Zeitschrift für Erziehungswissenschaft (2025) 28:1389–1411
https://doi.org/10.1007/s11618-025-01326-y

SCHWERPUNKT

Using digital tools in teacher education for fostering instructional competence among (pre-service) teachers

Christiane Kuhn · Katharina Depré · Olga Zlatkin-Troitschanskaia · Jasmin Reichert-Schlax

Received: 25 August 2024 / Revised: 14 March 2025 / Accepted: 27 March 2025 / Published online: 22 July 2025

Abstract Teachers' instructional competence to integrate information and communication technology into the classroom has become essential. However, teachers often lack the disposition to put these corresponding demands into practice. Recent research proposes that the use of (digital) learning tools in teacher education can help to promote the required content-specific and generic dispositions at an early stage. Following the critical discourse of competence models, teachers' technological pedagogical content knowledge (TPACK) and self-regulated learning (SRL) can be seen as relevant content-specific (TPACK) and generic (SRL) dispositions. This study aims to demonstrate how both dispositions can be promoted in university teacher education using tailor-made digital learning tools consisting of multimedia self-study material, focusing on TPACK and SRL. We integrated the tools into regular university courses, where economics education students used these tools to train their TPACK ($n=91$) and SRL ($n=35$). The results of the pre-post analyses indicated that these tools could meaningfully complement university teacher education to promote the intended dispositions.

✉ Dr. Christiane Kuhn · Dr. Katharina Depré · Prof. Dr. Olga Zlatkin-Troitschanskaia · Dr. Jasmin Reichert-Schlax
Business and Economics Education, Johannes Gutenberg University, Jakob Welder-Weg 9, 55128 Mainz, Germany
E-Mail: christiane.kuhn@uni-mainz.de

Dr. Katharina Depré
E-Mail: kdepre@uni-mainz.de

Prof. Dr. Olga Zlatkin-Troitschanskaia
E-Mail: troitschanskaia@uni-mainz.de

Dr. Jasmin Reichert-Schlax
E-Mail: jasmin.schlax@uni-mainz.de

Keywords Teachers' instructional competence · Technological pedagogical content knowledge · Self-regulated learning · Digital learning tools · Teacher education

Einsatz digitaler Tools in der Lehrkräftebildung zur Förderung instruktionaler Kompetenzen bei (angehenden) Lehrkräften

Zusammenfassung Die instruktionale Kompetenz von Lehrkräften, Informations- und Kommunikationstechnologien in den Unterricht zu integrieren, ist unerlässlich. Den Lehrkräften mangelt es jedoch oft an den notwendigen Dispositionen, um entsprechende Anforderungen in der Praxis bewältigen zu können. Die aktuelle Forschung indiziert, dass der Einsatz von (digitalen) Lerntools in der Lehrkräftebildung dazu beitragen kann, die fachspezifischen und fachübergreifenden Dispositionen frühzeitig zu fördern. Der kritische Diskurs zu Kompetenzmodellen stellt das Technological Pedagogical Content Knowledge (TPACK) und das selbstregulierte Lernen (SRL) von Lehrkräften als relevante fachspezifische (TPACK) und generische (SRL) Dispositionen dar. Diese Studie untersucht die Förderung dieser Dispositionen mittels digitaler Lerntools zu TPACK und SRL in der universitären Lehrkräftebildung. Die Tools wurden in reguläre universitäre Kurse des Studiengangs der Wirtschaftspädagogik integriert, so dass die Studierenden mit den Tools lernen konnten (TPACK $n = 91$; SRL $n = 35$). Die Prä-Post-Analysen deuten darauf hin, dass die Tools in der universitären Lehrkräftebildung zur Förderung dieser Dispositionen beitragen können.

Schlüsselwörter Instruktionale Kompetenz · Technologisch-pädagogisches Fachwissen · Selbstreguliertes Lernen · Digitale multimediale Lerntools · Lehrkräftebildung

1 Introduction

Teachers' instructional competence to integrate information and communication technology (ICT) into the classroom environment has become essential (König et al. 2020; Redecker and Punie 2017). However, teachers are often overwhelmed and unable to put the corresponding demands into professional practice (Minea-Pic 2020). On considering the critical discussion on teachers' competence (König et al. 2020), there is a need to determine the necessary prerequisites to fulfill these requirements and how they can be promoted early in teacher education (Meier et al. 2023).

Existing approaches focus on the requirements associated with the handling of ICT in classroom (Angeli et al. 2016; Koehler and Mishra 2009) or the challenge of integrating such new requirements into existing models (Heine et al. 2023). Based on general models of teachers' competence (Baumert and Kunter 2011; Blömeke et al. 2015) and the more specific heuristic by König et al. (2022), which focuses on the integration of ICT into lesson plans, the complex interplay of the various prerequisites associated with ICT integration in classrooms becomes clear.

In the theoretical framework, teachers' technological pedagogical content knowledge (TPACK) as well as self-regulated learning (SRL) can be seen as relevant content-specific (TPACK) and generic (SRL) dispositions (Kramarski and Michalsky 2010). TPACK provides a necessary knowledge base to meet the content-specific ICT requirements in classroom practice (Koehler and Mishra 2009; König et al. 2022). By regulating one's own professional process by considering the organization of learning, materials, objectives, and procedures, SRL needs to counteract the possible overwhelming demands when dealing with digital challenges (Broadbent and Poon 2015).

Recent research also indicates the challenge of fostering such dispositions in initial teacher education: Several studies show that the dispositions acquired in university education are often not successfully applied in teaching practice (Carlson and Daehler 2019; Kersting et al. 2016). To promote instructional competence, effective training programs utilize multimedia learning materials; e.g., the use of videos allows the authentic portrayal of the dynamic and intricate nature of teaching practice in university education (Seidel and Thiel 2017). Digital tools as structured computer-based learning opportunities allow various multimedia materials such as videos, audio- or text-based instructions, interactive exercises and feedback options, to be flexibly and adaptively integrated, and thus, help to individually address the diverse preconditions and needs of learners (Mayer 2014) when promoting specific competence facets (like TPACK and SRL).

Recently, some interventions have been undertaken to promote TPACK and SRL in university (teacher) education and to evaluate their impact (Bellhäuser et al. 2016; Gerber et al. 2023; Grassinger et al. 2022; König et al. 2022; Lachner et al. 2021). For student teachers' TPACK and SRL in economics, however, little is known about the implementation and evaluation of content-specific and generic interventions (Eckerlein et al. 2020). An increasingly digitalized and rapidly changing workplace of trainees in vocational education (e.g., the use of specific software for planning and controlling business processes) places especially high digital demands on student teachers in economics education (Thiel de Gafenco and Klusmeyer 2023). Thus, the present study investigates whether economics teachers' TPACK and SRL have increased after processing the corresponding digital learning tools, focusing on either TPACK or SRL, in initial teacher education. We integrated these tools into ten regular university courses. In eight courses, the student teachers ($n=91$) trained their TPACK, in two other courses, the student teachers ($n=35$) trained their SRL using the corresponding tools. We assessed students' TPACK and SRL before and after processing the tools and compared the assessment results with student teachers who did not work with the digital tools in the courses.

Based on this study, we propose that digital learning tools can meaningfully contribute to fostering economics student teachers' TPACK and SRL at an early stage. Together with other tailor-made digital tools developed to foster further instructional competence components (e.g., PCK, Brückner et al. 2024), we seek to provide a series of computer-based learning opportunities in initial (economics) teacher education which help to meet the digital demands in the classroom in a professional setting. Our focus on student teachers in economics aims to supplement findings from other subjects (STEM area, languages), which have mainly been the focus of investigation so far (Meier et al. 2023). At the same time, our tools can potentially be applicable to student teachers from other subjects, particularly to promote generic dispositions such as SRL (for a transfer study with teacher students of German, see Reichert-Schlax et al. 2023).

2 Theoretical background

2.1 Technology integration in classroom: the TPACK, ICAP, and SAMR model

Several approaches have been developed to describe teachers' technology integration in classroom (for an overview, König et al. 2022). The TPACK model defines the knowledge required to integrate technology effectively into instruction, based on the intersection of three core components: content (CK), pedagogy (PK), and technology (TK), including their overlaps (PCK, TPK, TCK), and the integration of all three areas (TPACK) (Koehler and Mishra 2009). These knowledge components have been shown to predict student learning progress (König and Pflanzl 2016) and support teachers in determining how effectively media and technologies can be used in classroom to convey subject matter (Koehler and Mishra 2009).

The use of the TPACK model is challenging, e.g., due to the complex interplay of the knowledge facets (Hamilton et al. 2016). In addition, the model does not specifically address the change in students' learning when using digital materials in the classroom. This focus, however, is highly relevant for teachers to understand and effectively and accordingly foster students' learning activities. The Interactive, Constructive, Active, and Passive (ICAP) model classifies students' learning activities into four modes and assumes that students' learning increases when they become cognitively engaged with the learning materials, from *passive* (new information is *stored*) to *active* (new information is *integrated*), *constructive* (new information is *inferred*), and *interactive* (new information is *co-inferred* with learning partners) (Chi and Wylie 2014). The ICAP framework relates students' cognitive engagement activities with any learning material and can therefore also be applied to digital materials.

Due to the daily challenge teachers face in integrating technology into practice, the Substitution, Augmentation, Modification, and Redefinition (SAMR) approach by Puentedura (2013) provides a practical orientation for teachers for their lessons (Hilton 2016), even if this model still lacks scientific quality (Hamilton et al. 2016). The approach encourages teachers to increase the levels of technology integration in classroom activities: At the substitution level, analog media is directly replaced with digital materials without any functional change. At the augmentation level, analog media is replaced with digital equivalents providing a functional improvement of tasks and tools. The modification level involves the reformulation of tasks, while at the redefinition level, the highest standard of technology integration is achieved by creating novel tasks (Puentedura 2013).

Since teachers' TPACK includes knowledge about the ICAP and the SAMR model on how to successfully integrate technology into the classroom at different levels, and consider students' learning process (Wekerle and Kollar 2022), these models provide central content in the learning tool developed in our study to foster teachers' TPACK in initial teacher education (Chap. 3.3.1; Frank et al. 2023).

2.2 Self-regulated learning (SRL)

SRL is essential for teachers to help learners achieve learning goals, e.g., to become actively engaged with learning materials (Chi and Wylie 2014), adapt activities as needed, and monitor progress, and to deal successfully with professional requirements (Michalsky 2012). Teachers must understand SRL to teach it effectively to students (Götz et al. 2013). Thus, SRL is important for teacher education and developing practical skills (Butler et al. 2004). Implementing SRL can enhance diagnostic skills and improve lesson planning for individual student needs (Paris and Winograd 2003), leading to better instruction and student learning outcomes (Peeters et al. 2014). Moreover, teachers are exposed to high stress due to new requirements in everyday working life, especially at the beginning of their careers. SRL can lead to lower perceptions of stress in early career teachers (Schmidt et al. 2017). Occupational well-being can be supported through self-regulated management of one's resources like time or energy (Klusmann 2013).

Finally, teachers need to self-regulate their professional tasks in an effective way. The shift to digital instruction required teachers to reorganize themselves within the realities of digital learning and teaching (Grassinger et al. 2022). Kramarski and Michalsky (2010) show the importance of student teachers' SRL specifically in the TPACK context: Explicitly promoting student teachers' SRL within a self-directed open-ended technology environment (hypermedia context) is more effective in fostering both TPACK as well as SRL, compared to a training in a hypermedia context without explicit SRL support. According to Shulman (1987, p. 8), PK facets (as component of TPACK alongside CK and TK, Chap. 2.1), such as SRL, serves as "knowledge with special reference to those broad principles and strategies of classroom management and organization that appear to transcend subject matter". Compared to CK and PCK, facets of PK are cross-disciplinary (König and Pflanzl 2016) and enable, e.g., a classroom climate conducive to learning (Koehler and Mishra 2009). In combination with the digital requirements for teaching, SRL as a facet of PK can thus enable supportive digital learning settings.

Especially at the beginning of teacher education, (prospective) teachers show deficits in facets of PK such as SRL (Kramarski and Michalsky 2009). Knowledge of SRL often may fail to transfer to real-life instruction in teacher education because of the complexity of converting learned content into practice (Eckerlein et al. 2020). This shows the importance of suitable tools to promote SRL in a situation-specific and practical way already during initial teacher education (Chap. 3.3.1).

2.3 Digital tools to foster teachers' instructional competence

According to the *Cognitive Theory of Multimedia Learning* (Mayer 2014), learning materials are more likely to lead to successful learning if they address the separate channels for visual/pictorial and verbal/auditory information processing (*dual-channel assumption*), the limitations on the capacity of each channel (*limited-capac-*

ity assumption), and the cognitive engagement in each channel (*active processing assumption*, Chi and Wylie 2014). In this study, digital tools describe structured computer-based learning opportunities which allow multimedia materials to be flexible and adaptive integrated; thereby considering the importance of being actively engaged with the information provided. Each digital tool aims to promote a specific competence facet (like TPACK or SRL) and enable student teachers to reflect on the complexity of teaching and act in a practice-oriented manner (Brühwiler and Vogt 2020; Chap. 3.3.1).

Recent studies highlight the effective role of digital tools in enhancing the competence components of pre-service teachers (Meier et al. 2023). For economics student teachers, Saas et al. (2020) demonstrated the potential of promoting action-related competencies (AC) and reflective competencies (RC) in an effective manner by using a video-based teaching-and-learning tool; thereby the tool was more effective in promoting AC than RC. AC is especially relevant during instructional situations in which teachers must react immediately (Saas et al. 2020). Gerber et al. (2023) also showed that digital tools enhance student teachers' abilities in adapting their teaching strategies to various scenarios, improving their intervention competencies. These findings were considered when designing the digital tools in our study; e.g., particular attention was given to creating learning opportunities that address the practice-oriented promotion of competence facets, which are not limited to the transfer of theoretical knowledge but enable student teachers to adapt their knowledge in specific teaching situations and to act in a problem-solving manner (Kramer et al. 2017). To this end, the university course content was underpinned with examples represented both visually and verbally from teaching practice in a digital way.

Muñiz-Rodríguez et al. (2018) explored the use of video vignettes to develop feedback competencies among mathematics student teachers. Video-based analysis was effective in improving student teachers' skills in providing constructive feedback. This method helps students critically assess teaching practices and enhances their feedback delivery. Following these findings, video-based elements were included in the design of the digital tools in our study (e.g., video vignettes), which present the learners with practical and problem-orientated content in a way that can be interpreted, enabling (repeated) exercises without (time) pressure and allowing the content to be viewed from various perspectives (Krammer and Reusser 2005). The videos were systematically supplemented with additional information such as commentaries (Gartmeier 2014) to promote more intensive engagement from the student teachers with the content than the reflection of own lesson video recordings, also with regard to emotional involvement (Kleinknecht et al. 2014).

König et al. (2022) conducted a scoping review on the integration of ICT into teachers' lesson plans. ICT tools improved lesson planning and pedagogical preparation. Effective ICT integration supported teachers in designing more engaging and well-structured lessons. Lee (2021) examined how technology-aided interventions enhance preservice teachers' noticing skills in mathematics pedagogy courses. Technology improved teachers' ability to observe and analyze classroom interactions, enhancing their instructional effectiveness. The digital tools in our study were therefore developed to explicitly address the use of media in the classroom and to promote the integration of ICT by student teachers through specific content on ICT (like the content on ICAP and SAMR). It is also assumed that the processing of the digitally designed tools itself promotes the use of digital content and methods (in the sense of the "pedagogical double-decker principle", Lange and Frommberger 2017).

2.4 The present study and research hypotheses

The current research indicates that the use of digital learning tools in teacher education (often implemented in laboratory settings) is conducive to increasing the level of content-specific and generic competence facets (Heine et al. 2023). To effectively implement tools in practical teaching following the Curriculum-Instruction-Assessment-Triad (Pellegrino 2012), the *TWIND* project, funded by the *Qualitative Offensive in Teacher Education* of the German Federal Ministry of Education and Research (BMBF) (Brückner et al. 2021), investigated the potential of tailor-made digital tools to be utilized in existing university courses and support an increase in targeted competence facets in teacher education practice.

In this article, we focus on fostering economics student teachers' TPACK and SRL. Student teachers trained their TPACK by utilizing a learning tool focused on TPACK connected to ICAP and SAMR (TPACK group), or their SRL by utilizing a tool focused on SRL (SRL group). In the pre-post-assessments, we compared the results with student teachers who did not work with the digital tools. Following recent research (Chap. 2.3), we expect that the use of digital tools will support a positive change in the respective competence facets TPACK or SRL. This leads to the following hypotheses (H):

H1 The TPACK group outperforms the group without TPACK tool processing on the TPACK assessment.

H2 The SRL group outperforms the group without SRL tool processing on the SRL assessment.

Current practice and policy stress the importance of digital learning tools to successfully manage the increasing heterogeneity of students (Wissenschaftsrat 2022). Learning tools should support all students equally, regardless of their individual characteristics. Recent studies show, however, that individual characteristics, such as gender (Senkbeil et al. 2019), migration background (Adam-Gutsch et al. 2021), and native language (Jentsch et al. 2021) may have an impact on the processing of digital learning opportunities in university courses of student teachers. In our study, to minimize such effects, a particular focus is placed upon developing visually and verbally presented instruction tasks in gender-neutral language and embedding them in heterogeneity-sensitive digital tools with supplementary materials for students of all educational backgrounds, considering that knowledge can be absorbed in different ways depending on specific learning (pre)conditions (Mayer 2014). We therefore expect that teacher students would benefit equally from the learning tools in our study. This leads to the following hypotheses:

H3 There is no significant influence of gender, migration background, and native language on the TPACK assessment results in the TPACK group.

H4 There is no significant influence of gender, migration background, and native language on the SRL assessment results in the SRL group.

Expertise research underlines the importance of practical experience for competence development (Bromme 2008). With a higher level of expertise, especially acquired under "deliberate practice" conditions, such as during initial teacher education and vocational training, there should be an increase in the competence components (Krauss 2011). Although there is a lack of research on the development of TPACK and SRL in economics teacher education, there are indications in the "basic curriculum for Business and Economics Education" and the framework regulations for vocational training that suggest the promotion of TPACK and SRL as key competency components (BWP 2014). This leads to the following hypotheses:

H5 There is a significant influence of study phase and completed vocational training on the TPACK assessment results in the TPACK group.

H6 There is a significant influence of study phase and completed vocational training on the SRL assessment results in the SRL group.

Furthermore, for long-term committed use of the tools in regular teacher education, student teachers need to recognize the benefits of the tools (Ertmer and Ottenbreit-Leftwich 2010). Thus, we additionally provide evidence on how students subjectively rate the benefits of the learning tools.

3 Method

3.1 Participants

Regarding the use of the TPACK tool, a sample of 91 economics student teachers (TPACK group) participated at two measurement points before and after the processing of this tool (*t1* and *t2*). In addition, a student group ($n=31$) without processing the tool participated in both measurements (TPACK comparison group). As shown in Table 1, both groups are comparable regarding their characteristics. Based on a χ^2-test, no significant differences were found between the groups regarding these characteristics. In the TPACK group, descriptively more students are male and in the master's program, which, however, gains no significance in a χ^2-test.

Regarding the use of the tool on SRL, a pre-post sample of 35 economics student teachers (SLR group) participated in both *t1* and *t2* before and after processing this tool. In addition, a student group ($n=32$) without processing the tool participated in both measurements (SRL comparison group). As shown in Table 2, both groups are again comparable regarding their characteristics. Based on a χ^2-test, significantly more students in the SRL group are male, and significantly more students in the

Table 1 Sample Description TPACK

Variables	TPACK group (91)	TPACK comparison group (31)	Differences between the groups (χ^2-test)
Gender, male, % (n)	37.36% (34/91)	19.35% (6/31)	0.065
No migration background % (n)	78.02% (71/91)	64.52% (20/31)	0.053
Native language, only German % (n)	92.31% (84/91)	83.87% (26/31)	0.173
Study phase, master's degree % (n)	42.22% (38/90)	22.58% (7/31)	0.121
Vocational training, absolved % (n)	30.77% (28/91)	32.26% (10/31)	0.119

Table 2 Sample Description SRL

Variables	SRL group (35)	SRL comparison group (32)	Differences between the groups (χ^2-test)
Gender, male, % (n)	31.43% (11/35)	68.75% (22/32)	0.002*
No migration background % (n)	74.29% (26/35)	65.63% (21/31)	0.741
Native language, only German % (n)	97.14% (34/35)	90.63% (29/32)	0.118
Study phase, master's degree % (n)	57.14% (20/35)	37.51% (12/32)	0.108
Vocational training, absolved % (n)	48.57% (17/35)	96.89% (31/32)	0.000*

SLR comparison group have completed a vocational training. The differences in these characteristics between the groups are considered in the following analyses. Furthermore, in the SRL group, more students are in the master's program, which gains no significance in a χ^2-test.

3.2 Design and procedures[1]

The digital tools on TPACK and SRL were implemented in regular initial teacher education courses, where students had the opportunity to process the tools over a period of two weeks in self-regulated learning phases and the courses together with the lecturers. The courses from the bachelor's and master's programs were attended by economics student teachers for vocational schools and focused on teaching didactic content. The tools were implemented and provided via a web-based learning management system.

[1] The data are available via Gutenberg Open Science. Over 30 digital tools have already been published under https://edusharing.vcrp.de/edu-sharing/components/collections?id=4a4cab21-f029-4e64-a767-cb0ddad8daa6.

The digital tool on TPACK was implemented in eight courses in Business and Economics Education programs at three German universities in the winter term 2021/2022, summer term 2022, winter term 2022/2023, and summer term 2023. Four parallel courses without focusing on TPACK content served as a group which did not process the tool.

The digital tool on SRL was implemented in two courses in Business and Economics Education programs at two German universities in summer term 2021. Three parallel courses without focusing on SLR content served as a group without tool processing.

The TPACK group and the SRL group were assessed in *t1* and *t2* with online surveys via SoSci Survey (Leiner 2019). A self-generated pseudonymous code was used to combine datasets of *t1* and *t2* via Stata (Stata Corp. 2021). Participation in the surveys was voluntary, although it was conducted as a component of the course. Students in the groups that did not utilize the tool were given a 25 € incentive to partake in both surveys, which occurred concurrently with the group using tools.

3.3 Tools and measures

3.3.1 Digital tools

General structure To help students to become actively engaged with the learning materials by initiating (meta)cognitive processes, the digital tools on TPACK and SRL are structured to give five phases: analysis phase, development phase, practical phase, application phase, and reflection phase. At the beginning of each tool, participants are put into the role of an economics teacher by presenting a problem-oriented teaching situation which must be overcome during each tool. To avoid a cognitive overload with information, the learning materials of each phase are preselected and consist of files to describe teaching contexts and objectives as well as knowledge and competency descriptions, audiovisual media such as explanation videos, learning tasks with instructional and feedback-related elements, as well as reflection and (self-)control elements. The digital tools can be completed by student teachers in 60 to 90 min of self-study. In addition, the lecturers can use the materials of the digital tools for their university courses and adapt them flexibly according to the learning objectives and needs of the respective learning group (for more details, Brückner et al. 2021; Frank et al. 2023).

Multimedia TPACK tool After processing the TPACK tool, learners should be able to understand the ICAP and SAMR models, evaluate the use of digital media in economics classroom situations, consider the use of digital media and levels of learning activities in their own future lesson planning, and link their own experiences to the knowledge they have acquired, as well as identify the limitations of both models (Frank et al. 2023).

Learners inform themselves of the purpose of the models by consulting explanatory videos and literature. To better understand the ICAP model, the learners work on an analog task, associating different teaching situations, each containing a learning activity, with one of the four levels of the ICAP model. Following this, the learners analyze the introductory teaching situation, consider possible reasons why the students did not participate in the lesson, formulate an alternative work assignment, and discuss their results with a digital neighbor. To work with the practice-oriented SAMR approach, the learners assign six teaching situations, each of which involves the use of digital media to one of the four levels. After completing the exercises, the learners compare their results to a sample solution, which allows them to control their own learning and solve the entry problem, which is crucial for successful self-directed learning.

In the linking phase, the learners must assign fictitious economics teaching situations (in text form and as video vignettes) to both the ICAP and SAMR models using additional tasks. The levels of the ICAP and SAMR models are cross tabulated to make the connections visible, and learners can add exemplary situations to the table to see the connection between the models, focusing on the interfaces of the TPACK model. In the end, the learners reflect on the newly learned content based on guiding questions, e.g., by justifying the application of the model in the classroom.

Multimedia SRL tool The SRL tool consists of three modules, each of which follows the same structure. The first module includes an explanatory video on the process model of self-regulation according to Zimmermann (2000), which covers all phases of an action in classroom: planning, executing, and reflecting. It also addresses the high importance of SRL to deal with increasing digital challenges in classroom. To deepen and apply the content, tasks with different levels of cognitive activation follow which the learners work on independently and on which they receive feedback.

The second module focuses on scenario-based training to promote learning strategies at each stage of lesson preparation (Mattern and Bauer 2014). In the first explanatory video, cognitive, metacognitive, and resource-related learning strategies were addressed, which can be applied to the pre-actional phase or lesson planning: e.g., the *Eisenhower matrix* to prioritize tasks (Bratterud et al. 2020), and the *ALPEN method* to analyze and optimize the individual use of time (Jinalee and Singh 2018). In the second explanatory video, self-motivation and cognitive learning strategies for the executing (actional) phase are discussed (Bruso et al. 2020): e.g., mind mapping and methods like the benefit clarification of a task, self-reward as well as positive self-instruction (Mattern 2012). The third explanatory video deals with learning strategies for the reflection (post-actional) phase. Here, root cause analysis for success and failure and the relevance of controllable factors as well as self-monitoring using learning diaries, or a portfolio are highlighted (Joseph 2006). Each explanatory video is followed by short essay tasks that require the content to be applied to the described situation-specific scenario from the teacher's everyday life. Sample solutions are provided.

The third module focuses on strategies for coping with anxiety and stress in everyday teaching, e.g., when dealing with digital challenges, including practical examples of application (Lehr et al. 2009). In the explanatory video, relaxation exercises, tips for recovery as well as the benefits of social support are presented. Each learner must choose the coping strategy that is right for them and realize that self-care and inner attitude are central to teacher health. Again, the video is also followed by a short essay task. The sample solution is more comprehensive in this module, as learners are given a wide range of coping strategies to choose from. All three modules conclude with a short summary of the essential core aspects.

3.3.2 Measures to assess TPACK and SRL

To assess case-specific knowledge (Shulman 1986) regarding the ICAP and the SAMR models as components of TPACK, nine multiple-choice items specifically embedded in a vocational classroom situation were self-developed based on the *Evidence-Centered Assessment Design* model (Mislevy and Riconscente 2006), validated in a pre-test according to AERA et al. (2014), and used at *t1* and *t2,* as available assessments did not sufficiently fulfill the needs of this study. Since both the ICAP and the SAMR model provide an insight on how to successfully integrate technology into the classroom at different levels, and also consider students' learning process, we assumed a one-factor structure of this TPACK test. Each correct response was coded with one point and incorrect or missing responses were coded with zero points, i.e. a sum score had a range of 0 to 9. The reliability of this test was acceptable with a Cronbach's α of 0.612 at *t1* and 0.713 at *t2*. The fit indices of the CFA for investigating the theoretically assumed one-factor structure of TPACK indicated a limited data fit to the previously assumed model (SRMR = 0.122; RMSEA = 0.165; CFI = 0.658; TLI = 0.544; for discussion of the limitations, see Chap. 5.2).

To assess SRL, 19 items of the situation-specific questionnaire Self-Regulated Learning Questionnaire for Action and Knowledge (SRL-QuAK) were adapted (Eckerlein et al. 2020) and used at *t1* and *t2*. The validated SRL-QuAK provides insights into SRL strategies based on the theoretical foundations of Zimmermann (2000). Each item was scored with one point, with a final sum score of 0 to 19 (Cronbach's $\alpha_{t1} = 0.881$, Cronbach's $\alpha_{t2} = 0.931$). The fit indices of the CFA for investigating the theoretically assumed one-factor structure of SLR indicate a limited model fit ($SRMR = 0.086$; $RMSEA = 0.128$; $CFI = 0.787$; $TLI = 0.761$; for limitations, see Chap. 5.2).

In addition, socio-biographical (e.g., gender, migration background, native language) and study-related (e.g., study phase and completion of vocational training) data were surveyed at *t1*. At *t2*, information on usage behavior and detailed feedback on the digital learning tool was collected in the groups with tool processing.

3.4 Data analysis

Regarding *H1* and *H2,* a 2 × 2 ANOVA with an independent condition (group assignment) and a dependent condition (measurement point) was calculated to investigate group differences regarding the dependent variables (TPACK and SRL). To evaluate the effect size η^2, small effects > 0.01, middle effects > 0.06, and large effects > 0.14 were considered.

Regarding *H3* to *H6* regression analyses on TPACK and SRL change between *t1* and *t2* were calculated, to obtain insights on whether the students with different characteristics in the groups that processed the tools benefited equally from the

Table 3 Descriptive Statistics TPACK

Time	Group	Mean ± *SD*	*n*
t1	TPACK group	3.90 ± 1.98	91
	TPACK comparison group	4.00 ± 2.27	30
t2	TPACK group	5.71 ± 2.17	90
	TPACK comparison group	3.93 ± 2.07	29

Deviations of *n* due to missing values

processing. Statistical analyses were performed via Stata version 17 (Stata Corp. 2021).

4 Results

Regarding *H1* on TPACK, results show higher scores in the TPACK group at *t2* compared to *t1*, while the scores of the TPACK comparison group are almost unchanged, they even drop slightly (Table 3). Baseline scores at *t1* did not differ significantly between groups using a *t*-test (diff = 0.099, $t[119] = 0.229$, $p = 0.820$).

Investigating the data with a 2 × 2 ANOVA show a significant model ($F[3,122] = 13.53$, $p < 0.000$, $R^2 = 14.68\%$) with a significant main effect of group assignment, i.e., on average (over both measurement points) the groups differ significantly ($F[1,122] = 7.12$, $p = 0.008$) and a significant main effect of time, i.e., on average over both groups, the score increases between *t1* and *t2* ($F[1,122] = 7.63$, $p = 0.006$). Furthermore, there is a significant interaction effect of group assignment and measurement point ($F[1,122] = 8.89$, $p = 0.003$). The groups develop differently in terms of TPACK between *t1* and *t2*.

Figure 1 illustrates the changes in test scores of both groups between *t1* and *t2*. Partial η^2 indicates for the main effect of group assignment a small effect size of $\eta^2 = 0.029$, for the main effect of time of $\eta^2 = 0.031$, and for the interaction effect of $\eta^2 = 0.036$. Post-estimations indicate a significant change in the student group that

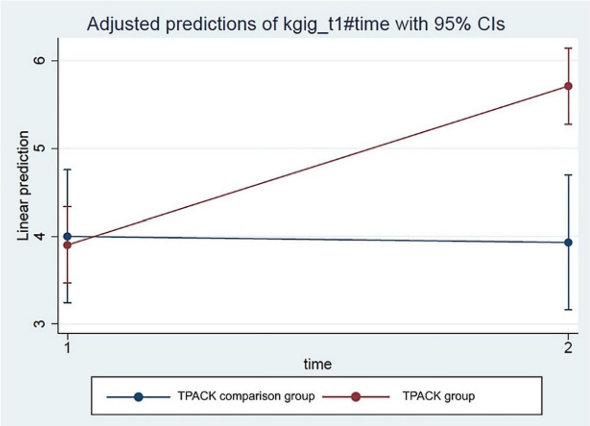


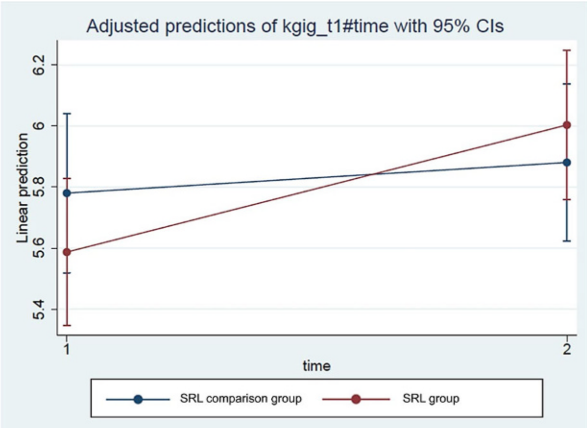
Fig. 1 Interaction Effect of Group Assignment and Time (*TPACK*)

Table 4 Descriptive Statistics SRL

Time	Group	Mean ± *SD*	*n*
t1	SRL group	5.59 ± 0.72	35
	SRL comparison group	5.78 ± 0.72	30
t2	SRL group	6.00 ± 0.62	34
	SRL comparison group	5.88 ± 0.82	31

Deviations of *n* due to missing values

Fig. 2 Interaction Effect of Group Assignment and Time (*SRL*)



processed the tools (diff = 1.81, t[1] = 5.79, $p < 0.001$) and no relevant change in the student group without tool processing (diff = –0.07, t[1] = –0.13, $p = 0.900$).

Regarding *H2* on SRL, results show higher scores in the SRL group at *t2* compared to *t1* (Table 4), while the scores of the SRL comparison group rise only weakly. Baseline scores at t1 did not differ significantly between groups using a *t*-test (diff = 0.193, $t[63] = 1.077$, $p = 0.286$).

Investigating the data with a 2 × 2 ANOVA shows a non-significant model ($F[3,67] = 2.04$, $p = 0.111$, $R^2 = 4.64\%$) with a non-significant main effect of group assignment, i.e., on average (over both measurement points) the groups do not differ ($F[1,67] = 0.08$, $p = 0.782$). However, the main effect of time is significant ($F[1,67] = 4.14$, $p = 0.044$). On average, across both groups, the SRL score increases from *t1* to *t2* assessments. There is a non-significant interaction effect of group assignment and measurement point, but the trend can be seen ($F[1,67] = 1.55$, $p = 0.215$).

Figure 2 illustrates the changes in test scores of both groups between *t1* and *t2*. Partial η^2 indicates for the main effect of time a small effect size of $\eta^2 = 0.032$. Post-estimations also indicate a significant change in the student group that processed the tools (diff = 0.416, $t[1] = 2.40$, $p = 0.018$)[2] and no relevant change in the student group without tool processing (diff = 0.100, $t[1] = 0.54$, $p = 0.588$).

[2] Due to the group differences in the characteristics of gender and completion of vocational training between the student group who have processed the tools and the student group without tool processing, it was

Table 5 Regression Analysis on Change in TPACK

Variables	*B*	*SE*	*p*
	$F(5,80) = 0.82$, $p = 0.541$, $R^2 = 0.049$		
Gender	0.135	0.595	0.240
Migration background	0.117	0.705	0.318
Native language	–0.063	0.530	0.587
Study phase	0.170	0.588	0.139
Vocational training	0.057	0.634	0.627

Regarding *H3* and *H5,* regression analysis provides insights on whether students in the TPACK group benefited equally from the processing and shows that students' characteristics have no significant influence on the change of TPACK, i.e. are not significant in terms of difference scores from *t1* to *t2* (Table 5). This indicates that the change of TPACK can be seen as independent of the characteristics considered.

Regarding *H4* and *H6*, the regression analysis shows that students' characteristics on gender, migration background, native language, and completion of a vocational training do not influence the score change. However, the study phase is significant in terms of difference score from *t1* to *t2*. The score increases more among students in the master's program than among bachelor students (Table 6). This indicates that students in the master's program benefited more from the processing of the learning tools on SRL than the students in the bachelor's program.

Students subjectively rate working with the TPACK and SRL learning tools. They are interested in the topics of the tools (TPACK: $x \pm SD = 3.17 \pm 0.773$; SRL: $x \pm SD = 3.56 \pm 1.014$; scale 1 "not at all" to 5 "very much") and consider working with the tools to be useful for their later work (TPACK: $x \pm SD = 2.97 \pm 0.726$; SRL: $x \pm SD = 3.53 \pm 1.163$; scale 1 "does not apply at all" to 5 "fully applies"[3]). The tools offer an added value (TPACK: $x \pm SD = 3.11 \pm 0.586$; SRL: $x \pm SD = 4.06 \pm 0.840$) and are an innovative addition to existing teaching in higher education (TPACK: $x \pm SD = 3.18 \pm 0.622$; SRL: $x \pm SD = 3.61 \pm 1.029$). Students rate independent learning positively (TPACK: $x \pm SD = 3.53 \pm 0.603$; SRL: $x \pm SD = 4.41 \pm 0.756$) and the intu-

Table 6 Regression Analysis on Change in SRL

Variables	*β*	*SE*	*p*
	$F(5,57) = 1.88$, $p = 0.112$, $R^2 = 0.142$		
Gender	–0.193	0.148	0.151
Migration background	–0.075	0.155	0.558
Native language	0.039	0.169	0.774
Study phase	0.313	0.141	0.016*
Vocational training	–0.118	0.158	0.363

investigated whether these characteristics have a significant influence on the difference score in the two groups to rule out the possibility that the different score change can be attributed to these characteristics. Regression analyses show that the two characteristics have no significant influence on the difference score in both groups.

[3] This 1 to 5 scaling was also used for the following ratings.

Table 7 Excerpts of Feedback

Answers on TPACK tool	
Clear formulations, very comprehensible learning videos, appropriate level of difficulty of the tasks, comprehensible solutions [...] *(ar09arv)*	
The videos are an interesting way to put yourself in the situation, an exciting change, and better than just text *(nn04dwo)*	
Different senses were addressed through the use of Word documents, videos, visualizations, and audio *(nd27dej)*	
Answers on SRL tool	
Good choice of content → job-related content aroused my interest *(an25ldh)*	
Varied tasks *(ud31ppn)*	
The clarity and variety of the learning method *(an21nds)*	

itive use (TPACK: $x \pm SD = 3.38 \pm 0.659$; SRL: $x \pm SD = 3.97 \pm 0.822$). They would recommend the tool to others (TPACK: $x \pm SD = 3.21 \pm 0.623$; SRL: $x \pm SD = 4.03 \pm 0.918$). Excerpts from the feedback are presented in Table 7.

5 Discussion

5.1 Summary and interpretation of the findings

The practice-oriented *TWIND* project aims to provide tailor-made learning opportunities in initial (economics) teacher education which can be easily and flexibly used in regular university courses and prepare students for the digital demands in the classroom at an early stage. In this study, we conducted analyses with group comparisons to show that the use of the digital tools on TPACK and SRL can support a positive change in the respective competence facets of student teachers' TPACK and SRL in a pre-post-assessment.

Our results indicate that the use of the digital tool on TPACK contributes to a significant positive change in student teachers' TPACK. The group with TPACK tool processing outperforms the group without TPACK tool processing. After using the digital tool on SRL, a positive change in student teachers' SRL is also evident; however, this change is not significant, which is contrary to our expectations and the findings of other studies (e.g., Kramarski and Michalsky 2010). Overall, these findings reflect the state of research from teacher education projects for specific domains which aimed to generate initial evidence on the effectiveness of new teaching and learning opportunities under the most realistic conditions possible for teaching and learning, and thereby contributing to further strengthening the evidence base in this field (e.g., Meier et al. 2023). For instance, in line with our findings, Lachner et al. (2021) confirmed the effectiveness of their TPACK modules regarding the acquisition of student teachers' content-specific TPACK, but not for the generic technological pedagogical knowledge (TPK). They see a possible explanation in a typical problem of instructional research, namely the difficulty of applying knowledge which is generated through subject-specific interventions to general teaching situations (Lachner et al. 2021). This could possibly explain our findings. While

TPACK was assessed as case-specific knowledge (Shulman 1986) using tasks that represent typical vocational classroom situations, the measurement of SRL relied on an instrument that represents general teaching situations (see 3.3.2). Regarding this, Kramarski and Michalsky (2010) emphasize the importance of a suitable instrument for measuring SRL that addresses an event-based digitalization context.

In line with conclusions of studies from other domains (e.g., Meier et al. 2023), the use of digital tools in business and economics education seems to make a valuable contribution in the first phase of teacher education, given the target competence facets are appropriately assessed. Digital tools seem to be particularly important when they consider overarching design features, e.g., authentic experiences, reflection, and feedback (e.g., the SQD-model by Tondeur et al. 2012), that were also implemented in our study. In this form, the digital tools provide students with the opportunity to adapt learned content to specific teaching and learning situations within a domain, e.g., which is illustrated through authentic videos, and to solve and reflect realistic problems from the perspective of a teacher (e.g., Brühwiler and Vogt 2020; Kramer et al. 2017).

Students subjective ratings of working with the digital tools also underline the perceived benefit of the tools as interesting and varied learning resources that add value to existing university teaching formats for long-term use, suggesting that a higher cognitive engagement with the learning materials can be expected (e.g., in line with the assumptions of the ICAP model, Chi and Wylie 2014; and the Cognitive Theory of Multimedia Learning, Mayer 2014).

With regard to other hypotheses, including possible influencing factors, the level of the competence facets revealed by TPACK and SRL were not influenced by gender, migration background, or native language, indicating that the student teachers benefited equally from the tool processing and are not disadvantaged by individual characteristics. These results are not in line with other studies where gender (e.g., Lin et al. 2013), and background effects (e.g., Käck et al. 2019) were found. Our results speak in favor for a heterogeneity-sensitive design (e.g. through gender-neutral language) implemented in the digital tools in our study (e.g., Brodesser et al. 2020).

In line with our hypotheses, there was a significant influence of the study phase on the change of the SRL score in the SRL group, but not, as expected, on the TPACK score change in the TPACK group. Contrary to our assumption, completing vocational training didn't have any influence either on the TPACK score change in the TPACK group or on the SRL score change in the SRL group, which could be due to the specific teacher education-related content of both tools. Regarding the TPACK results, one explanation could be the focus on the ICAP and SAMR models in the TPACK tool. This content can be considered quite specific and may not have been explicitly covered in vocational training (e.g., KMK 2023) or university education before (e.g., JGU 2023). At the same time, the SRL tool covers fundamental content (e.g. learning strategies) that the students have already covered in previous semesters, and can be linked with prior teacher knowledge (e.g., JGU 2023).

5.2 Limitations and implications for future research

The results provide initial indications that digital learning tools can be used in teacher training to contribute to the promotion of central competence facets. However, the study was designed as a field project in teacher education which explains the small groups attending the courses in these study programs, and, thus, limitations in the interpretation of the results, especially regarding the influence of the tools on competence change. To overcome the limitations of the study, which are inherent in (digital) training in real educational (non-experimental) settings (e.g., Meier et al. 2023), a follow-up study in which the digital tools on TPACK and SRL are implemented in a laboratory setting is being planned to obtain more generalizable results. With regard to Kramarski and Michalsky (2010), the question of the extent to which a combined training with the TPACK *and* SRL tools can make a more fundamental contribution to the promotion of student teachers' TPACK and SRL should be investigated.

As the fit indices for measuring TPACK and SRL as unidimensional constructs are insufficient, the measurement instruments must be optimized to ensure a reliable and valid assessment of the targeted competence facets. For instance, for the rather broad conceptual construct definition of TPACK, additional items should be developed and evaluated for their diagnostic quality.

In follow-up studies, digital learning tools, which focus on further competence facets (e.g., conversational skills and dealing with ChatGPT, Frank et al. 2024), are also to be included regarding their potential to extensively prepare for the professional demands in classroom at an early stage. In addition, deeper analyses are needed to better understand the internal and external conditions of knowledge and skill development using the tools. Thus, the next steps include the labor-based evaluation of digital tools and the identification of central factors influencing teacher competence change in digital interventions.

5.3 Conclusion

Despite the limitations, intervention studies with the tools in the experimental settings cannot replace field studies in real contexts as in the context of *Qualitative Offensive in Teacher Education* (Meier et al. 2023), if insights are to be gained into the usefulness of digital tools in educational practice, as in our study, where all learning tools are to be transferred into regular teacher training (and uploaded online as Open Educational Resources).

Our findings, consistent with prior research (König et al. 2022), indicate that the use of multimodal tools and their integration in teacher education is crucial for addressing the challenges of diverse digital learning environments and students' preconditions. The findings presented suggest that engaging pre-service teachers in multimedia-based learning activities can provide practical insights to support their preparation for professional teaching. This approach provides for more effective and individualized learning opportunities across domains of teacher education in each study phase, helping to cater to students' diverse needs, reduce knowledge gaps, and promote professionalism (for more details on cross-disciplinary tools such as communication and multilingualism in classrooms and on the results of their use in other domains of teacher education, see Reichert-Schlax et al. 2023).

Overall, this study contributes to the provision of digital training tools that approximate real-life situations in the teaching profession. To sustainably improve teacher education, the learning tools help teachers to prepare for professional practice, e.g., to meet the high demands of everyday teaching. The development of these tools and their implementation in teacher education are particularly relevant regarding the (current and future) challenges of digital learning. Since all learning tools are based on internationally established teacher competence models, they can therefore be adapted and used in the U.S. and internationally, as has become evident in previous international collaborative projects (Day et al. 2022). This can be an important contribution to the professionalism-oriented preparation of teacher students in higher education.

Acknowledgements We would like to thank the reviewers and the editors for their valuable feedback and comments, which have contributed significantly to improving the article.

Funding This research was funded by the *Qualitative Offensive in Teacher Education* of the German Federal Ministry of Education and Research (BMBF) under grant no. 01JA2042A.

Funding Open Access funding enabled and organized by Projekt DEAL.

Conflict of interest C. Kuhn, K. Depré, O. Zlatkin-Troitschanskaia and J. Reichert-Schlax declare that they have no competing interests.

References

Adam-Gutsch, D., Paschel, F., Ophardt, D., & Huck, J. (2021). *Studieren im Corona-Online-Semester. Bericht zur Befragung der Lehramtsstudierenden der Technischen Universität Berlin im Sommersemester 2020*. Berlin: Technische Universität. https://doi.org/10.14279/depositonce-11343.

AERA (American Educational Research Association), APA (American Psychological Association), & NCME (National Council on Measurement in Education) (2014). *Standards for educational and psychological testing*. AERA.

Angeli, C., Valanides, N., & Christodoulou, A. (2016). Theoretical considerations of technological pedagogical content knowledge. In M. C. Herring, M. J. Koehler & P. Mishra (Eds.), *Handbook of Technological Pedagogical Content Knowledge (TPACK) for Educators* (2nd edn., pp. 11–32). Routledge.

Baumert, J., & Kunter, M. (2011). Das Kompetenzmodell von COACTIV. In M. Kunter, J. Baumert, W. Blum, U. Klusmann, S. Krauss & M. Neubrand (Eds.), *Professionelle Kompetenz von Lehrkräften. Ergebnisse des Forschungsprogramms COACTIV* (pp. 29–53). Waxmann.

Bellhäuser, H., Lösch, T., Winter, C., & Schmitz, B. (2016). Applying a web-based training to foster self-regulated learning—Effects of an intervention for large numbers of participants. *Internet and Higher Education*, *31*, 87–100. https://doi.org/10.1016/j.iheduc.2016.07.002.

Blömeke, S., Gustafsson, J.-E., & Shavelson, R.J. (2015). Beyond dichotomies: Competence viewed as a continuum. *Zeitschrift für Psychologie*, *223*(1), 3–13. https://doi.org/10.1027/2151-2604/a000194.

Bloom, B.S., Engelhart, M.D., Furst, E.J., Hill, W.H., & Krathwohl, D.R. (1956). *Taxonomy of educational objectives: the classification of educational goals: handbook I: cognitive domain*. David McKay.

Bratterud, H., Burgess, M., Fasy, B.T., Millman, D.L., Oster, T., & Sung, E.C. (2020). The sung diagram: revitalizing the eisenhower matrix. In A.-V. Pietarinen, P. Chapman, L. Bosveld-de Smet, V. Giardino, J. Corter & S. Linker (Eds.), *Diagrammatic representation and inference* (pp. 498–502). Springer.

Broadbent, J., & Poon, W.L. (2015). Self-regulated learning strategies & academic achievement in online higher education learning environments: a systematic review. *The Internet and Higher Education*, *27*, 1–13.

Brodesser, E., Frohn, J., Welskop, N., Liebsch, A.-C., Moser, V., & Pech, D. (2020). *Inklusionsorientierte Lehr-Lern-Bausteine für die Hochschullehre. Ein Konzept zur Professionalisierung zukünftiger Lehrkräfte*. Julius Klinkhardt.

Bromme, R. (2008). Lehrerexpertise: teacher's skills. In W. Schneider & M. Hasselhorn (Eds.), *Handbuch der Pädagogischen Psychologie* (pp. 159–167). Hogrefe.

Brückner, S., Saas, H., Reichert-Schlax, J., Zlatkin-Troitschanskaia, O., & Kuhn, C. (2021). Digitale Medienpakete zur Förderung handlungsnaher Unterrichtskompetenzen von angehenden Lehrkräften mit Fach Wirtschaft. *Berufs- und Wirtschaftspädagogik online, 40*. https://www.bwpat.de/ausgabe40/brueckner_etal_bwpat40.pdf.

Brückner, S., Frank, K., Zlatkin-Troitschanskaia, O., Schell, M., Liederbach, N., Reichert-Schlax, J., & Kuhn, C. (2024). Digitale Medienpakete für Lehramtsstudierende, Referendar:innen und Lehrkräfte (TWIND Broschüre). Technik & Wirtschaft: Integrierte Didaktik. https://openedu-rlp.de/edu-sharing/components/render/5b234ab0-bbe1-4788-83ee-adecb99bf876.

Brühwiler, C., & Vogt, F. (2020). Adaptive teaching competency. Effects on quality of instruction and learning outcomes. *Journal for Educational Research*, *12*(1), 119–142. https://www.pedocs.de/frontdoor.php?source_opus=19121.

Bruso, J., Stefaniak, J., & Bol, L. (2020). An examination of personality traits as a predictor of the use of self-regulated learning strategies and considerations for online instructions. *Educational Technology Research and Development*, *68*, 2659–2683.

Butler, D.L., Lauscher, H.N., Jarvis-Selinger, S., & Beckingham, B. (2004). Collaboration and self-regulation in teachers' professional development. *Teaching and Teacher Education*, *20*(5), 435–455. https://doi.org/10.1016/j.tate.2004.04.003.

BWP (Sektion Berufs- und Wirtschaftspädagogik) (2014). Basiscurriculum für das universitäre Studienfach Berufs- und Wirtschaftspädagogik im Rahmen berufs- und wirtschaftspädagogischer Studiengänge. https://www.dgfe.de/fileadmin/OrdnerRedakteure/Sektionen/Sek07_BerWiP/2014_Basiscurriculum_BWP.pdf

Carlson, J., & Daehler, K.R. (2019). The refined consensus model of pedagogical content knowledge in science education. In A. Hume, R. Cooper & A. Borowski (Eds.), *Repositioning pedagogical content knowledge in teachers' knowledge for teaching science* (pp. 77–92). Springer. https://doi.org/10.1007/978-981-13-5898-2_2.

Chi, M.T.H., & Wylie, R. (2014). The ICAP framework. Linking cognitive engagement to active learning outcomes. *Educational Psychologist*, *49*(4), 219–243.

Day, S.H., Kuhn, C., & Saas, H. (2022). Evaluating and developing teacher instructional practices in economics using a new video-based test. *The Journal of Social Studies Research*, *46*(4), 379–393. https://doi.org/10.1016/j.jssr.2021.09.006.

Eckerlein, N., Dresel, M., Steuer, G., Foerst, N.M., Ziegler, A., Schmitz, B., Spiel, C., & Schober, B. (2020). Modelling, assessing, and promoting competences for self-regulated learning in higher education. In O. Zlatkin-Troitschanskaia, H. Pant, M. Toepper & C. Lautenbach (Eds.), *Student learning in German higher education: Innovative measurement approaches and research results* (pp. 165–179). SpringerLink.

Ertmer, P.A., & Ottenbreit-Leftwich, A.T. (2010). Teacher technology change: How knowledge, confidence, beliefs, and culture intersect. *Journal of Research on Technology in Education*, *42*(3), 255–284.

Frank, K., Zlatkin-Troitschanskaia, O., Brückner, S., Schell, M., Liederbach, N., Dormann, C., & Reichert-Schlax, J. (2023). Evaluation of multimedia teaching-learning tools to promote the media-didactic knowledge of student teachers in teacher education. *Lehrerbildung auf dem Prüfstand*, *16*(2), 144–163.

Frank, K., Kuhn, C., Zlatkin-Troitschanskaia, O., & Brückner, S. (2024). Digitale Lehr-Lerntools für eine praxisnahe Lehrkräftebildung – Umgang mit ChatGPT im Unterricht. *SEMINAR*, *3*(30), 72–82. https://doi.org/10.3278/SEM2403W.

Gartmeier, M. (2014). Fiktionale Videofälle in der Lehrerinnen- und Lehrerbildung. *Beiträge zur Lehrerinnen- und Lehrerbildung*, *32*(2), 235–246. https://doi.org/10.25656/01:13868.

Gerber, S., Quarder, J., Greefrath, G., & Siller, H.-S. (2023). Promoting adaptive intervention competence for teaching simulations and mathematical modelling with digital tools: theoretical background and empirical analysis of a university course in teacher education. *Frontiers in Education*, *8*, 1141063. https://doi.org/10.3389/feduc.2023.1141063.

Götz, T., Nett, U. E., & Hall, N. C. (2013). Self-regulated learning. In N. C. Hall & T. Götz (Eds.), *Emotion, motivation, and self-regulation: A handbook for teachers* (pp. 123–166). Emerald.

Grassinger, R., Bernhard, G., Müller, W., Schnebel, S., Stratmann, J., Weitzel, H., Aumann, A., Gaidetzka, M., Günther, V., Heiberger, L., Mustaca, M., Schmidt, C., & Visotschnig, M. S. (2022). Fostering digital media-related competences of student teachers. *SN Computer Science*, *3*(4), 258–264. https://doi.org/10.1007/s42979-022-01135-8.

Hamilton, E. R., Rosenberg, J. M., & Akcaoglu, M. (2016). The substitution augmentation modification redefinition (SAMR) model: a critical review and suggestions for its use. *TechTrends*, *60*, 433–441. https://doi.org/10.1007/s11528-016-0091-y.

Heine, S., Krepf, M., & König, J. (2023). Digital resources as an aspect of teacher professional digital competence: one term, different definitions—a systematic review. *Education and Information Technologies*, *28*, 3711–3738. https://doi.org/10.1007/s10639-022-11321-z.

Hilton, J. T. (2016). A case study of the application of SAMR and TPACK for reflection on technology integration into two social studies classrooms. *The Social Studies*, *107*(2), 68–73. https://doi.org/10.1080/00377996.2015.1124376.

Jentsch, A., Doll, J., Stangen, I., Meyer, D., & Kaiser, G. (2021). Die Bedeutung von sprachbezogenen Merkmalen und von in universitären Lerngelegenheiten genutzten Studieninhalten für den Wissenserwerb von Lehramtsstudierenden. *Journal for Educational Research Online*, *13*(2), 5–29. https://doi.org/10.25656/01:24156.

JGU (Johannes Gutenberg-Universität Mainz) (2023). Modulhandbuch Master of Education Wirtschaftspädagogik. https://studienbuero.rewi.uni-mainz.de/downloads/?folder=WiWi/WiP%C3%A4d_Master%20of%20Education/Studiengang.

Jinalee, N., & Singh, A. K. (2018). A descriptive study of time management models and theories. *International Journal of Advanced Scientific Research and Management*, *3*(9), 141–147.

Joseph, N. (2006). Strategies for success: teaching metacognitive skills to adolescent learners. *New England reading association journal*, *42*(1), 33–39.

Käck, A., Barbutiu, S. M., & Fors, U. (2019). Migrant teachers' self-estimated digital competence: a study within Swedish teacher education. *Contemporary Issues in Technology and Teacher Education*, *19*(2), 256–278. https://www.learntechlib.org/primary/p/187409/paper_187409.pdf.

Kersting, N. B., Sutton, T., Kalinec-Craig, C., Stoehr, K. J., Heshmati, S., Lozano, G., & Stigler, J. W. (2016). Further exploration of the classroom video analysis (CVA) instrument as a measure of usable knowledge for teaching mathematics: taking a knowledge system perspective. *ZDM Mathematics Education*, *48*(1–2), 97–109. https://doi.org/10.1007/s11858-015-0733-0.

Kleinknecht, M., Schneider, J., & Syring, M. (2014). Varianten videobasierten Lehrens und Lernens in der Lehrpersonenaus- und -fortbildung – Empirische Befunde und didaktische Empfehlungen zum Einsatz unterschiedlicher Lehr-Lern-Konzepte und Videotypen. *Beiträge zur Lehrerinnen- und Lehrerbildung*, *32*(2), 210–220. https://doi.org/10.25656/01:13866.

Klusmann, U. (2013). Occupational self-regulation. In M. Kunter, J. Baumert, W. Blum, U. Klusmann, S. Krauss & M. Neubrand (Eds.), *Cognitive activation in the mathematics classroom and professional competence of teachers. Results from the COACTIV project* (pp. 291–308). Springer.

KMK (2023). Rahmenlehrplan für den Ausbildungsberuf Industriekaufmann und Industriekauffrau (Beschluss der Kultusministerkonferenz vom 15.12.2023). https://www.bibb.de/dienst/berufesuche/de/index_berufesuche.php/profile/apprenticeship/indust24

Koehler, M. J., & Mishra, P. (2009). What is technological pedagogical content knowledge? *Contemporary Issues in Technology and Teacher Education (CITE Journal)*, *9*(1), 60–70.

König, J., & Pflanzl, B. (2016). Is teacher knowledge associated with performance? On the relationship between teachers' general pedagogical knowledge and instructional quality. *European Journal of Teacher Education*, *16*(39), 419–436.

König, J., Jäger-Biela, D. J., & Glutsch, N. (2020). Adapting to online teaching during COVID-19 school closure: teacher education and teacher competence effects among early career teachers in Germany. *European Journal of Teacher Education*, *43*(4), 608–622.

König, J., Heine, S., Jäger-Biela, D., & Rothland, M. (2022). ICT integration in teachers' lesson plan: a scoping review of empirical studies. *European Journal of Teacher Education*. https://doi.org/10.1080/02619768.2022.2138323.

Kramarski, B., & Michalsky, M. (2009). Investigating preservice teachers' professional growth in self-regulated learning environments. *Journal of Educational Psychology*, *101*(1), 161–175.

Kramarski, B., & Michalsky, T. (2010). Preparing preservice teachers for self-regulated learning in the context of technological pedagogical content knowledge. *Learning and Instruction*, *20*(5), 434–447.

Kramer, C., König, J., Kaiser, G., Ligtvoet, R., & Blömeke, S. (2017). Der Einsatz von Unterrichtsvideos in der universitären Ausbildung: Zur Wirksamkeit video- und transkriptgestützter Seminare zur Klassenführung auf pädagogisches Wissen und situationsspezifische Fähigkeiten angehender Lehrkräfte. *Zeitschrift für Erziehungswissenschaft*, *20*(1), 137–164. https://doi.org/10.1007/s11618-017-0732-8.

Krammer, K., & Reusser, K. (2005). Unterrichtsvideos als Medium der Aus- und Weiterbildung von Lehrpersonen. *Beiträge zur Lehrerbildung*, *23*(1), 35–50. https://doi.org/10.25656/01:13561.

Krauss, S. (2011). Das Experten-Paradigma in der Forschung zum Lehrerberuf. In E. Terhart, H. Bennewitz & M. Rothland (Eds.), *Handbuch der Forschung zum Lehrerberuf* (pp. 171–191). Waxmann.

Lachner, A., Fabian, A., Franke, U., Preiß, J., Jacob, L., Führer, C., Küchler, U., Paravicini, W., Randler, C., & Thomas, P. (2021). Fostering pre-service teachers' technological pedagogical content knowledge (TPACK): a quasi-experimental field study. *Computers & Education*, *174*, 104304. https://doi.org/10.1016/j.compedu.2021.104304.

Lange, S., & Frommberger, S. (2017). Zur Ausgestaltung schulischer Praxisphasen im beruflichen Lehramtsstudium – Ergebnisse einer ersten Analyse. In J. Seifried, S. Seeber & B. Ziegler (Eds.), *Jahrbuch der berufs- und wirtschaftspädagogischen Forschung 2017* (pp. 113–128). Barbara Budrich. https://doi.org/10.25656/01:18420.

Lee, M. Y. (2021). Improving preservice teachers' noticing skills through technology-aided interventions in mathematics pedagogy courses. *Teaching and Teacher Education*, *101*, 103301.

Lehr, D., Hillert, A., & Keller, S. (2009). What can balance the effort? Associations between effort-reward imbalance, overcommitment, and affective disorders in German teachers. *International Journal of Occupational and Environmental Health*, *15*(4), 374–384.

Leiner, D. J. (2019). SoSci Survey (Version 3.1.06) [Software]. https://www.soscisurvey.de

Lin, T.-C., Tsai, C.-C., Chai, C. S., & Lee, M.-H. (2013). Identifying science teachers' perceptions of technological pedagogical and content knowledge (TPACK). *Journal of Science Education and Technology*, *22*, 325–336. https://doi.org/10.1007/s10956-012-9396-6.

Mattern, J. (2012). Selbstregulation im Lehrberuf: Entwicklung eines Trainings für angehende Lehrkräfte. *Unterrichtswissenschaft*, *40*(2), 156–173.

Mattern, J., & Bauer, J. (2014). Does teachers' cognitive self-regulation increase their occupational well-being? The structure and role of self-regulation in the teaching context. *Teaching and Teacher Education*, *43*, 58–68.

Mayer, R. E. (2014). Cognitive theory of multimedia learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (2nd edn., pp. 43–71). Cambridge University Press. https://doi.org/10.1017/CBO9781139547369.005.

Meier, M., Greefrath, G., Hammann, M., Wodzinski, R., & Ziepprecht, K. (2023). Lehr-Lern-Labore und Digitalisierung. Strömungen und Veränderungen in der Lehr-Lern-Labor-Landschaft als Folge des digitalen Wandels. In M. Meier, G. Greefrath, M. Hammann, R. Wodzinski & K. Ziepprecht (Eds.), *Lehr-Lern-Labore und Digitalisierung* (pp. 1–16). Springer VS. https://doi.org/10.1007/978-3-658-40109-2.

Michalsky, T. (2012). Shaping self-regulation in science teachers' professional growth: Inquiry skills. *Science Education*, *96*(6), 1106–1133. https://doi.org/10.1002/sce.21029.

Minea-Pic, A. (2020). *Innovating teachers' professional learning through digital technologies* (OECD Education Working Papers No. 237). OECD Publishing. https://doi.org/10.1787/3329fae9-en.

Mislevy, R. J., & Riconscente, M. M. (2006). Evidence-centered assessment design. In S. M. Downing & T. M. Haladyna (Eds.), *Handbook of test development* (pp. 61–90). Mahwah: Erlbaum. https://fatihegitim.wordpress.com/wp-content/uploads/2014/03/hndb-t-devt.pdf.

Muñiz-Rodríguez, L., Alonso, P., Rodríguez-Muñiz, L. J., De Coninck, K., Vanderlinde, R., & Valcke, M. (2018). Exploring the effectiveness of video-vignettes to develop mathematics student teachers'

feedback competence. *EURASIA Journal of Mathematics, Science and Technology Education*, *14*(9), em1573. https://doi.org/10.29333/ejmste/92022.
Paris, S. G., & Winograd, P. (2003). *The role of self-regulated learning in contextual teaching: principles and practices for teacher preparation*. Office of Educational Research and Improvement. https://files.eric.ed.gov/fulltext/ED479905.pdf
Peeters, J., De Backer, F., Reina, V. R., Kindekens, A., Buffel, T., & Lombaerts, K. (2014). The role of teachers' self-regulatory capacities in the implementation of self-regulated learning practices. *Procedia—Social and Behavioral Sciences*, *116*, 1963–1970. https://doi.org/10.1016/j.sbspro.2014.01.504.
Pellegrino, J. W. (2012). The design of an assessment system focused on student achievement. A learning sciences perspective on issues of competence, growth and measurement. In S. Bernholt, K. Neumann & P. Nentwig (Eds.), *Making it tangible—Learning outcomes in science education* (pp. 79–107). Waxmann.
Puentedura, R. (2013). *SAMR: Getting to Transformation.* Hippasus. http://www.hippasus.com/rrpweblog/archives/2013/04/16/SAMRGettingToTransformation.pdf
Redecker, C., & Punie, Y. (2017). *European framework for the digital competence of educators: DigCompEdu*. Publications Office of the European Union. https://doi.org/10.2760/159770.
Reichert-Schlax, J., Zlatkin-Troitschanskaia, O., Frank, K., Brückner, S., Schneider, M., & Müller, A. (2023). Development and evaluation of digital learning tools promoting applicable knowledge in economics and German teacher education. *Education Sciences*, *13*(5), 481. https://www.mdpi.com/2227-7102/13/5/481.
Saas, H., Kuhn, C., & Zlatkin-Troitschanskaia, O. (2020). Ein videobasiertes Lehr-Lernformat als innovativer hochschuldidaktischer Ansatz in der wirtschaftspädagogischen Lehramtsausbildung. In I. Gogolin, B. Hannover & A. Scheunpflug (Eds.), *Evidenzbasierung in der Lehrkräftebildung* (pp. 315–340). Springer VS.
Schmidt, J., Klusmann, U., Lüdke, O., Möller, J., & Kunter, M. (2017). What makes good and bad days for beginning teachers? A diary study on daily uplifts and hassles. *Contemporary Educational Psychology*, *48*, 85–97.
Seidel, T., & Thiel, F. (2017). *Videobasierte Unterrichtsforschung. Analysen von Unterrichtsqualität, Gestaltung von Lernangelegenheiten und Messung professionellen Wissens* (pp. 137–164). Springer VS.
Senkbeil, M., Ihme, J. M., & Schöber, C. (2019). Wie gut sind angehende und fortgeschrittene Studierende auf das Leben und Arbeiten in der digitalen Welt vorbereitet? Ergebnisse eines Standard Setting-Verfahrens zur Beschreibung von ICT-bezogenen Kompetenzniveaus. *Zeitschrift für Erziehungswissenschaft*, *22*(1), 1359–1384. https://doi.org/10.1007/s11618-019-00914-z.
Shulman, L. S. (1986). Those who understand: knowledge growth in teaching. *Educational Researcher*, *15*(2), 4–14. https://doi.org/10.3102/0013189X015002004.
Shulman, L. S. (1987). Knowledge and teaching: foundations of the new reform. *Harvard Educational Review*, *57*(1), 1–23. https://doi.org/10.17763/haer.57.1.j463w79r56455411.
Stata Corp (2021). *Stata statistical software: Release 17*. StataCorp LLC. Software
Thiel de Gafenco, M., & Klusmeyer, J. (2023). Fach- und mediendidaktische Verschränkung digitaler Lern- und Arbeitsmittel. In M. Meier, G. Greefrath, M. Hammann, R. Wodzinski & K. Ziepprecht (Eds.), *Lehr-Lern-Labore und Digitalisierung* (pp. 255–268). Springer VS. https://doi.org/10.1007/978-3-658-40109-2_25.
Tondeur, J., van Braak, J., Sang, G., Voogt, J., Fisser, P., & Ottenbreit-Leftwich, A. (2012). Preparing pre-service teachers to integrate technology in education: a synthesis of qualitative evidence. *Computers & Education*, *59*(1), 134–144. https://doi.org/10.1016/j.compedu.2011.10.009.
Wekerle, C., & Kollar, I. (2022). Using technology to promote student learning? An analysis of pre- and in-service teachers' lesson plans. *Technology, Pedagogy and Education*, *31*(5), 597–614.
Wissenschaftsrat (2022). Empfehlungen zur Digitalisierung in Lehre und Studium. https://www.wissenschaftsrat.de/download/2022/9848-22.pdf?__blob=publicationFile&v=12
Zimmermann, B. J. (2000). Attaining self-regulation: A social cognitive perspective. In M. Boekaerts, P. R. Pintrich & M. Zeidner (Eds.), *Handbook of self-regulation* (pp. 13–39). Academic Press.