written informed consent to participate in this study. They were given important information about the project, data protection, data security and further processing of the data. Participation in the study was voluntary for the students. There were no disadvantages for non-participation.
Author contributions: NB: Conceptualization, Data curation, Investigation, Methodology, Project administration, Software, Visualization, Writing – original draft, IM: Conceptualization, Methodology, Project administration, Resources, Supervision, Writing – original draft. All authors have accepted responsibility for the entire content of this manuscript and approved its submission.
Use of Large Language Models, AI and Machine Learning Tools: The authors acknowledge the use of OpenAI's generative AI technologies ChatGPT 4o, DeepL and DeepL Write for some translations.
Conflict of interest: The authors state no conflict of interest.
Research funding: None declared.
Data availability: The datasets presented in this article are not readily available because in the context of the written consent form, we assured the students that their data will only be stored on devices belonging to our university. Hence, we are not permitted to disclose the data publicly. Requests to access the datasets should be directed to IM.

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