# Effects of e-learning formats on student teachers' knowledge and attitude towards evidence-based instruction

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## Abstract

University teacher education aims at developing sustained knowledge and positive attitudes towards evidence-based instructional concepts. This experimental study examined (a) if two e-learning formats help develop sustained knowledge and positive attitudes towards evidence-based reading instruction, (b) if self-regulative principles can boost these effects, and (c) if effects are moderated by learner characteristics (namely prior knowledge, self-efficacy, learning preferences). 100 student teachers participated in one of two different e-learning formats on evidence-based reading instruction. While one group attended an e-learning course with self-regulative elements (adaptivity and feedback), the other group watched an e-lecture without these self-regulative elements. In both groups, participants showed positive attitudes and mastery of declarative knowledge, as the majority reached a minimum of 80% in criterion-oriented tests. However, participants' procedural knowledge was less pronounced. A MANOVA showed no significant group differences between the e-learning course with self-regulative elements and the e-lecture without self-regulative elements with regard to knowledge and attitude acquisition. Path analyses displayed that individual learner characteristics (prior knowledge, self-efficacy, learning preferences) had an impact on attitudes, but not on knowledge acquisition. Implications for university education are discussed in the context of combining e-learning formats with face-to-face courses to also achieve mastery of procedural knowledge and to strengthen the effect of self-regulative elements.

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# Introduction

Research-based university education is considered the cornerstone for developing students' professional competencies, particularly for student teachers (Darling-Hammond et al., 2017). To develop necessary competencies like sustained knowledge and positive attitudes towards evidence-based concepts, e-learning formats are increasingly coming into focus as a flexible and individualised form of university education (Dede et al., 2016; Elliot, 2017). However, to date, it has rarely been evaluated whether e-learning formats meet key academic learning goals. When developing scientifically sound e-learning formats, incorporating self-regulative elements may be particularly effective (e.g., Cavalcanti et al., 2021). For this experimental study, two different formats of e-learning tools on evidence-based reading instruction were developed for student teachers: (1) an e-lecture, and (2) an e-learning course with identical structure and content, which additionally allowed for self-paced learning and provided automated feedback (Fig. 1). A first goal was to examine whether participants developed mastery in specified academic learning goals (i.e., sustained knowledge and favourable attitudes towards evidence-based reading instruction). As research on self-regulation has already yielded information on adaptivity and feedback as potential effective learning principles (e.g. Cavalcanti et al., 2021), a second goal was to investigate whether self-regulative principles can further boost these effects. Moreover, individual learner characteristics may influence the achievement of learning goals (e.g., Sitzmann & Ely, 2011). A third goal was therefore to investigate moderating effects of participants' prior knowledge, self-efficacy and learning preferences. In this way, the strengths and limitations of e-learning formats in university teacher education will be assessed.

**Figure 1**

*Framework for studying the effects of e-learning formats on students' knowledge and attitudes*
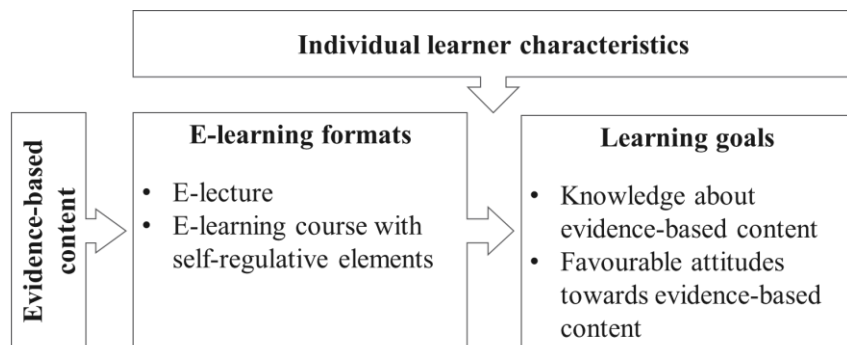


# Literature

### Learning goals in university teacher education

Acquiring evidence-based content is a key goal of higher education, and particularly important for student teachers, as it provides the basis for effective teaching practices (Darling-Hammond et al., 2017). Research-based teacher education thereby should address specific knowledge of core concepts as well as develop positive attitudes towards effective innovations (Baumert & Kunter, 2011). The competency "knowledge" covers declarative and procedural knowledge, while positive attitudes may include approving of evidence-based content (acceptability) and being ready to

implement the content in practice (adoption) (Proctor et al., 2011). Helping student teachers develop sustained knowledge and favourable attitudes towards evidence-based content is indeed beneficial for their future profession, as teachers with high knowledge typically reach higher levels of teaching quality (Depaepe & König, 2018) and of student learning (Agathangelou et al. 2016). For future teachers of reading, for instance, learning contents may focus on evidence-based reading methods such as repeated reading and reciprocal teaching and their theoretical foundations (Palincsar & Brown, 1984; Therrien, 2004). Similarly, teachers with positive attitudes towards evidence-based concepts implement evidence-based innovations more often (Lakin & Shannon, 2015). A pressing challenge for university teacher education is thus to develop effective learning formats so that student teachers attain mastery of the competencies knowledge and attitudes.

**Designing effective e-learning formats (with self-regulative principles)**

E-learning formats have the advantage that students can learn independent of time and place and that learning processes can be easily adapted to individual needs (Dede et al., 2016; Elliott, 2017). Even though students as well as teaching staff believe that e-learning can help improve academic learning (Maatuk et al., 2022), previous e-learning formats have rarely been evaluated in terms of whether they contribute to achieving set learning standards (i.e., declarative and procedural knowledge, positive attitudes). When designing e-learning formats, self-regulative principles represent a particularly promising approach to optimising effectiveness (Jansen et al., 2020; Sitzmann & Ely, 2011). In e-learning environments, when students' learning processes are less regulated by the teacher, self-regulative principles can help students to monitor their own learning (Jansen et al., 2020). Indeed, first intervention studies showed that students' overall performance as well as course completion can be improved if they are encouraged to engage with self-regulative principles (Jansen et al., 2020; Yeomans & Reich, 2017). Self-regulative principles can, for instance, include adaptivity and feedback. Advantages of adaptivity, i.e., allowing learners to determine their own learning pace and to omit or read up on selected content more intensively, are well documented (e.g., Kühl et al., 2014). Moreover, positive effects of multiple-try (Attali, 2015) and automated feedback (Cavalcanti et al., 2021) on knowledge acquisition have been frequently reported. Including elements of adaptivity and feedback might therefore additionally be beneficial to achieve learning goals in e-learning formats. To date, however, a recent systematic review displayed that studies rarely describe how self-regulative principles can be practically applied to e-learning formats (Lai & Hwang, 2023).

**Individual learner characteristics as potential moderators**

Individual learner characteristics may further help explain learning achievements (Sitzmann & Ely, 2011). For instance, prior knowledge of the subject matter is generally associated with higher learning gains (Zambrano et al., 2019). Following cognitive load theory (Sweller et al., 1998), individuals with high prior knowledge have more cognitive resources available to retain new content. In self-regulative learning arrangements, they should perform particularly well because they are able to allocate their resources more effectively. High levels of prior knowledge might further go along with effects of recognition and thus more positive attitudes. Similarly, self-efficacy beliefs are associated with increased knowledge (Sitzmann & Ely, 2011), and with positive attitudes towards the subject matter (Donnell & Gettinger, 2015). Self-regulative learning

environments invite individuals to experience their self-efficacy, which should lead to more positive attitudes and also to enhanced knowledge via its effect on persistence (Bandura, 1977). Finally, individual learning preferences for self-regulative learning arrangements are singled out as a third moderator, as training effects depend on whether the received training fits an individual's learning preferences ('aptitude-treatment-interaction theory'; Seufert et al., 2009).

### Research questions

This study investigates the effects of two e-learning formats (e-lecture, e-learning course) on academic learning goals (declarative and procedural knowledge acquisition, acceptability and adoption of evidence-based content). Our research questions are:

1. Do the developed e-learning formats help achieve academic learning goals?

Hypothesis: Both e-learning formats produce high levels of declarative and procedural knowledge as well as of acceptability and adoption. A minimum of 80% mastery in criterion-oriented tests is used as a benchmark.

2. Do elements of self-regulative learning (adaptivity, feedback) have an additional effect on knowledge and attitudes?

Hypothesis: It is expected that the self-regulative approach leads to higher knowledge acquisition and more positive attitudes.

3. Do individual learner characteristics moderate the effects on knowledge and attitudes?

Hypotheses: The higher the prior knowledge and self-efficacy, the greater the positive effects, especially of the condition with self-regulative elements. Greater positive effects are expected when individual learning preferences match the condition.

# Method

### Sample

Our sample consisted of $n = 100$ student teachers ($M_{Age} = 22.49$, $SD_{Age} = 3.31$, 83% female) of which the majority (70%) were in the bachelor's program. Participants were rewarded with 15 euro.

### Study design and material

The study was conducted as an experiment with two conditions. First, participants completed an online pre-test. Based on these results, participants were assigned to one of two groups using a pair-matching procedure (Hsu, 1989). This was done to ensure that participants did not differ by chance on the covariates prior knowledge, self-efficacy and learning preferences despite randomized assignment. Pair-matching is based on a distance matrix and matches two participants that are similar with respect to the given covariates. One person of the pair is then randomly assigned to one group and the other person to the other group. It could not be ensured that both persons of a matched pair actually participated in the intervention (e.g., due to illness). 54 participants completed the pre-test, but then dropped out (drop-out rate: 35.1%). However, the

procedure was successful: the participants of both groups did not differ with respect to the covariates included, $F(4,95) = 0.42$, $p = .797$.

The actual e-learning opportunity took place at university to ensure experimentally controlled conditions. First, all participants watched a video with basic preliminary information on children's reading development. They then participated in one of two learning formats. In the first group (EG1, $n = 47$), participants watched an e-lecture in a video format. The video consisted of designed PowerPoint slides, which were organised in a series of units and narrated by this study's author. The second group (EG2, $n = 53$) completed an ILIAS-based e-learning course in which they clicked through the same series of units. All participants worked individually on laptops and with headphones and were not allowed to take notes. After that, they completed an online post-test. The study material is documented in the OSF (https://osf.io/zrv54/).

Data collection followed ethical standards. Prior to the study, participants were informed that data would be collected and analyzed pseudonymously and that no inferences could be drawn about individuals. Participants provided informed consent to this. At the end of the study, participants were informed about the study's aim and were given the opportunity to view the results.

### Description of the learning content

Both the e-lecture and the e-learning course aimed at preparing student teachers for the implementation of a differentiated, assessment-based reading intervention. The intervention is called "The Reading Sportsperson" (Kawohl, 2015). Based on diagnostic information about students' reading skills, teachers can choose between the three evidence-based methods of syllable-based reading, repeated reading, and reciprocal teaching (Müller et al., 2020; Palincsar & Brown, 1984; Therrien, 2004). The learning units addressed conceptual knowledge (facets of reading literacy, evidence-based reading methods) as well as practice-oriented knowledge on the implementation of "The Reading Sportsperson" in the classroom.

### Similarities of the formats

In addition to the identical content that was imparted, both e-learning formats shared the same structure: Starting with an advance organizer, each chapter included information on the goals and principles as well as explanations on the implementation of each method. Each chapter ended with a summary. Participants were encouraged to actively think about the presented content, for instance by reflecting upon which method works best for which students. Further, both e-learning formats included explanatory videos on the implementation of each reading method.

### Differences between the formats

We manipulated two self-regulative elements: (1) Participants in the e-learning course could self-determine the pace in which they clicked through the units (with an overall guideline of approx. 45 minutes), while participants in the e-lecture followed the learning pace given by the speaker (37 minutes) and could not pause in between or rewind sequences. (2) In the e-learning course, participants were given a total of six opportunities to test their understanding of the different units, e.g., by drag-and-drop tasks, and instantly received automated, multiple-try feedback on the correctness of their answer. In the e-lecture, participants were presented with the same tasks, but

the speaker immediately demonstrated a sample solution without individual task solving and feedback.

## Measures

Moderator variables were collected online in a pre-test before the intervention. In a post-test immediately after the intervention, we assessed the dependent variables (i.e., declarative and procedural knowledge, acceptability, adoption). To assess the learning goals of declarative and procedural knowledge, we first specified the content that needs to be learned. For all relevant content areas (e.g., established concepts of reading development, procedures of reading methods), we then developed subject-specific test items. In that way, we followed Carroll's (1970) recommendations by developing criterion-referenced tests to achieve high content validity. An overview of all instruments is provided in Table 1. Full questionnaires can be found in the OSF. Self-efficacy, acceptability and adoption were rated on a six-point Likert scale ranging from 1 = "does not apply at all" to 6 = "applies completely". Each participant's score for prior, declarative, and procedural knowledge was calculated using a rating guide. For the true-false items (prior and declarative knowledge), one point per item could be obtained. For the open questions (prior and procedural knowledge) a sample solution was prepared. For prior knowledge, one-word answers were required and checked for. For procedural knowledge, the required answer was divided into sub-answers and the number of points per sub-answer was specified (e.g., 1 point per sub-answer, 0 points if the sub-answers were in the wrong order). Ratings were given by two independent observers. In case of inconsistency, they agreed on a joint rating. After evaluating test results, an α-optimization was conducted.

To additionally control for potential differences in the perception of the learning formats' design, we asked participants to evaluate the learning formats (Peter et al., 2015) and assessed the cognitive load they produced according to Klepsch et al. (2017). While both formats were evaluated positively and produced moderate intrinsic and germane, but low extrinsic cognitive load, no significant differences between the e-learning formats were shown.

## Statistical analyses

For research question 1, we set 80% of the maximum score of all dependent variables as a criterion for achieving satisfactory mastery performance, which is in line with recommendations from previous research (Carroll, 1970). In the results, we provide the percentage of participants who reached the stated mastery level.

For research question 2, we conducted a MANOVA with the factor "condition" (e-lecture vs. e-learning course) as the independent variable and declarative knowledge, procedural knowledge, acceptability, and adoption as dependent variables. Although values were not normally distributed across all dependent variables (Shapiro-Wilk-test p-value < .05), a MANOVA was conducted due to the balanced sampling ratio and robustness against violated assumptions (Finch, 2005).

**Table 1**

*Overview of instruments*

| | Item example | α | No. of items |
|---|---|---|---|
| **Moderator variables (pre-test)** | | | |
| Prior knowledge (self-developed test) * | *True-false items*: Children can only read silently at first before they can read aloud.<br>*Open questions*: What is phonological awareness? | .67 | 16 |
| Self-efficacy towards learning (Pintrich & De Groot, 1990) | I am confident I can understand the basic concepts taught in this course. | .74 | 5 |
| Learning preference for adaptivity (self-developed) | *Scale with two extremes*: I like to self-determine my learning time. vs. I like when learning times are given. | - | 1 |
| Learning preference for feedback (self-developed) | *Scale with two extremes*: I find it helpful to complete a task alone first and receive individual feedback after. vs. I find it helpful to receive an explanation of a sample solution. | - | 1 |
| **Dependent variables (post-test)** | | | |
| Declarative knowledge (self-developed test) * | *True-false items*: [A child who] hardly makes any reading mistakes, but still reads very slowly and haltingly should […] use methods for reading aloud. | .67 | 26 |
| Procedural knowledge (self-developed test) * | *Open questions*: Layla and Imran are working on their reading comprehension with the reading canoe. Explain in bullet points to Layla and Imran what their respective tasks are. | .67 | 14 |
| Acceptability (Meudt et al., 2020) | I like the approach of the Reading Sportsperson. | .86 | 5 |
| Adoption (self-developed) | I would be willing to use the Reading Sportsperson regularly in class. | .78 | 4 |

For research question 3, two separate path models were estimated in R (R Core Team, 2022) using the *lavaan*-package (Rosseel, 2012). In path model 1, declarative and procedural knowledge were treated as dependent variables; in path model 2, acceptability and adoption were treated as dependent variables. In both models, prior knowledge, self-efficacy, and individual learning preferences for both adaptivity and feedback were modelled as moderators. The unrestricted models, in which the interaction terms of group and moderators were freely estimated, were compared via a $\chi^2$-difference test with the restricted models, in which the interaction terms were fixed at zero. The interactions between group and learning preferences for adaptivity and feedback were always freely estimated because the fit between learning preference and condition was of interest. We applied robust maximum likelihood estimation. The treatment

variables were modelled as dummy-coded variables with the e-lecture representing the reference category (0 = EG1, e-lecture; 1 = EG2, e-learning course). All variables were $z$-standardised. One-tailed tests were used for all analyses since directional hypotheses were formulated. For group comparisons, we provide Cohen's $d$ (Cohen, 1988; conventions: small: $d = 0.2$, moderate: $d = 0.5$, large: $d = 0.8$).

# Results

Means, standard deviations and the percentage of participants who achieved mastery (i.e., 80% of the maximum score) are presented for all dependent variables in Table 2.

**Table 2**

*Means, standard deviations and percentage of achieved mastery level for all dependent variables*

| | e-lecture (EG1, $n = 47$) | | | e-learning course (EG2, $n = 53$) | | | group comparison |
|---|---|---|---|---|---|---|---|
| | *M* | *SD* | %mastery | *M* | *SD* | %mastery | Cohen's *d* |
| Declarative Knowledge | 23.49 | 2.86 | 91.5 | 23.43 | 2.05 | 88.7 | 0.02 |
| Procedural Knowledge | 8.70 | 2.75 | 21.3 | 8.85 | 2.17 | 20.8 | -0.06 |
| Acceptability | 5.50 | 0.58 | 93.6 | 5.60 | 0.47 | 94.3 | -0.18 |
| Adoption | 5.13 | 0.73 | 70.2 | 5.27 | 0.61 | 73.6 | -0.21 |

*Note.* EG1 (e-lecture) = 0, EG2 (e-learning course) = 1. Declarative knowledge: max. 26 points, procedural knowledge: max. 14 points, acceptability and adoption: Likert 1-6.

Concerning research question 1, a substantial proportion of participants achieved mastery in the declarative knowledge test and in acceptability of the content (>90%). High, but slightly lower mastery scores were also achieved for adoption. In the procedural knowledge test, only one fifth of the students reached the stated mastery level. For research question 2, results of the MANOVA revealed no significant differences between the groups on all dependent variables, $F(4, 95) = 0.30$, $p = .438$, partial $\eta^2 = 0.01$, Wilk's $\Lambda = 0.99$. On a descriptive level, mean values were slightly higher for the e-lecture concerning declarative knowledge ($d = 0.02$; Table 2). For all other dependent variables, effects were slightly higher for the e-learning course with small effects for both attitudes (procedural knowledge: $d = -0.06$; acceptability: $d = -0.18$; adoption: $d = -0.21$).

Regarding research question 3, we estimated two separate path models (model 1: declarative and procedural knowledge as dependent variables; model 2: acceptability and adoption as dependent variables). For both models, the $\chi^2$-difference test was not significant (model 1: $\chi^2(4) = 1.17$, $p = .884$; model 2: $\chi^2(4) = 0.38$, $p = .984$). Thus, the parsimonious, restricted models are displayed here. Results of the unrestricted models are provided in the supplemental material. Both proposed models displayed excellent model fit (model 1: $\chi^2(4) = 1.17$, RMSEA = 0.00, SRMR = 0.01, CFI = 1.00, TLI = 3.01; model 2: $\chi^2(4) = 0.38$, RMSEA = 0.00, SRMR = 0.00, CFI = 1.00, TLI = 1.30). Regarding declarative and procedural knowledge (model 1), treatment effects were not moderated by the selected characteristics and we only found small effects (see Figure 2). In this model, the explained variance for declarative knowledge was $R^2 = 0.03$ and for procedural knowledge $R^2 = 0.04$. For attitudes (model 2, see Figure 3), treatment effects were partly

moderated by the selected characteristics. Self-efficacy was positively related to both acceptability ($\beta$ = 0.19, $p$ = .011) and adoption ($\beta$ = 0.21, $p$ = .009). The higher the level of prior knowledge, the higher the acceptability ($\beta$ = 0.15, $p$ = .042) and adoption ($\beta$ = 0.20, $p$ = .025). Regarding the interaction effects, we report $\beta$ as an estimate for the effect in EG1 (e-lecture) as well as $\beta_{Int}$ as an estimate for the difference between the effects in both groups. The effect in EG2 (e-learning course) can thus be calculated by adding both coefficients. For adaptivity, interaction effects are in line with our hypotheses: Having a high preference for adaptive learning, but watching the e-lecture, leads to negative effects on acceptability ($\beta$ = -0.27, $p$ = .012) and adoption ($\beta$ = -0.33, $p$ = .005). Congruently, participating in the e-learning course, has a significant, positive effect on adoption compared to the e-lecture ($\beta_{Int}$ = 0.41, $p$ = .008). The interaction effect for acceptability is positive, but not significant ($\beta_{Int}$ = 0.22, $p$ = .094). Concerning feedback, results were incongruent with our hypotheses. Having a high preference for feedback has a positive effect on adoption when watching the e-lecture ($\beta$ = 0.32, $p$ = .018), but the effect decreases when taking the e-learning course ($\beta_{Int}$ = -0.44, $p$ = .012). In this model, the explained variance for acceptability was $R^2$ = 0.12 and for adoption $R^2$ = 0.16.
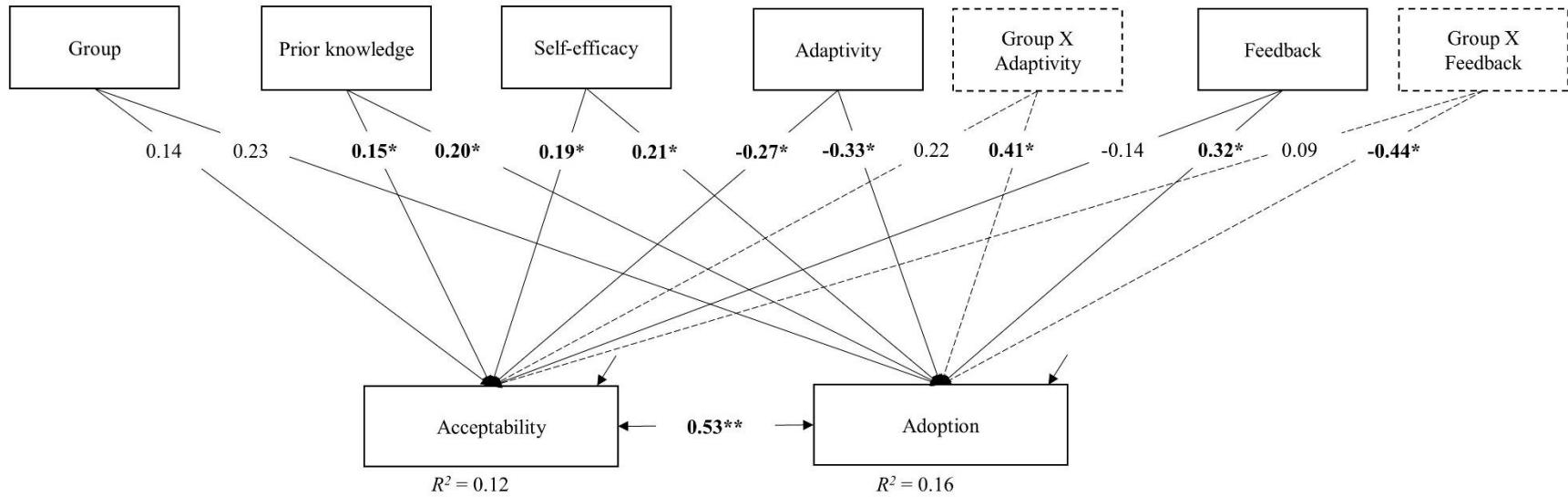
**Figure 2**

*Path model for declarative and procedural knowledge*
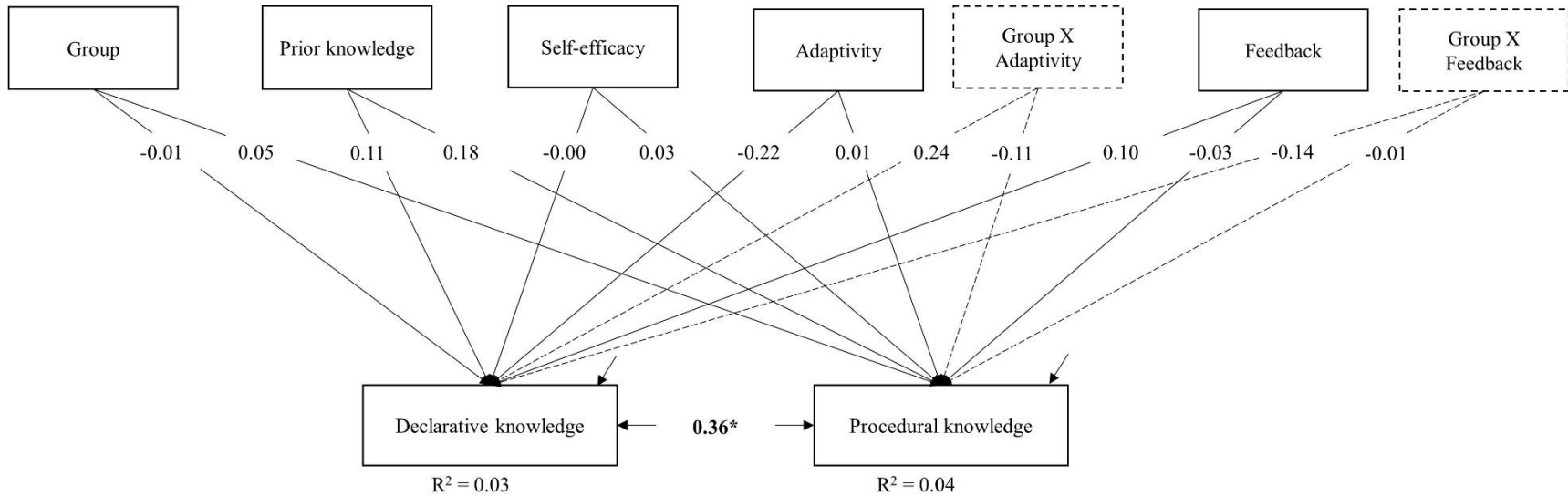


*Note.* *$p < .05$. 0 = EG1 (e-lecture), 1 = EG2 (e-learning course). standardized regression coefficients are presented. interaction effects of adaptivity and feedback: the paths in solid lines (boxes Adaptivity and Feedback) refer to the estimator of the e-lecture ($\beta$), the paths in dashed lines (boxes Group X Adaptivity and Group X Feedback) to the difference in regression coefficients between the e-lecture and the e-learning course ($\beta_{Int}$). The effect in EG2 can be calculated by adding the respective coefficients.

**Figure 3**

*Path model for acceptability and adoption*



*Note.* *$p$ < .05; **$p$ < .001. 0 = EG1 (e-lecture), 1 = EG2 (e-learning course). standardized regression coefficients are presented. interaction effects of adaptivity and feedback: the paths in solid lines (boxes Adaptivity and Feedback) refer to the estimator of the e-lecture ($\beta$), the paths in dashed lines (boxes Group X Adaptivity and Group X Feedback) to the difference in regression coefficients between the e-lecture and the e-learning course ($\beta_{Int}$). The effect in EG2 can be calculated by adding the respective coefficients.

# Discussion

The present study aimed at investigating the effects of two e-learning formats (one with and one without self-regulative elements) as well as the effects of individual learner characteristics on students' knowledge and attitudes. In line with our hypothesis for research question 1, both formats resulted in high levels of declarative knowledge and positive attitudes. However, the mastery level of procedural knowledge turned out to be quite low. Contrary to our hypothesis for research question 2, results showed no advantage of the condition with self-regulative elements. With regard to potential moderator effects (research question 3), there was no effect of prior knowledge, self-efficacy, or learning preferences for knowledge acquisition, but effects on attitudes were mostly moderated by these variables.

Our findings underline the promising use of e-learning formats in university education, as the goal of teaching basic competencies to student teachers could be successfully achieved with this flexibly usable approach (Elliott, 2017). Detailed declarative knowledge and positive attitudes towards an evidence-based teaching method were robustly pronounced among participants with an investment of less than 45 minutes. This shows that the e-learning formats effectively address both important cognitive and affective learning goals. However, developing procedural knowledge seems more demanding. For fully online environments, this constraint needs to be kept in mind. Acquiring practical skills in online environments is inherently problematic. Thus, if we want student teachers to be adequately prepared for their future profession, completely dispensing with face-to-face events would not appear reasonable. Where this is needed, more elaborate online learning formats are required, for instance, in form of synchronous virtual classrooms (e.g., Martin & Parker, 2014). A combination with additional learning formats also seems promising. A consequence for practical implementation could be, for example, a flipped classroom approach in which students acquire basic competencies with e-learning formats, while procedural competencies are subsequently taught in face-to-face settings (Dede et al., 2016). For instance, university lecturers could use e-learning formats to lay the groundwork but could include hands-on activities and reflective discussions in face-to-face events. Thus, e-learning formats are well suited for achieving stated learning goals, but they also have their limitations with regard to the acquisition of procedural knowledge.

Surprisingly, we found no additional effect of including self-regulative elements like adaptivity and feedback in the learning format. However, the conclusion that the two elements feedback and adaptivity are not conducive to learning does not seem supportable. The learning effectiveness of these principles has already been proven several times (e.g., Attali, 2015; Kühl et al., 2014). Instead of questioning the effectiveness of self-regulative principles per se, their concrete implementation should be examined more closely. It is well known that under certain circumstances difficulties can arise in the application of learning strategies like elements of self-regulated learning. For example, learners may have availability deficiencies where skills and metacognitive knowledge for self-regulation are not yet sufficiently developed. Introducing strategies to students before attending the e-learning course might help. Further, production deficiencies may occur where learners have the skills and knowledge for self-regulated learning but do not use them adequately in the respective learning situation (Veenman et al., 2000). One possible approach to counteract production deficiencies is prompting. Prompting refers to an economical, instructional method in which short cues or questions are used to activate existing

knowledge and skills (Wirth, 2009). Possibly, prompts should be implemented in the e-learning course so that students make greater use of the opportunity for self-regulated learning. This idea is supported by research findings on self-paced learning, which revealed that the advantage of self-pacing over system-pacing in learning word pairs is mainly the result of learners allocating more time to the difficult word pairs (de Jonge et al., 2015). If students do not use the opportunity of self-determined resource allocation, the strategy will become less effective. Our findings must thus be interpreted against the background of our specific design, which included a specific study sample of student teachers, a study duration of approx. 45 minutes, and two e-learning formats with narrowly defined subject content.

Contrary to our expectations, we found no moderation effects for declarative or procedural knowledge (research question 2). Based on cognitive load theory, we started from the premise that individuals with high prior knowledge may have more cognitive resources available to retain new content (Sitzmann & Ely, 2011; Sweller et al., 1998; Zambrano et al., 2019). However, it is possible that the two e-learning formats were so clearly structured (and thus the cognitive demands so low) that students did not necessarily need prior knowledge and thus, self-efficacy to acquire the knowledge needed to understand the intervention. For the reading intervention's implementation in practice, however, this is an encouraging finding, as it demonstrates that necessary knowledge can be spread easily and with relatively low expenditure.

Effects on attitudes, were partially moderated by the specified variables. Consistent with our expectations, prior knowledge and self-efficacy showed a positive effect on acceptability and adoption (which, however, were not stronger in the self-regulative condition). When the preference for adaptive learning matched the condition, i.e., participants attended the e-learning course, higher adoption and slightly higher acceptability scores were found. This pattern suggests that individual learner characteristics rather than the learning environment influence attitude acquisition. Differential effects for acceptability and adoption have already been reported by previous research (Donnell & Gettinger, 2015; State et al., 2017). For instance, Donnell and Gettinger (2015) found moderate correlations of acceptability ratings with self-efficacy and congruent beliefs, and State et al. (2017) identified gender and years in position as important predictors. Our findings thus provide cumulative evidence for the importance of focusing on individual learner characteristics in professional development, especially when aiming at changing (student) teachers' attitudes. In contrast, though, the pattern of findings for feedback was inconsistent and not in line with our hypothesis. Having a high preference for learning with feedback but watching the e-lecture instead of attending the e-learning course, led to positive effects on adoption. For acceptability, no significant effects were found. Perhaps learning preferences for feedback are also associated with a low tolerance for ambiguity more than with a preference for self-regulative learning arrangements. Thus, the e-lecture with more direct instruction may accommodate better to individuals in need of certainty.

### Limitations

This study's strength lies in its controlled experimental design, which required a clear focus on specific learning contents and competencies. However, this limits the findings' generalisability to other contexts. Moreover, in realistic settings, the extent to which e-lectures allow learners to self-pace their learning is higher. The detection of group differences as well as potential moderator

effects might further have been impaired by limited variance with respect to the dependent variables. In future studies, extending the time interval between learning and retrieval could contribute to an increase in variance while providing insight into the sustainability of acquired knowledge and attitudes. In addition, log-file based data (e.g., Cocea & Weibelzahl, 2009) could provide more information about the use of self-regulative elements. In this study, it was technically not possible to record participants' behaviour in the e-learning course. Therefore, it cannot be ruled out that the participants only made limited use of adapting their learning pace and learning from multiple-try feedback.

# Conclusion

The present study makes valuable contributions by presenting how e-learning formats can be designed to support students' mastery of important competencies (Dede et al., 2016; Elliott, 2017). Both e-learning formats led to detailed declarative knowledge, and participants indicated high levels of acceptability and adoption towards evidence-based teaching methods – all of which are necessary competencies for their later professional lives. At the same time, successfully implementing such formats in university teaching practice should depend on the specified learning goals and might require significant changes in didactic structures. For instance, to strengthen the acquisition of procedural knowledge, we recommend that e-learning formats are combined with face-to-face learning opportunities, which include concrete practice phases and critical, cooperative reflections.

# Acknowledgements

# References

Agathangelou, S. A., Charalambous, C. Y., & Koutselini, M. (2016). Reconsidering the contribution of teacher knowledge to student learning: Linear or curvilinear effects? *Teaching and Teacher Education*, *57*, 125–138. https://doi.org/10.1016/j.tate.2016.03.007

Aust, L.*, Ehlert, M.*, & Souvignier, E. (2024). Effects of e-learning formats on student teachers' knowledge and attitude towards evidence-based instruction. OSF. https://osf.io/zrv54/

Attali, Y. (2015). Effects of multiple-try feedback and question type during mathematics problem solving on performance in similar problems. *Computers & Education*, *86*, 260–267. https://doi.org/10.1016/j.compedu.2015.08.011

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review*, *84*, 191–215. https://doi.org/10.1037/0033-295X.84.2.191

Baumert, J., & Kunter, M. (2011). *Das mathematikspezifische Wissen von Lehrkräften, kognitive Aktivierung im Unterricht und Lernfortschritte von Schülerinnen und Schülern. Professionelle Kompetenz von Lehrkräften* [Teachers' mathematics-specific knowledge, cognitive activation in the classroom and students' learning progress]. In M. Kunter, J. Baumert, & W. Blum (Eds.). *Professionelle Kompetenz von Lehrkräften: Ergebnisse des Forschungsprogramms COACTIV* [Teachers' professional competence - Results of the COACTIV research programme] (pp. 163-192). Waxmann.

Carroll, J. B. (1970). Problems of measurement related to the concept of learning for mastery. *Educational Horizons*, *48*(3), 71-80. https://www.jstor.org/stable/42923880

Cavalcanti, A. P., Barbosa, A., Carvalho, R., Freitas, F., Tsai, Y.-S., Gašević, D., & Mello, R. F. (2021). Automatic feedback in online learning environments: A systematic literature review. *Computers and Education: Artificial Intelligence*, *2*, 100027. https://doi.org/10.1016/j.caeai.2021.100027

Cocea, M., & Weibelzahl, S. (2009). Log file analysis for disengagement detection in e-learning environments. *User Modeling and User-Adapted Interaction*, *19*(4), 341–385. https://doi.org/10.1007/s11257-009-9065-5

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences* (2nd ed.). Lawrence Erlbaum Associates, Publishers. https://doi.org/10.4324/9780203771587

Darling-Hammond, L., Burns, D., Campbell, C., Goodwin, A. L., Hammerness, K., Low, E.-L., McIntyre, A., Sato, M., & Zeichner, K. (2017). *Empowered educators: How high-performing systems shape teaching quality around the world*. John Wiley & Sons.

de Jonge, M., Tabbers, H. K., Pecher, D., Jang, Y., & Zeelenberg, R. (2015). The efficacy of self-paced study in multitrial learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *41*(3), 851–858. https://doi.org/10.1037/xlm0000046

Dede, C., Eisenkraft, A., Frumin, K., & Hartley, A. (2016). *Teacher Learning in the Digital Age: Online Professional Development in STEM Education*. Harvard Education Press.

Depaepe, F., & König, J. (2018). General pedagogical knowledge, self-efficacy and instructional practice: Disentangling their relationship in pre-service teacher education. *Teaching and Teacher Education*, *69*, 177–190. https://doi.org/10.1016/j.tate.2017.10.003

Donnell, L. A., & Gettinger, M. (2015). Elementary school teachers' acceptability of school reform: Contribution of belief congruence, self-efficacy, and professional development. *Teaching and Teacher Education*, *51*, 47–57. https://doi.org/10.1016/j.tate.2015.06.003

Elliott, J. C. (2017). The evolution from traditional to online professional development: A review. *Journal of Digital Learning in Teacher Education*, *33*(3), 114–125. https://doi.org/10.1080/21532974.2017.1305304

Finch, H. (2005). Comparison of the performance of nonparametric and parametric MANOVA test statistics when assumptions are violated. *Methodology: European Journal of Research Methods for the Behavioral and Social Sciences*, *1*(1), 27-38. https://doi.org/10.1027/1614-1881.1.1.27

Hsu, L. M. (1989). Random sampling, randomization, and equivalence of contrasted groups in psychotherapy outcome research. *Journal of Consulting and Clinical Psychology, 57*, 131–137. https://doi.org/10.1037/0022-006X.57.1.131

Jansen, R. S., van Leeuwen, A., Janssen, J., Conijn, R., & Kester, L. (2020). Supporting learners' self-regulated learning in Massive Open Online Courses. *Computers & Education*, *146*, 103771. https://doi.org/10.1016/j.compedu.2019.103771

Kawohl, E. (2015). *Diagnosebasierte individuelle Leseförderung in der Grundschule. [Assessment-based differentiated reading instruction in elementary schools]*. (Doctoral dissertation, University of Münster). Kovac.

Kühl, T., Eitel, A., Damnik, G., & Körndle, H. (2014). The impact of disfluency, pacing, and students' need for cognition on learning with multimedia. *Computers in Human Behavior*, *35*, 189–198. https://doi.org/10.1016/j.chb.2014.03.004

Klepsch, M., Schmitz, F., & Seufert, T. (2017). Development and validation of two instruments measuring intrinsic, extraneous, and germane cognitive load. *Frontiers in Psychology*, *8,* 1997. https://doi.org/10.3389/fpsyg.2017.01997

Lai, C. L., & Hwang, G. J. (2023). Strategies for enhancing self-regulation in e-learning: a review of selected journal publications from 2010 to 2020. *Interactive Learning Environments*, *31*(6), 3757-3779. https://doi.org/10.1080/10494820.2021.1943455

Lakin, J. M., & Shannon, D. M. (2015). The role of treatment acceptability, effectiveness, and understanding in treatment fidelity: Predicting implementation variation in a middle school science program. *Studies in Educational Evaluation*, *47*, 28–37. https://doi.org/10.1016/j.stueduc.2015.06.002

Maatuk, A. M., Elberkawi, E. K., Aljawarneh, S., Rashaideh, H., & Alharbi, H. (2022). The COVID-19 pandemic and E-learning: challenges and opportunities from the perspective of students and instructors. *Journal of Computing in Higher Education*, *34*(1), 21-38. https://doi.org/10.1007/s12528-021-09274-2

Martin, F., & Parker, M. A. (2014) Use of synchronous virtual classrooms: Why, who, and how. *MERLOT Journal of Online Learning and Teaching, 10*(2), 192-210. Retrieved from https://jolt.merlot.org/vol10no2/martin_0614.pdf

Meudt, S.-I., Zeuch, N., Neuber, L., & Souvignier, E. (2020). Kurzskalen zur Erfassung des Transfererfolgs von Leseförderkonzepten in der Schulpraxis [Short scales for assessing the transfer success of reading concepts in school practice]. In K. Mackowiak, C. Beckerle, S. Gentrup, & C. Titz (Eds.), *Forschungsinstrumente im Kontext institutioneller (schrift-)sprachlicher Bildung [Research tools in the context of institutional (written) language education]* (pp. 141–157). Klinkhardt. https://doi.org/10.35468/5801_08

Müller, B., Richter, T., & Karageorgos, P. (2020). Syllable-based reading improvement: Effects on word reading and reading comprehension in Grade 2. *Learning and Instruction*, *66*, 101304. https://doi.org/10.1016/j.learninstruc.2020.101304

Palincsar, A. S., & Brown, A. L. (1984). Reciprocal teaching of comprehension-fostering and comprehension-monitoring activities. *Cognition and Instruction*, *1*(2), 117–175. https://doi.org/10.1207/s1532690xci0102_1

Peter, J., Leichner, N., Mayer, A.-K. & Krampen, G. (2015). IEBL. Inventar zur Evaluation von Blended Learning [Inventory for the evaluation of blended learning]. In Leibniz-Institut für Psychologie (ZPID) (Eds.), *Open Test Archive*. https://doi.org/10.23668/psycharchives.4590

Pintrich, P. R., & De Groot, E. V. (1990). Motivational and self-regulated learning components of classroom academic performance. *Journal of Educational Psychology*, *82*, 33–40. https://doi.org/10.1037/0022-0663.82.1.33

Proctor, E., Silmere, H., Raghavan, R., Hovmand, P., Aarons, G., Bunger, A., Griffey, R., & Hensley, M. (2011). Outcomes for implementation research: Conceptual distinctions, measurement challenges, and research agenda. *Administration and Policy in Mental Health and Mental Health Services Research*, *38*(2), 65–76. https://doi.org/10.1007/s10488-010-0319-7

R Core Team (2022). *R: A language and environment for statistical computing.* R Foundation for Statistical Computing. https://www.R-project.org/

Rosseel, Y. (2012). lavaan: An R package for structural equation modeling. *Journal of Statistical Software*, *48*, 1–36. https://doi.org/10.18637/jss.v048.i02

Seufert, T., Schütze, M., & Brünken, R. (2009). Memory characteristics and modality in multimedia learning: An aptitude–treatment–interaction study. *Learning and Instruction*, *19*(1), 28–42. https://doi.org/10.1016/j.learninstruc.2008.01.002

Sitzmann, T., & Ely, K. (2011). A meta-analysis of self-regulated learning in work-related training and educational attainment: What we know and where we need to go. *Psychological Bulletin*, *137*(3), 421–442. https://doi.org/10.1037/a0022777

State, T. M., Harrison, J. R., Kern, L., & Lewis, T. J. (2017). Feasibility and acceptability of classroom-based interventions for students with emotional/behavioral challenges at the high school level. *Journal of Positive Behavior Interventions*, *19*(1), 26–36. https://doi.org/10.1177/1098300716648459

Sweller, J., van Merrienboer, J. J. G., & Paas, F. G. W. C. (1998). Cognitive architecture and instructional design. *Educational Psychology Review*, *10*(3), 251–296. https://doi.org/10.1023/A:1022193728205

Therrien, W. J. (2004). Fluency and comprehension gains as a result of repeated reading: A meta-analysis. *Remedial and Special Education*, *25*(4), 252–261. https://doi.org/10.1177/07419325040250040801

Veenman, M. V. J., Kerseboom, L., & Imthorn, C. (2000). Test anxiety and metacognitive skillfulness: Availability versus production deficiencies. *Anxiety, Stress, & Coping*, *13*(4), 391–412. https://doi.org/10.1080/10615800008248343

Wirth, J. (2009). Promoting self-regulated learning through prompts. *Zeitschrift für Pädagogische Psychologie, 23*(2), 91–94. https://doi.org/10.1024/1010-0652.23.2.91

Yeomans, M., & Reich, J. (2017). Planning prompts increase and forecast course completion in massive open online courses. In *Proceedings of the Seventh International Learning Analytics & Knowledge Conference* (pp. 464-473). https://doi.org/10.1145/3027385.3027416

Zambrano, J., Kirschner, F., Sweller, J., & Kirschner, P. A. (2019). Effects of group experience and information distribution on collaborative learning. *Instructional Science*, *47*(5), 531–550. https://doi.org/10.1007/s11251-019-09495-0