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Processing Evidence-Based Information for Mathematics and Science Teachers Using the Example of Teaching and Learning with Digital Tools

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Abstract

Over the past decades, evidence-based approaches have emerged in some disciplines, including education. According to this approach, practitioners are expected to base their actions and decisions on empirical evidence, which can be associated with various challenges at the same time. Corresponding research results are usually addressed to the respective scientific community in content and form. Understanding and applying the relevant content requires skills and resources that actors in educational practice, such as teachers, often do not possess to an adequate extent. To counteract this problem, various efforts have been made to appropriately prepare relevant research findings and make them more accessible to educational practitioners. To date, there is little research on how these efforts serve the desired purpose or on specific formats to promote evidence-based practice in education.

This dissertation project addressed the aforementioned research gap using a mixed-method approach. The present framework paper encompasses two main publications that form the basis of this dissertation and associated publications that are briefly described. The study in Publication A is a comprehensive meta-analysis on the use of digital tools in secondary school mathematics and science education—as a practice-relevant topic in particular need of evidence-based information. Data were based on 117 effect sizes from a total of k = 92 systematically obtained primary studies. Moderator analyses also examined contextual factors with practical relevance. The results show significant positive effects of learning with digital tools regarding both academic performance and students' attitudes toward the subject taught. The provision of teacher training on digital tool use proved to be a significant moderator variable. These and other practice-relevant findings of the meta-analysis were presented in a separate practice brochure as an evidence-based source for teachers of mathematics and science subjects. Publication B presents an interview study in which the aforementioned target group of teachers (N = 12) was asked about the relevance of evidence-based information, its use, and concomitant barriers. The data analysis shows that although the overall relevance is considered high, the actual use in practice is low. According to the analyses, an essential quality indicator of evidence-based information is the applicability of the findings. Based on the findings of the interview study, the potential of evidence-based formats such as the practice brochure is discussed. In summary, the research project results show that teachers should be supported in implementing evidence-based practice through appropriate formats. As illustrated by the holistic approach in the present dissertation, one possibility is processing evidence-based information in the practice brochure format based on practice-relevant findings from research syntheses.

Zusammenfassung

Evidenzbasierte Ansätze haben sich in den letzten Jahrzehnten in verschiedenen Fachbereichen entwickelt und so auch im Bildungsbereich. Demnach sollen Praktikerinnen und Praktiker ihr Handeln und ihre Entscheidungen auf empirische Evidenz stützen, was gleichzeitig mit verschiedenen Herausforderungen verbunden sein kann. Entsprechende Forschungsergebnisse sind in der Regel an die jeweilige Wissenschaftsgemeinschaft adressiert – sowohl inhaltlich als auch formal. Das Verstehen und Anwenden entsprechender Inhalte erfordert Kompetenzen und Ressourcen, die Akteurinnen und Akteuren der Bildungspraxis wie Lehrkräften häufig nicht in ausreichendem Maße zur Verfügung stehen. Um diesem Problem entgegenzuwirken wurden verschiedene Anstrengungen unternommen, relevante Forschungsergebnisse auf eine geeignete Art und Weise aufzubereiten und für Bildungspraktikerinnen und -praktiker leichter zugänglich zu machen. Die Wirksamkeit dieser Anstrengungen sowie konkrete Formate zur Förderung einer evidenzbasierten Praxis sind bislang wenig beforscht.

In diesem Promotionsprojekt wurde sich der genannten Forschungslücke mittels eines Mixed-Method-Ansatzes gewidmet. Die vorliegende Rahmenschrift umfasst zwei Publikationen, die die Grundlage dieser Dissertation darstellen sowie daran anknüpfende Publikationen, die kurz beschrieben werden. Im Rahmen der Studie in Publikation A wurde eine umfassende Metaanalyse zum Einsatz digitaler Tools im mathematisch-naturwissenschaftlichen Unterricht der Sekundarstufe durchgeführt – als ein praxisrelevantes Thema mit besonderem Bedarf an evidenzbasierten Informationen. Die Daten basierten auf 117 Effektgrößen aus insgesamt $k = 92$ systematisch gewonnenen Primärstudien. Im Rahmen von Moderatoranalysen wurden auch praxisrelevante Kontextfaktoren beim Einsatz digitaler Tools im Unterricht untersucht. Die Ergebnisse zeigen signifikant positive Effekte beim Lernen mit digitalen Tools sowohl in Bezug auf die Leistung als auch die Einstellung der Schülerinnen und Schüler zum entsprechenden Unterrichtsfach. Als signifikante Moderatorvariable erwies sich die Durchführung von Lehrkräftetrainings zum verwendeten Tool. Diese und weitere durch die Metaanalyse gewonnene praxisrelevante Erkenntnisse wurden in einer separaten Praxisbroschüre als evidenzbasierte Quelle für Lehrkräfte der Mathematik und Naturwissenschaften aufbereitet. In Publikation B wird eine Interviewstudie präsentiert, in der die genannte Zielgruppe der Lehrenden ($N = 12$) zur Relevanz evidenzbasierter Informationen, ihrer Nutzung sowie damit einhergehenden Schwierigkeiten befragt wurde. Die Analyse der Daten zeigte, dass die Relevanz zwar insgesamt als hoch eingeschätzt wird, die tatsächliche Nutzung in der Praxis jedoch gering ausfällt. Ein wesentliches Qualitätsmerkmal evidenzbasierter Informationen ist laut der Analysen die Anwendbarkeit der Erkenntnisse.

Basierend auf den Erkenntnissen der Interviewstudie werden die Potenziale evidenzbasierter Formate wie das der Praxisbroschüre diskutiert. Zusammenfassend zeigen die Ergebnisse des Forschungsprojekts, dass Lehrkräfte in der Umsetzung evidenzbasierter Praxis durch geeignete Formate unterstützt werden sollten. Wie durch den holistischen Ansatz dieser Arbeit veranschaulicht wurde, ist eine Möglichkeit hierfür die Aufbereitung evidenzbasierter Informationen im Format der Praxisbroschüre auf der Grundlage praxisrelevanter Erkenntnisse aus Forschungssynthesen.

Included and Associated Publications

Included Publications

Hillmayr, D., Ziernwald, L., Reinhold, F., Hofer, S. I. & Reiss, K. M. (2020). The potential of digital tools to enhance mathematics and science learning in secondary schools: A context-specific meta-analysis. *Computers & Education, 153*, 103897*.*
doi: 10.1016/j.compedu.2020.103897 (Publication A)

Hillmayr, D., Reinhold, F., Holzberger, D., & Reiss, K. (2024). STEM teachers' beliefs about the relevance and use of evidence-based information in practice: a case study using thematic analysis. *Frontiers in Education, 8*, 1261086.
doi: 10.3389/feduc.2023.1261086 (Publication B)

Associated Publications

Hillmayr, D., Reinhold, F., Ziernwald, L., Hofer, S.I., Reiss, K. (2023). Zum Zusammenhang zwischen Leistungs- und Motivationseffekten beim Einsatz digitaler Tools im mathematisch-naturwissenschaftlichen Unterricht der Sekundarstufe. Eine Forschungssynthese. In K. Scheiter & I. Gogolin (Eds.), *Bildung für eine digitale Zukunft. Edition ZfE* (Vol. 15, pp. 103-123). Wiesbaden: Springer VS. doi: 10.1007/978-3-658-37895-0_5

Hillmayr, D., Reinhold, F., Ziernwald, L. & Reiss, K. (2017). *Digitale Medien im mathematisch-naturwissenschaftlichen Unterricht der Sekundarstufe. Einsatzmöglichkeiten, Umsetzung und Wirksamkeit*. Waxmann. https://waxmann.com/buch3766

Hillmayr, D., Reinhold, F. & Reiss, K. (2022). Das Potenzial digitaler Tools für einen qualitätsvollen Unterricht: Ein Blick auf aktuelle Forschungsbefunde. *SchulVerwaltung spezial, 1*, 34-36.

Reiss, K. & Hillmayr, D. (2018). Wirksamkeit digitaler Medien im mathematisch-naturwissenschaftlichen Unterricht: Eine Analyse des aktuellen Forschungsstands. *SchulVerwaltung spezial, 4*, 178-180.

Contents

1 Introduction

We live in a fast-moving, consumer-oriented society where more and more sources of information are available, thanks to innovative technologies and centuries of scientific effort. As a result, abilities to search, select, understand, and evaluate relevant information has never been more important. In the field of education, in particular, where actions of (individual) stakeholders can substantially influence the development and success of learning individuals, a sound foundation for decision-making is essential. Evidence-based practice in education has thus become a hot topic in recent decades (e.g., Bauer et al., 2015; Schiepe-Tiska et al., 2021). Mosteller (2004) stated that "findings from educational research may be our greatest resource for supporting and improving educational practice" (Mosteller, 2004, p. 29). There is a consensus among politicians, researchers, and educators that practitioners such as teachers should base their decisions and actions on evidence-based findings rather than solely on subjective experiential knowledge (Bauer et al., 2015; Bromme et al., 2014). However, prior studies showed that the use of evidence-based information among teachers is generally relatively low (Dagenais et al., 2012; Hetmanek et al., 2015). According to Barnat (2019), seeking out relevant evidence-based information is not an action that belongs to teachers' daily routines. Instead, they tend to actively search for such information if they face a specific problem.

An evidence-based practice, which means considering "the best available research and data before adopting programs or practices that will affect significant numbers of students" (Whitehurst, 2004, p. 1), comes along with several prerequisites like availability of relevant sources, skills as well as time resources to search, interpret, and eventually apply the information (Lysenko et al., 2014; Thomm et al., 2021a). Moreover, teachers' individual experiences and attitudes toward using and evaluating evidence play an important role. For example, according to Thomm et al. (2021b), teachers tend to devaluate "educational research when scientific evidence contradicts (…) prior beliefs" (Thomm et al., 2021b, p. 1069). Given the challenges mentioned above, specifically prepared evidence-based knowledge—provided in a suitable way for the target group—has the potential to facilitate and promote the use of this knowledge by teachers as well as the applicability of relevant evidence (e.g., Fleischman, 2009).

So far, there is little research on how teachers make use of evidence-based information, and ways of providing relevant information are still underexplored (e.g., Dagenais et al., 2012; Gräsel, 2019; Kiemer & Kollar, 2021). The present dissertation thus addresses these research gaps by exploring approaches to gain and specifically process relevant evidence for mathematics and science teachers. As the use of digital tools is currently one of the most

topical issues concerning teaching and learning in schools, this topic was used as an example to work on the first part of this dissertation (Publication A).

Within the long-term endeavors of establishing a well-functioning evidence-based practice, it is essential to “involve educators at every step of the way” (Fleischman, 2009, p. 80). Therefore, in the second part of this dissertation, the claims and needs for evidence-based information of mathematics and science teachers were examined by considering their thoughts about the relevance, the usage of evidence in practice, and, ultimately, concomitant barriers (Publication B).

The present work serves to place these two main studies produced as part of this dissertation project in a broader context. In addition to the two main publications, insights are provided into associated publications developed in conjunction with the project. As the first theoretical part of this framework paper (Section 2), the concept of evidence-based practice in general, as well as research syntheses as a possible source of evidence-based information, are elaborated. It is then considered why and how evidence can be used in practice and the extent to which teachers—from an empirical perspective—actually use evidence. This section concludes by outlining ways to support evidence-based practice in education. In the second theoretical part (Section 3), the topic of teaching and learning with digital tools is addressed as a current topic in need of evidence-based information. Here, both the theoretical foundations and empirically based potentials are considered. This is followed by presenting the dissertation project's study objectives, the corresponding methodological approaches, and results (Sections 4-6). Finally, the results are discussed in relation to existing literature as well as with regard to methodological limitations and practical implications. In particular, insights for processing evidence-based information and the contribution of research synthesis to support evidence-based decision-making in education will be discussed here (Section 7).

2 The Concept of Evidence-Based Practice

Following common approaches in human sciences with practical fields of application, such as the medical or education sectors, it is intended that actors continuously reflect on their routine actions—if possible—based on current scientific findings and adapt them if necessary (Gogolin et al., 2020). In medicine, where the concept of *evidence-based practice* emerged in the early 1990s, the use of evidence aims to "identify and apply the most efficacious interventions to maximize the quality and quantity of life for individual patients" (Sackett et al., 1996, p. 72). In general, evidence-based practice comes along with the judicious, conscientious, and explicit consideration of the best available evidence regarding relevant factors that can have a substantial and long-term impact on the lives of individuals (Gräsel, 2019; Sackett et al., 1996; Whitehurst, 2004). The recognition of evidence-based practice has prevailed despite continuous criticism in the medical field, as can be seen, for example, in the institutionalization by the *Cochrane Collaboration* or the *German Network for Evidence-Based Medicine (DNEbM e.V.)* aiming to promote evidence-based medicine for example, by systematically providing current relevant evidence for practitioners. In education, however, the practical reality is different because teachers' consideration or use of evidence cannot be considered routine (Dagenais et al., 2012; Hetmanek et al., 2015).

The below-average results of German students in large-scale studies such as the *Programme for International Student Assessment* (PISA) in the year 2000 (OECD, 2001) and the results in PISA 2018, which remain merely mediocre (OECD, 2019), for example, can potentially be seen as a consequence of a teacher education system fraught with weaknesses (Gogolin et al., 2020) such as a lack of evidence orientation in the context of teacher education. Therefore, in higher education, as well as professional teacher training, scientific findings on teaching and learning are increasingly being taken into account, and issues relating to the handling and use of scientific studies by teachers are playing an increasingly important role (e.g., Hartmann et al., 2016). There have been increasing efforts in recent years to develop ways of promoting and supporting evidence-based practice during teacher education as well as in later professional practice. More concretely, to empower teachers to contemporarily and effectively design lessons despite increased student heterogeneity, first approaches have been developed that provide specifically prepared evidence-based information or to support practitioners in understanding and applying scientific content (e.g., Diery et al., 2020a; Wenglein et al., 2015).

It is emphasized here that the concept of evidence-based practice is not intended to devalue practitioners' individual expertise and experiential knowledge by focusing on scientific findings. These remain the basis for important decisions but should be supplemented by evidence

where possible, “and neither alone is enough” (Sackett et al., 1996, p. 72). The use of evidence, therefore, cannot be prescriptive. Additionally, it seems useful in this context to distinguish between different forms of evidence and to evaluate them according to the individual situation (Beelmann, 2014; Bromme et al., 2014).

2.1 Research Synthesis as Source of Evidence

In the medical field, research syntheses such as systematic reviews or meta-analyses have been established as a common evidence-based format used to mediate between current scientific findings and their application in practice (see *Cochrane Library;* Haynes, 2001; Gräsel, 2019). Only recently, and also due to the prominence of Hattie’s controversial meta-study (Hattie, 2009), has the format of research synthesis emerged in the education field as a possible source for evidence-based decision-making and action in practice. However, a structural provision of such systematically synthesized knowledge as in medicine has not yet been established (Gräsel, 2019).

Sackett et al. (1996) already emphasized the importance of systematic reviews in the context of evidence-based practice, calling them the *gold standard,* as “the systematic review of several randomized trials, is so much more likely to inform us and so much less likely to mislead us” (Sackett et al., 1996, p. 72). To better classify the relevance and quality of studies, a hierarchical model of evidence presented in the form of a pyramid is postulated by the Cochrane Collaboration. According to this principle, systematic reviews and meta-analyses are given more weight than individual (randomized or quasi-)experimental studies, which is why they represent the top of the pyramid. Accordingly, case studies, theoretical papers, or practical reports have the lowest significance and form the base (e.g., Bromme et al., 2014). The susceptibility to errors of the respective evidence decreases towards the top.

However, in some cases—as is often the case, for example, in the school context—randomized study designs are not possible or appropriate (Sackett et al., 1996). This is also why the shape of the pyramid looks different in education than in medicine. Since empirical research in educational science is comparatively young and randomization in studies is often impractical, the top level in the hierarchic model is much weaker than in the medical field (Bromme et al., 2014). In case there are too few or no randomized studies, the next best available evidence should be used as the basis for decision-making (Sackett et al., 1996), such as quasi-experimental studies and respective systematic reviews.

Besides the high validity and their low susceptibility to errors, research syntheses bring several advantages, making them attractive as a source of evidence-based information. First, research

syntheses such as meta-analyses—the form of evidence on which this dissertation project focuses—can be used to provide a systematic overview of the current state of research on specific controversial topics such as learning and teaching with digital tools. This is of interest to researchers and practitioners alike. Second, meta-analyses allow for identifying research gaps and further developing and verifying theoretical assumptions, for example, by considering the influence of external learning conditions through moderator analyses (Borenstein et al., 2009). Furthermore, the generalizability of the results is increased by using meta-analyses, as the database consists of a number of studies with diverse samples and conditions (Beelmann, 2014). According to Cumming (2012), meta-analyses, therefore, have the potential to influence decision-making by policymakers as well as practitioners.

However, the potentials of meta-analyses mentioned to promote evidence-based practice are countered by the problem that evidence from educational research—based on primary or secondary data analyses—is usually published in scientific journals, primarily addressed to the scientific community. As there are specific skills to gather, understand, and interpret scientific information, this may lead to over- or underestimation of reported findings by non-scientists, i.e., practitioners or policymakers (Bromme et al., 2014).

2.2 How to Use Evidence and Why

The *Organisation for Economic Cooperation and Development* (OECD) considers scientific literacy as a key competency "defined in terms of the ability to use knowledge and information interactively" and that "represents a major goal for science education" (OECD, 2013, p. 4). The importance of this competency in the school context is independent of whether students later aim for a career in the field of technology or science. They should, in any case, "become informed critical consumers of scientific knowledge—a competency that all individuals are expected to need during their lifetimes" (OECD, 2013, p. 5). Therefore, one essential skill is "to interpret and evaluate data and evidence scientifically and evaluate whether the conclusions are warranted" (OECD, 2013, p. 5).

The critical use of information and evidence plays an important role not only with regard to students but logically also concerning teachers' competencies. Accordingly, this is stated as a core task of teachers, for example, in the framework of the German standards for teacher education published by the *Kultusministerkonferenz* (KMK): Teachers are able to design, reflect on, and evaluate teaching and learning processes based on scientific findings. In addition, it is stated explicitly that teachers should be familiar with the aims and methods of educational research and be able to interpret and apply its results (KMK, 2004). Empirically,

“recent results document higher levels of instructional quality, increased teaching self-efficacy, and positive learning outcomes among pupils of teachers who possess more scientific educational/psychological knowledge” (Kiemer & Kollar, 2021, p. 2).

Epistemic activities are essential in the competent use of evidence: The user should, therefore, be able to analyze evidence, reflect critically on it, and ultimately apply it (Bauer et al., 2017). For this, not only cognitive skills but also motivational and persuasive dispositions are important (Bauer et al., 2017; Kiemer & Koller, 2021), as well as certain external conditions (Thomm et al., 2021a). Concerning the latter, access to appropriate sources of evidence is a basic requirement, as are the time resources needed to search for, select, and make use of appropriate information. An essential aspect of evidence-based decision-making is undoubtedly the type of source used as a basis, as it can influence the quality of decisions. Both the selection and use of a source are influenced primarily by personal beliefs about the utility of the kind of information in question (Kiemer & Kollar, 2021). Therefore, it is crucial for practitioners to differentiate between various types of information, for example, subjective theories, experiential knowledge, and scientific findings (see Franke & Wecker, 2019), and to be clear about their significance.

In terms of cognitive skills, the user must be able to evaluate scientific findings, specifically their relevance, quality, and significance, considering limitations—for example, limitations of generalizability—as well as potential contradictions between different findings (Bauer et al., 2017). For scientists, these activities are part of the daily routine. For non-scientists such as teachers, however, searching for and reading articles in scientific journals tend to be associated with major challenges (e.g., Hetmanek et al., 2015)—in terms of the required skills, but also due to the aforementioned external conditions as well as motivational and persuasion-related factors.

2.3 Teachers' Use of Evidence

Unlike in the medical field, it can generally be noted that the use of evidence does not yet seem to be part of everyday practice in the educational sector (e.g., Dagenais et al., 2012; Hetmanek et al., 2015; Kiemer & Kollar, 2021). So far, evidence-based actions in education have mainly been observed at the system level, such as the expansion of all-day schools in Germany as a consequence of the PISA study results (Köller, 2017). At the instructional level, however, the direct impact of evidence on teaching and learning appears to be rather small overall. There might be various reasons for this rare application—and the use of evidence by teachers is still underexplored—but it probably starts with attitude-related dispositions of teachers. According

to Thomm et al. (2021a), it is questionable whether teachers see the need to engage with findings from educational research, as they tend to “base their practice on tradition, common knowledge, and experience” (Thomm et al., 2021a, p. 3), and they feel they are essentially contributing to the success of students with this approach (TALIS 2018; Schmich & Itzlinger-Bruneforth, 2019). Generally, teachers tend to base their decisions and actions on experiential knowledge, such as from colleagues, rather than scientific evidence (van Schaik et al., 2018; Williams & Coles, 2007). The role of experiential knowledge in the teaching profession was also illustrated in a study by Landrum et al. (2002). The authors found that teachers rated their experienced colleagues not only as more accessible sources of information than, for example, professional journals but also “as a source of more trustworthy and usable information” (Landrum et al., 2002, p. 46). Furthermore, they found no significant differences between more or less experienced teachers.

At this point, disadvantageous reciprocal effects may arise because

> unfavorable beliefs about the utility of educational theories and evidence might not only act as barriers to the actual use of educational theories and evidence. They might already come into play in the decision on whether or not to even consult scientific sources. (Kiemer & Kollar, 2021, p. 2)

Overall, a heterogeneous picture emerges when considering the state of research on the appreciation of findings from educational research by teachers since both positive and negative views prevail (Dagenais et al., 2012; van Schaik et al., 2018).

As mentioned in Section 2.2, skills, time resources to find and interpret information, and access to relevant sources are basic requirements for the use of evidence. In their review study, van Schaik et al. (2018) identified barriers to secondary school teachers' utilization of academic knowledge in peer-reviewed papers published between 2001 and 2016. They identified several main barriers, such as the perceived applicability and relevance of research knowledge or “teachers’ skills in finding and applying academic knowledge into their own practice, as well as interpreting academic knowledge” (van Schaik et al., 2018, p. 57). Williams and Coles (2007) examined the information literacy skills of teachers from different school types in the UK, focusing on their strategies and confidence. The authors concluded that the teachers had overall positive attitudes toward the use of evidence. However, the actual use of evidence-based information was low. Lack of time and access to sources were identified as the main barriers to using research information from the teachers' perspective. Van Schaik et al. (2018) stated that “in many studies, negative attitudes and perceptions seem to be closely related to issues of accessibility and applicability. Teachers criticize research knowledge being unapproachable, inaccessible, difficult and incomprehensible” (van Schaik et al., 2018, p. 54).

They mainly seek out applicable solutions to everyday problem situations (Beelmann, 2014), which often do not appear in studies of educational research (e.g., Lysenko et al., 2014). Consequently, another possible reason for the lack of evidence-based practice at the classroom level is that scientific findings have limited direct applicability to practical situations and are, therefore, often seen by teachers as irrelevant to solving everyday challenges (Farley-Ripple et al., 2018).

Against the backdrop of the circumstances mentioned above and based on the well-founded assumptions that evidence-based practice can have a positive impact on teaching and learning (e.g., Bauer & Prenzel, 2012; Diery et al., 2020a), various efforts have been made to support the necessary processes involved. For example, first approaches have been developed to provide practitioners with information in specific and targeted ways, outlined in the following section.

2.4 Supporting Evidence-Based Practice in Education

Despite the research on the topic mentioned above, still little is known about what specific aspects play a role in selecting information sources for teachers (Kiemer & Kollar, 2021). Furthermore, there is little evidence about how scientific findings can be successfully transferred into practice (Gräsel, 2019). Nevertheless, some efforts have been made to promote evidence-based practice in the school context. As noted earlier, teachers often appear to be insufficiently equipped with the necessary skills to use research evidence, and time resources, for example, appear to be problematic for implementing evidence-based practice. Against this background, different formats have been developed, on the one hand, aiming at equipping teachers with the necessary skills to use research evidence independently (e.g., Wenglein et al., 2015), and on the other hand, formats offering specifically prepared evidence-based information for the target group of practitioners (e.g., Diery et al., 2020a; Seidel et al., 2017).

Wenglein et al. (2015) developed a short-term training course for pre-service teachers focusing on argumentative skills as an essential aspect of competent use of evidence. As the post-training competencies between participants in a control group differed significantly from those in the experimental group, and the individuals in the control group more often based their arguments on personal experiential knowledge rather than scientific evidence, the authors concluded that existing curricula in teacher education programs do not sufficiently address appropriate competencies. Moreover, according to the authors, the fact that participants in the experimental group made only limited use of evidence and that critical evaluations were rarely

observed here suggests that further long-term learning opportunities should supplement appropriate short-term interventions. This illustrates that teaching the relevant skills requires a great deal of organization and time, and even if teachers are equipped with the necessary skills, there is no guarantee that they will be able to put them into practice.

Providing specially prepared evidence-based information and improving accessibility of practice-relevant evidence for educators may circumvent these problems and is therefore considered a promising way to promote evidence-based practice.

The first organization dedicated to systematically promoting evidence-based practice by preparing relevant current research findings for practitioners is the global and independent network *Cochrane Collaboration*, established in 1993 (www.cochrane.org). Today, the network brings together scientists, physicians, health professionals, and patients to link research and practice in the medical field. Systematic reviews are produced and freely available for decision-making based on high-quality evidence. “With the success of the Cochrane Collaboration, the same type of organization was soon suggested for reviewing social and educational evaluations” (Petrosino et al., 2001, p. 26). Hence, following the example of Cochrane, the *Campbell Collaboration*, founded in 2000 (https://www.campbellcollaboration.org), aims to promote evidence-based policy and practice by producing and using “rigorous syntheses of research on social, economic, and behavioral interventions” (Littell & White, 2018, p. 6). Further organizations in the education field have developed along these lines, such as the *What Works Clearinghouse*, established in 2002 by the U.S. Department of Education's Institute of Education Sciences (https://ies.ed.gov/ncee/wwc/). Here, too, high-quality research findings on education programs, products, practices, and policies are systematically summarized and made available to practitioners.

The first clearinghouse in educational sciences for the German-speaking area is the *Clearing House Unterricht*, founded in 2015 at the Technical University of Munich (www.clearinghouse.edu.tum.de). Preparing scientific findings in the form of short reviews is aimed primarily at teacher educators, and its purpose is to support evidence-based teacher education. Meta-analyses on questions in the field of STEM teaching are used as the basis for the specifically prepared and quality-assessed information (Seidel et al., 2017).

The Johns Hopkins University School of Education’s *Best Evidence Encyclopedia* is another example of using the method of meta-analysis to inform educators about practice-relevant research findings (https://bestevidence.org/). The initiatives listed here to promote evidence-based practice thus have in common that they use the method of systematic reviews. As already described in more detail in Section 2.1, “the foremost advantage of systematic reviews is that when done well and with full integrity, they provide the most reliable and comprehensive

statement about what works" (Petrosino et al., 2001, p. 20) and there seems to be a consensus today on the potential of such methods to support evidence-based practice.

The evidence-based information from these various organizations is presented in formats such as *short reviews* (e.g., Diery et al., 2020a), so-called *plain language summaries* (e.g., Benz et al., 2021; Campbell Collaboration), or *practice guides* (e.g., Fuchs et al., 2021). Short reviews summarize key findings of systematic reviews such as meta-analysis and their evaluation compactly. By collecting direct user feedback during the preparation process, the Clearing House Unterricht aims to prepare comprehensible, relevant, and practically useful evidence for the target group (Seidel et al., 2017). Since the communication of practice-relevant research findings in formats such as short reviews or plain language summaries, unlike in medicine, has rarely been observed in the field of educational psychology, the *PLan Psy* project was launched in 2021 at the Leibniz Institute of Psychology in Trier. The project primarily concerns developing guidelines for preparing generally understandable, layman-friendly, and guideline-compliant short summaries based on partly complex findings from psychological meta-analyses. The user's expectations and needs when reading plain language summaries are thus being investigated in several studies. To find out how plain language summaries can ideally be designed in concrete terms, formal text structures, the use of statistical terms, technical terms, and other characteristics are being varied in test versions (Benz et al., 2021). These research projects are expected to provide important insights into preparing and communicating practice-relevant evidence to non-scientists or scientists from outside the field.

Practice guides such as those published by the What Works Clearinghouse differ from the formats mentioned above because, in addition to insights gained from systematic reviews of relevant research, they also provide information on possibilities for concrete application and offer practical recommendations for practitioners. "Each recommendation includes features of intervention and/or instructional practices, with guidance on how to implement them, advice on how to overcome potential obstacles, and a short summary of the research evidence that supports the recommendation" (Fuchs et al., 2021, p. 2). The user-friendly presentation of scientific findings and, above all, the derivation of concrete and practical recommendations for action address the problem that practitioners often consider scientific sources to be of little use (e.g., van Schaik et al., 2018). As with producing short reviews, practitioner-friendly, straightforward, and nontechnical language is generally used in evidence-based practice guides (see Development Guidelines of WWC Practice Guide for Educators, 2012). However, little research has been conducted on what specific characteristics—such as formal design or content—this type of format should have to serve its intended purpose (e.g., Demski & Racherbäumer, 2015; Gräsel, 2019; Hartmann et al., 2016).

How useful evidence-based information ultimately can be to the target group depends fundamentally and logically not only on the format of the source but especially on the topic that is the focus of the underlying research. When selecting topics, the concrete needs of the respective target group are decisive. For this reason, the PLan Psy study mentioned above, which aims to make evidence available to laypersons, first conducted comprehensive surveys of the public's interest in scientific topics (Benz et al., 2021). Practice guides, as published by the What Works Clearinghouse, “are designed to provide practical, evidence-based recommendations to teachers and administrators about how to address current challenges in education” (WWC Practice Guide for Educators, 2012, p. 1). Furthermore, preference is given to topics expected to have a particular potential for improving student outcomes, such as specific teaching and learning methods. In addition to the topicality of the issues and their political and practical relevance, a sufficient research base on the relevant subject is required.

One area of empirical education research that has seen a tremendous increase in studies since 2000 is research on teaching and learning STEM subjects. Looking specifically at the state of research on STEM topics, the comparatively high number of available meta-analyses shows that questions relevant to educational psychology—specifically digital tools and innovative teaching approaches—are receiving considerable attention in the context of educational research (Seidel et al., 2017). Particularly regarding topics on which many individual studies are available, it is important to offer structured and systematic summaries so that users can get an overview of the topic and transfer the research findings into practice (Gräsel, 2019).

Discussions on teaching and learning science and mathematics—as two crucial subject areas of STEM—are currently receiving a great deal of attention from society as a whole, particularly in context with the developments resulting from digitalization (e.g., Lewalter et al., 2023; Reinhold et al., 2023). Theoretically assumed potentials of using digital tools for promoting teaching and learning STEM have been investigated in various studies, which provide a solid basis for developing up-to-date and practice-relevant evidence-based information. Since the criteria mentioned above regarding selecting appropriate topics for processing evidence-based information are fulfilled herewith, teaching and learning science and mathematics with digital tools is the thematic focus of this dissertation.

3 Teaching and Learning Mathematics and Science Subjects with Digital Tools: A Topic in Need of Evidence-Based Information

Although computers are now clearly part of the everyday lives of adults and children, and numerous studies are available on teaching and learning with digital tools, the findings on the overall effectiveness are inconclusive, and use in the school context thus remains controversial (e.g., Zierer, 2020).

As early as the eighties and nineties, there were arguments about the added value of media in learning. A well-known example in this context is the *media methods debate*, primarily between the educational psychologist Clark (1983; 1994) and the media theorist Kozma (1994). While Clark strictly separated media and learning methods, Kozma saw the learning-promoting potential of a necessary external component within individuals' reciprocal and interactive learning processes in the medium. Based on a review of then-current studies and meta-analyses on educational media, Clark concluded “that all current reviews of media comparison studies suggest that we will not find learning differences that can be unambiguously attributed to any medium of instruction” (Clark, 1983, p. 457). One of Clark's most famous and controversial quotes is as follows: “The best current evidence is that media are mere vehicles that deliver instruction but do not influence student achievement any more than the truck that delivers our groceries causes changes in our nutrition” (Clark, 1983, p. 445). Clark's quote as an unambiguous conclusion about the added value of media is taken up critically by Kozma in 1994, who aimed to reframe the debate about educational media as a whole:

> To understand the role of media in learning we must ground a theory of media in the cognitive and social processes by which knowledge is constructed, we must define media in ways that are compatible and complementary with these processes, we must conduct research on the mechanisms by which characteristics of media might interact with and influence these processes, and we must design our interventions in ways that embed media in these processes. (Kozma, 1994, p. 8)

According to these approaches, various theories of learning with media have been developed, such as Mayer's *cognitive theory of multimedia learning* (CTML; Mayer, 2014), which is widely known today. First, there are several basic assumptions underlying the CTML, such as the *dual-channel assumption*, which states that learners can process content via visual and auditory cognitive structures. The second assumption is that because there is *limited capacity* for processing content in the different cognitive structures, media can benefit learning if it stimulates both channels of the cognitive structure. The third assumption focuses on the

learner's *activity*, which can lead to a coherent linking of new unknown content with already existing knowledge (Mayer, 2014). Thus, as with Kozma (1994), the interactive process plays a significant role in the learner's use of the medium.

According to Moreno and Mayer (2007), “an interactive multimodal learning environment is one in which what happens depends on the actions of the learner,” which means, for example, that “the presented words and pictures depend on the learner’s actions during learning” (Moreno & Mayer, 2007, p. 310). In contrast to non-interactive media such as video or textbooks, interactive tools enable communication between the learner and the instructor in *both* directions.

This means that digital media—when used as a type of interactive learning tool—no longer have the function to merely convey knowledge but, in particular, to offer the possibility of actively constructing and communicating knowledge (Nattland & Kerres, 2009). Digital tools can enable different types of interactivity, including *dialoguing, controlling*, and *manipulating* (Moreno & Mayer, 2007). Dialoguing is enabled when the digital tool allows users to enter questions and answers and/or receive feedback on entered content. An example is a tool where the user can call up additional information via hyperlinks or a pedagogical agent providing the learner with individual help. Controlling means that the digital tool offers the possibility to go through the learning content at an individual speed and/or to have the content presented in an individually preferred order. By manipulating the “learner sets parameters for a simulation, or zooms in or out, or moves objects around the screen” (Moreno & Mayer, 2007, p. 311), which represents an active engagement with the learning object.

To enable interactive learning, several instructional principles play an essential role in the design of digital learning tools. According to Moreno and Mayer (2007), feedback to the learner, pacing, and guided activity, for example, are effective learning principles that can be theoretically and empirically proven. In line with more traditional teaching, feedback is particularly helpful when it is explanatory and not exclusively corrective (Hattie & Timperley, 2007), as “explanatory feedback reduces extraneous processing by providing students with proper schemas to repair their misconceptions” (Moreno & Mayer, 2007, p. 316).

In a study on understanding multimedia messages, Mayer and Chandler (2001) found that learners who had control over the presentation speed of the content to be learned performed better on a transfer test than learners who had no control over speed. A possible explanation is that “if the animation is complex, […], and the pace of presentation is fast, learners may not have enough time to organize the words and images into a mental model and integrate the model with prior knowledge” (Moreno & Mayer, 2007, p. 319). The pacing principle hence enables learners to interact with the digital tool or the corresponding learning content by individually controlling the speed as well as the sequence of the learning content.

Scaffolding as a type of guided activity often occurs in the context of problem-centered instructional approaches (Belland et al., 2017). According to the guided activity principle, the learner is individually supported by a more capable guide. For example, a meta-analysis by Belland et al. (2017) “indicates that computer-based scaffolding in STEM disciplines is highly efficacious” (Belland et al., 2017, p. 335). By encouraging students to actively select, organize, and integrate new information, a pedagogical agent can guide their cognitive processing and hence promote deeper understanding (Moreno & Mayer, 2007).

There are many gradations between two extremes—non-interactive learning environments and highly interactive learning environments—which is why Moreno and Mayer (2007) see interactivity as a continuum. This can be illustrated by looking at common digital tools used in the context of teaching and learning today. These can be divided into five categories based on Nattland and Kerres' (2009) characterization: drill and practice programs, tutoring systems, intelligent tutoring systems, simulations, and hypermedia systems (see Hillmayr et al., 2017). While all of these tools enable interactive learning, they partly differ in their respective design features and thus offer different levels of interactivity. One design feature that is usually common to all is the pacing principle, according to which the user can determine temporal components as well as the sequence of presented content or tasks (exceptions are, for example, tutoring systems that do not allow control over the pace of presented learning content). Concerning the design feature feedback, the situation is different: in drill and practice programs and tutoring systems, feedback is given to the learner, but in contrast to intelligent tutoring systems, the feedback is often not explanatory but purely corrective. Pure simulations and hypermedia systems are usually not designed to provide feedback unless appropriate features are combined. The principle of guided activity is primarily found in the context of tutoring systems, whereby it is particularly effective in intelligent tutoring systems since adaptive features can take into account the individual abilities and needs of the learner and thus enable optimal learning processes (Nattland & Kerres, 2009). Since understanding new learning content requires active and, if possible, autonomous engagement (Mayer, 2014), all five types of the above digital tools suggest that their interactive design can potentially support learning, albeit to varying degrees.

Principles such as guided activity or feedback represent aspects of teaching quality. These aspects of teaching quality, which can be summarized, among others, as cognitive activation—where the focus is on learning with understanding (Baumert et al., 2011)—play an essential role in both traditional teaching and the design of digital tools to enable effective learning. In this context, it is not only important that learners actively engage with the learning content but also that they can focus on specific learning objectives, link new content to existing knowledge, and that challenging cognitive processes are stimulated and maintained (Fauth &

Leuders, 2018). Corresponding design features can be found in simulation tools: Regarding manipulating as one way of interactive learning, the learner can actively deal with the learning content by controlling various parameters and can thus directly observe and grasp cause-effect relationships of complex scientific phenomena (Moreno & Mayer, 2007). Existing knowledge can be expanded and deepened by experimenting in simulations, which can prevent the learner's cognitive resources from being overtaxed to abstract complex relationships. Also, and especially in mathematics, such interactive, explorative learning can be beneficial when students are asked to understand abstract problems such as in geometry, algebra, and calculus (Bhagat & Chang, 2015; Lichti & Roth, 2018; Shadaan & Leong, 2013). Furthermore, according to Vygotsky's zone of proximal development (Vygotsky, 1978), learners should be individually challenged and supported according to their prior knowledge and cognitive resources. Through external constructive support provided by the teacher in the context of traditional instruction, learners should be able to reach the next stage in their development (Sliwka et al., 2019). Adaptive digital tools such as intelligent tutoring systems continuously monitor users' learning status and potential learning difficulties. They can thus provide appropriate, individualized assistance already during the learning process. With differentiated instructions, the use of adaptive tools can initiate self-directed learning processes and reflection on one's own ideas (e.g., Ma et al., 2014; Nattland & Kerres, 2009). Finally, new learning content must be internalized and deepened through repetition and intelligent practice to be permanently recalled (Fauth & Leuders, 2018). Appropriate opportunities for intelligent practice and repetition can also be found in adaptive tools, as these are not only oriented to the learning content but primarily to the learner's prerequisites (e.g., Nattland & Kerres, 2009).

In summary, not all interactive digital tools show equally beneficial characteristics for learning. Concerning aspects of cognitive activation and the associated constructive support, as well as possibilities for the intelligent practice of automatized skills, simulation tools, and intelligent tutoring systems, in particular, suggest beneficial learning effects. Non-adaptive tools like drill and practice programs, tutoring systems, or hypermedia systems show the mentioned aspects of teaching quality, such as cognitive activation and the linked design principles (guided activity, pacing, feedback) according to Moreno & Mayer (2007)—if at all—only to a limited extent. To find out to what extent the use of currently popular digital tools is actually more or less conducive to learning and to derive practical implications, research should focus on the different types—as well as their corresponding design principles—and thus directly compare the associated effects (e.g., Higgins et al., 2019).

Today, there is a large number of studies on the use of digital tools in the school context, and the results do not always provide a clear picture (e.g., Al-Balushi et al., 2017; Bayraktar, 2001/2002; Özyurt et al., 2014; Perry & Steck, 2015; Van der Kleij et al., 2015). Although there

are promising theoretical assumptions, some teachers, for example, are concerned about the negative effects of using digital tools in the classroom. According to the *International Computer and Information Literacy Study* (ICILS), almost 40% of teachers believe that using digital tools distracts students from learning (Fraillon et al., 2019). In fact, contextual factors—such as students' age—are of particular interest, as they can provide important information about the effective application of corresponding tools in the classroom (e.g., Cheung & Slavin, 2013; Steenbergen-Hu & Cooper, 2013; Sung et al., 2017).

Also for science subjects and mathematics, numerous studies and meta-analyses have been investigating the effectiveness of using digital tools (e.g., Steenbergen-Hu & Cooper, 2014; Sung et al., 2017; Wang et al., 2022; Van der Kleij et al., 2015). As “learning these disciplines has been considered to have various difficulties and challenges due to the subject’s complex, abstract, and multi-dimensional nature” (Wang et al., 2022, p. 1), secondary school students around the world face significant challenges in learning and understanding the relevant subject content (OECD, 2016a; OECD, 2019). Moreover, a substantial amount of secondary school students in diverse OECD countries have a low interest in sciences (OECD, 2016b). Especially given the continuing need for qualified employees in science and technology (OECD, 2016b) as well as the need for mathematical and science literacy as fundamental prerequisites for participation in today's society (OECD, 2016a), the learning-promoting potential of using digital tools in these subject areas, therefore, appears to be of particular interest.

In numerous existing studies, both negative and positive effects have been found regarding the use of digital tools as well as corresponding contextual factors. Existing meta-analyses on the use of digital tools in mathematics and science subjects have either dealt with game-based approaches, focused on intelligent tutoring systems—that suggest particular potentials from a learning theory point of view—or per se investigated the advantages of using digital media in comparison with non-digital teaching methods (e.g., Clark et al., 2016; Steenbergen-Hu & Cooper, 2013; Sung et al., 2017). In terms of practical applicability, a comparison of currently popular digital tools in education seems useful as a basis for evidence-based action and decision-making.

Overall, and also according to the considerations described in Section 2.4, the effectiveness of digital tool use in mathematics and science subjects at secondary school is a topic in special need of evidence-based information to inform researchers as well as politicians and practitioners. For this reason, in the present dissertation project, the potential of digital tools to foster learning in mathematics and science subjects—and the effects regarding practice-relevant contextual factors—were investigated by systematically collecting, analyzing, and summarizing prior studies in a comprehensive meta-analysis, as described in more detail in the next section.

4 The Present Research

The starting point for the present dissertation was a research project in collaboration with the *Kultusministerkonferenz* aiming to systematically gain evidence-based information on the use of digital tools in secondary schools and to provide specifically processed information for mathematics and science teachers. As mentioned above, with many students around the world struggling to understand mathematics and natural sciences at secondary schools (e.g., OECD, 2016b; OECD, 2019), the potential benefits of using digital tools, particularly in these subjects, have been hotly debated for years by researchers, policymakers, and practitioners alike. Because of the large number of studies on this topic, as well as the tremendous current interest in the potential of teaching and learning with digital tools, the method of research synthesis as a solid source of evidence was used to address the objectives in the first part of this dissertation project.

As follow-up projects to support evidence-based practice in the school context were planned at the *Centre for International Student Assessment (ZIB)*—an affiliated institute of the Technical University of Munich funded by the German federal and Länder governments—the project also served to pilot the method of research synthesis as a way of gaining and a basis for providing practically relevant evidence for educators. Against this background, and given the lack of research on how to provide evidence for teachers, the second part of this dissertation project aimed to gain insights into teachers' claims and needs toward evidence-based information. The overarching research question of the present dissertation project—approached through a holistic and mixed-method design—is as follows:

RQ 0: How can evidence-based practice in secondary school mathematics and science subjects be promoted using research synthesis as source of evidence-based information (on teaching and learning with digital tools)?

Publication A served as the basis for the evidence on using digital tools, which was processed for mathematics and science teachers aiming to promote evidence-based practice in secondary schools. Educators should know and understand “the comparative effects of different approaches” (Chen et al., 2018, p. 804) and which conditions are expected to be more or less beneficial. Publication A, thus, examined the impact of using digital tools in mathematics, chemistry, physics, and biology on secondary school students' academic performance (and attitudes) and considered a wide range of contextual factors. It addressed the following research questions:

RQ 1.1: Do secondary school students learning with digital tools in mathematics and science classes have different learning outcomes (and attitudes towards the subject taught) compared to students learning without the use of digital tools?

RQ 1.2: Which conditions of learning with digital tools in mathematics and science classes are favorable with regard to student learning outcomes?

After conducting the comprehensive meta-analysis (Publication A), the findings were presented to the scientific community (Hillmayr et al., 2020) and additionally provided in a separate and user-oriented format for teachers (Hillmayr et al., 2017).

The first author initiated the study presented in Publication B as part of the present dissertation project. It aimed to address the research gap regarding appropriate ways of processing evidence-based information for practitioners. As mentioned above, authors of prior studies stated that the extent of teachers' use of evidence-based information is relatively low (Dagenais et al., 2012; Hetmanek et al., 2015). Furthermore, little is known about why or why not and under what circumstances teachers can use evidence effectively. As the involvement of practitioners in researching practice-relevant issues is helpful and important (Fleischman, 2009), an interview study with mathematics and science teachers was conducted. The qualitative study aimed to gain insights into teachers' claims and needs toward evidence-based information by considering their attitudes regarding the relevance of evidence in practice, their usage behavior, and concomitant barriers. Based on the insights of the interview study, it is discussed in Publication B if and how the format of user-oriented practice brochures—such as the resulting brochure based on the findings of Publication A—can potentially meet the claims and needs of science and mathematics teachers. The following research questions were addressed:

RQ 2.1: What are STEM teachers' beliefs about the relevance of evidence-based information?

RQ 2.2: How do STEM teachers use evidence-based information?

RQ 2.3: What barriers do STEM teachers face when using evidence-based information?

In addition to the two included main publications, four associated publications were published during the work on this dissertation project:

Besides the above-mentioned user-oriented practice brochure, two further articles were published in the practice-oriented journal *SchulVerwaltung spezial* to provide evidence for principals and teachers (Hillmayr et al., 2022; Reiss & Hillmayr, 2018). Both were also based on the findings of the meta-analysis in Publication A. In each case, specific aspects of the results that are relevant to practice—such as the effectiveness of different types of digital tools

or the possibilities of influencing the quality of teaching through the use of digital tools—were processed in a way appropriate for the target group.

Furthermore, an exploratory study and in-depth analysis of the data gained in the meta-analyses was carried out on the connection between performance and motivation effects regarding the use of digital tools. For this purpose, the systematic literature selection of $k = 16$ primary studies from the meta-analysis was used as a starting point for correlation and cluster analyses. These studies reported the impact of using digital tools on students' academic performance as well as motivational aspects. The findings, which are relevant both for practice and for future research projects, were published in the peer-reviewed book series of *Edition ZfE* (Hillmayr et al., 2023).

5 Methodology

The overarching research question of this dissertation was investigated using a mixed-method approach combining the meta-analysis (Publication A) and the thematic analysis applied in the interview study (Publication B). The procedures of both studies are explained in more detail below.

5.1 Meta-Analysis

The meta-analysis presented in Publication A is based on 117 effect sizes out of k = 92 primary studies regarding the academic performance of N = 14,910 secondary school students. In k = 16 primary studies, additional effect sizes were reported regarding students' attitudes toward the subject taught. With the aim of a representative basis of the current state of research, three relevant major databases were used to search for primary studies: *ERIC*, *Scopus,* and *Web of Science*. The following syntax was used to obtain a broad selection of potentially relevant studies:

"study" OR "empiric" OR "research" AND "digital media" OR "tablet" OR "computer" OR "whiteboard" OR "smartboard" OR "ipad" OR "pc" OR "cas" OR "ict" OR "netbook" OR "software" AND "stem" OR "math*" OR "mint" OR "physic*" OR "chemistry" OR "biology" OR "science" AND "secondary school" OR "high school" OR "secondary education" OR "middle school" NOT "computer science" NOT "informatics" NOT "engineering".*

Combining these keywords gained a selection of k = 6,572 studies from the three databases. In the next step, the studies were screened and either included or excluded based on the following predefined inclusion criteria:

- Primary data were reported in the study.
- Digital tools (computer, tablet, smartboard, mobile phone, notebook, or CAS computer) were used during mathematics, physics, chemistry, biology, or science class in general (and were not additionally used at home).
- The sample comprised secondary school students (grade levels 5 to 13).
- The sample did not consist only of students with special educational needs (e.g., only gifted or only disabled students).
- The dependent variable was student performance and, optionally, student attitudes in addition.
- The study had a pre-post-control-group design.
- The study did not investigate the effects of computer games.

- Effect sizes or data necessary for effect size calculation were reported in the study.
- The control group consisted of students taught with instruction methods that did not use digital tools.
- The study was published between 2000 and 5 October 2018.
- The study was published in a peer-reviewed journal, and a full text was available in English or German (Hillmayr et al., 2020, p. 7).

After the screening process, *k* = 92 studies remained as they met each inclusion criteria. The complete selection process is shown in Figure 1.

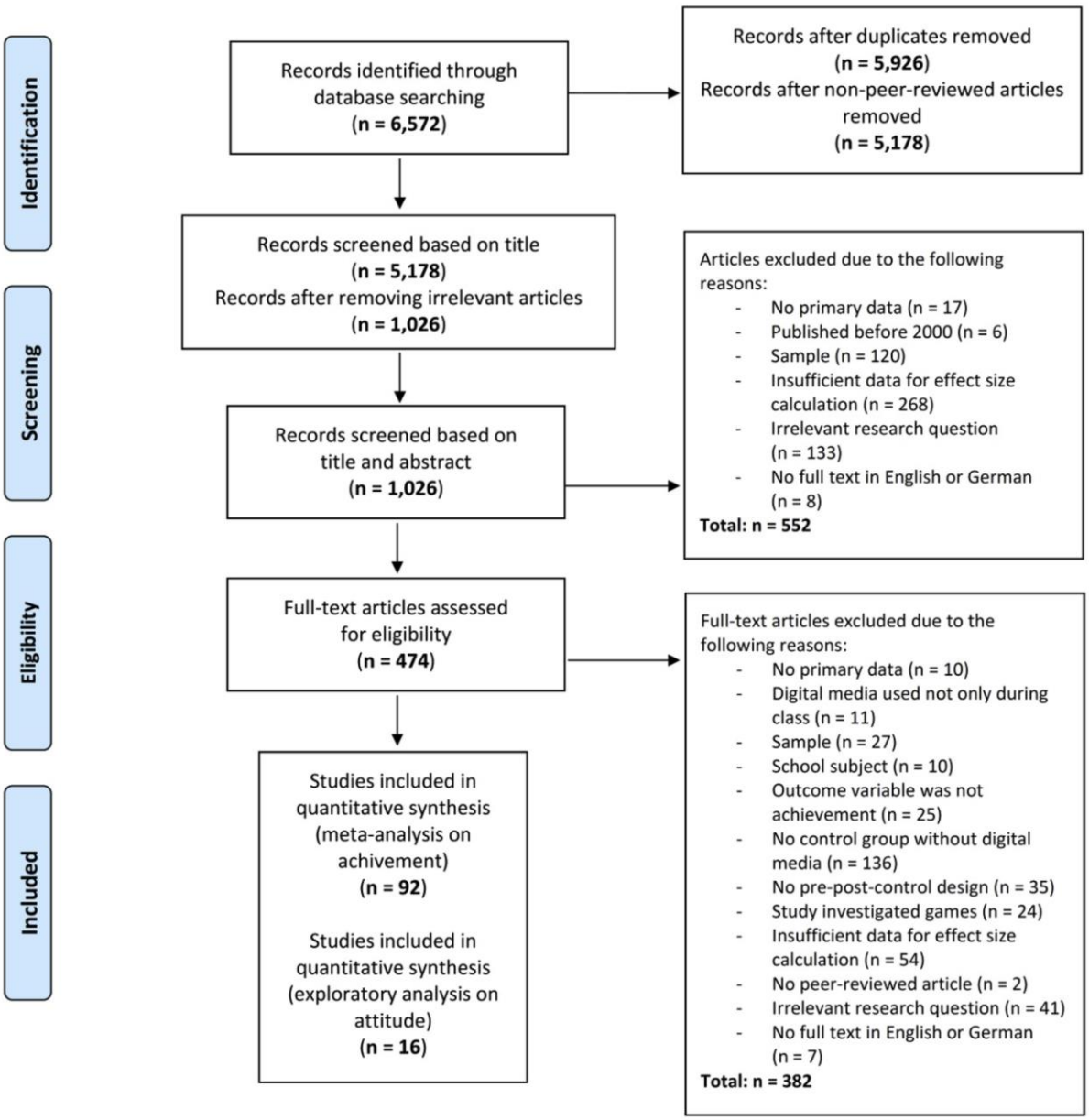

Figure 1. Flowchart of the study selection process following the guidelines of The PRISMA Group (Hillmayr et al., 2020; Moher et al., 2009).

The coding process of the studies was done independently by at least two raters. The self-developed coding form contained a variety of categories considered, such as the type of digital tool, the subject, the provision of teacher training, or methodological factors of the primary studies. Practical relevance was considered in determining the categories to ensure utility in promoting evidence-based practice in schools.

All effect sizes were first converted to Hedges' *g* to ensure data comparability. All analyses in this study were based on a random-effects model, as heterogeneity among primary studies might have been influenced by different conditions of respective individual studies (e.g., Borenstein et al., 2009). Moderator analyses aimed to examine the influence of individual study features—and thus of specific conditions of teaching and learning with digital tools—on the overall effect size regarding the use of digital tools. These analyses, as well as analyses to determine the likelihood of publication bias, were performed using *Comprehensive Meta-Analysis (CMA)* software.

5.2 Interview Study

The study in Publication B is based on interview data from *N* = 12 secondary school teachers (nine female). As this dissertation project focuses on promoting evidence-based practice in mathematics and science subjects, teachers who teach at least one of these subjects (i.e., biology, chemistry, physics, natural sciences in general, or mathematics) at a German secondary school were selected.

Due to contact restrictions as a result of the COVID-19 pandemic, interviews were conducted by telephone from March to July 2020. A self-developed guide was used to conduct the open-ended interviews in a structured yet flexible manner. The average duration of the interviews was 25.67 minutes (*SD* = 10.23).

Since this study aimed to systematically gain deeper insights into teachers' different attitudes and views, the qualitative method of thematic analysis (Braun & Clarke, 2006) was used to analyze the complex data. This method "offers an accessible and theoretically flexible approach to analyzing qualitative data […] in and beyond psychology" (Braun & Clarke, 2006, p. 77). Thematic analysis allows the researcher to generate unanticipated insights, and the method "can be useful for producing qualitative analyses suited to informing policy development" (Braun & Clarke, 2006, p. 97). The theoretically and empirically founded main themes (beliefs about *relevance, usage* behavior*, barriers*) were identified beforehand. As some of the research questions in this study are rather exploratory, further sub-themes were identified inductively based on the generated data material from the interviews. A theme

“captures something important about the data in relation to the research question” (Braun & Clarke, 2006, p. 82).

The first author of Publication B did the entire coding process of the interview transcripts to ensure an in-depth and targeted examination of the text material, supported by a second and independent coder. *MaxQDA*, a qualitative analysis software, was used to handle the complex data set systematically. The themes (including the associated codes) identified in the present study are presented in Table 1. The frequencies of mention were counted only once per interviewee, even if the relevant aspect came up several times during the interview.

Table 1

Identified themes with associated codes and their frequency of mention in the interviews.

Relevance (Extent)	**Frequency of mention**
in general high	10
depending on feasibility	4
depending on individual needs	3

Relevance (Justification)	**Frequency of mention**
support and orientation	7
further development	4
objective basis for decisions & actions	3

Usage	**Frequency of mention**
no influence of evidence	5
direct influence of evidence	4
indirect influence of evidence	3

Barriers	**Frequency of mention**
organizational framework conditions	9
time resources	9
available material	6

Concrete Examples of Usage	**Frequency of mention**
use (and handling) of digital tools	8 (2)
student support and differentiation	5
lesson planning and design	3
curriculum itself	3
research-based student learning	3
none	1

Table 1 (continued)

Quality Indicators	**Frequency of mention**
feasibility in class	10
type of source	5
expected learning success of students	4
plausibility with own experience	3
conciseness of information	3
subject specificity	2

Sources	**Frequency of mention**
magazines	9
teacher training	8
internet (social media)	7 (3)
school environment	6
higher education institutions	5
state institutes	2
news formats	2
education fairs	1

6 Summary of Publications

6.1 Publication A: *The Potential of Digital Tools to Enhance Mathematics and Science Learning in Secondary Schools: A Context-Specific Meta-Analysis*

The first author was mainly responsible for this publication, including conceptualization of the study, data collection, data analyses, writing the original draft, and revising the manuscript based on suggestions of co-authors and reviewers. The first author corresponded with the journal throughout the review process. The co-authors, Dr. Lisa Ziernwald and Prof. Dr. Frank Reinhold, were involved in conceptualizing the study, collecting and analyzing data, and they contributed to developing the publication with critical reviews. Prof. Dr. Sarah I. Hofer contributed to developing the publication with critical reviews. Prof. Dr. Kristina Reiss supervised the entire process and contributed with critical reviews to the development of conceptualization as well as the publication of this study.

The manuscript was submitted to the international peer-reviewed journal *Computers & Education* on 13 September 2018 and was accepted for publication on 10 April 2020.

6.1.1 Research Aims

In Publication A, it was examined how the use of digital tools can enhance learning mathematics and science in secondary schools. The authors aimed to provide a sound data basis for evidence-based decision-making by systematically gaining, analyzing, and reporting relevant current research findings. Hence, a comprehensive meta-analysis based on a systematic literature search of studies published since the year 2000 was conducted.

The selected studies investigated the impact of using digital tools by comparing the learning outcomes of an experimental group with a control group taught without using digital tools. Based on theories of technology-based learning (e.g., Mayer, 2014; Moreno & Mayer, 2007), it was assumed that especially interactive tools that enable active, self-paced learning can positively impact learning outcomes. To gain insights into more or less conducive conditions for teaching and learning with digital tools at school, specific (practice-relevant and methodological) characteristics of individual studies were considered in moderator analyses.

6.1.2 Main Findings

The effect sizes regarding learning outcomes ranged from $g = –0.33$ to $g = 2.46$, whereas effect sizes regarding students' attitudes ranged from $g = –2.24$ to $g = 1.59$.

Overall, the meta-analysis yielded a medium positive, statistically significant effect of using digital tools on student learning outcomes, $g = 0.65$, 95% CI [0.54, 0.75], $p < .001$. Regarding students' attitudes toward the subject taught, the analyses yielded a small positive, statistically significant effect, $g = 0.45$, $p < .05$.

Moderator analyses revealed one variable that significantly moderated the overall effect: the provision of teacher training. Regarding different types of digital tools, the impact of using intelligent tutoring systems or simulations such as dynamic mathematical tools was significantly higher than that of hypermedia systems, which aligned with the theoretical assumptions. Moreover, the effect size was larger when digital tools were used in addition to other methods, such as paper-based instruction, and not as a substitute—however, the difference was not statistically significant. Other variables, such as student-to-computer ratio or student support, did not significantly moderate the overall effect either, but interesting tendencies were discussed on a descriptive level. The positive overall effect appears robust, as its size does not change significantly across different school levels or subjects.

In summary, the findings highlight the importance of contextual factors regarding the use of digital tools in the classroom as well as the role of the qualified teacher, eventually pointing to the potential of adaptive tools with feedback. To promote evidence-based practice, this meta-analysis's findings were discussed with regard to scientific and practical relevance.

The findings of the meta-analysis were also processed in the form of a user-oriented practice brochure and distributed to mathematics and science teachers at the secondary school level. Based on the results, subject-oriented examples of using digital tools were developed that offer concrete suggestions for implementation in class.

6.2 Publication B: *STEM Teachers' Beliefs about the Relevance and Use of Evidence-Based Information in Practice: A Case Study Using Thematic Analysis*

The first author was mainly responsible for this publication including conceptualization of the study, data collection, data analyses, writing the original draft, and revising the manuscript based on suggestions of co-authors and reviewers. The first author corresponded with the journal throughout the review process. The co-authors, Prof. Dr. Frank Reinhold, Prof. Dr.

Doris Holzberger, and Prof. Dr. Kristina Reiss, contributed to the development of the publication with critical reviews.

The manuscript was submitted to the international peer-reviewed journal *Frontiers in Education, Section Teacher Education* on 18 July 2023 and was accepted for publication on 28 December 2023.

6.2.1 Research Aims

As studies on how teachers deal with evidence are still rare, while calls for a more evidence-oriented approach from politicians and society are becoming ever louder (e.g., Dagenais et al., 2012; Schiepe-Tiska et al., 2021), the study in Publication B complements the current state of research with a qualitative approach and a focus on STEM teachers, as there is a particular need and high potential for the use of evidence-based information in this area (e.g., Bathgate et al., 2019; Hillmayr et al., 2020). First, the topic's relevance is discussed, specifically the need for and potential of evidence-based information in teaching and learning STEM subjects. After discussing existing research studies on the topic and previous efforts to promote evidence-based practice in education, the question of whether teachers routinely use evidence or why they do not is approached. Both internal factors, such as teachers' perceived relevance of evidence-based information for their daily work, and external factors, such as the availability of material that enables a direct application of evidence-based information, were considered here (Thomm et al., 2021a; van Schaik et al., 2018). To gain insights into this complex process of applying evidence-based information in school practice, secondary school mathematics and science teachers were interviewed about the perceived *relevance* of evidence in practice, how they use evidence-based information (i.e., *influence of evidence on their work, specific examples of usage, used sources of evidence, quality indicators of evidence-based information*), and which *barriers* they face when using it.

6.2.2 Main Findings

The thematic analysis of the qualitative interview data showed that most teachers considered evidence-based teaching relevant (see Table 1). At the same time, there was a certain reluctance on the part of teachers to use evidence-based information in their teaching. Only a few teachers confirmed that they consciously use evidence-based information in their everyday work. Concrete examples of the use of evidence-based information were mainly related to the support of teaching techniques such as the use of digital tools or the differentiation of learners.

Subject-specific content was hardly mentioned here. The interviewees saw the most significant potential in evidence-based material that supports and guides them in planning and designing lessons. The main barriers to using evidence were the external framework conditions they encounter at school and the time resources the teachers thought they need to invest. From the teachers' point of view, important quality criteria for evidence-based information were its applicability in the classroom and the associated learning success for the students. In addition, subject-specific examples would benefit the teachers. A particular need for teachers at secondary schools, especially for the lower track *Mittelschule*, was expressed in several cases. Based on the results of the interview study, possible conclusions for processing evidence in appropriate ways to promote evidence-based practice in STEM teaching were discussed. An important conclusion from the data is that, from the teachers' perspective, using evidence-based information was associated with additional effort—sometimes coupled with problematic conditions that prevent them from using evidence. This should be considered when making efforts to support the evidence-based practice of teaching and learning STEM at secondary schools.

7 Discussion

The studies conducted as part of this dissertation addressed a current and still under-explored issue: the gap between research and practice in the context of teaching and learning in secondary schools. The present research focused on two approaches: Firstly, the use of research syntheses to process relevant research findings for practitioners—in this case on teaching and learning with digital tools in mathematics and science subjects as a current topic in need of evidence-based information—and secondly, the involvement of practitioners in the research process—in this case teachers of science subjects and mathematics at secondary schools. Regarding the overarching research question of this dissertation, in the following section, conclusions are drawn from the two main studies, and the results are discussed in the context of prior research. In addition, the section critically reflects on the methodological approach and the limitations of the studies. At the very least, implications for practice are described, and research desiderata are discussed.

7.1 Findings of the Main Studies

The use of digital tools for teaching and learning is a currently much-discussed topic in academia, as well as in educational practice, politics, and society (e.g., Zierer, 2020). There is a particular need for reliable evidence on this topic and evidence-based didactic concepts. The present meta-analysis (Publication A) took a comprehensive approach, generating and then providing a broad database and focusing on the most common digital tools currently used in teaching and learning science and mathematics subjects in today's schools.

The findings of the present meta-analysis indicate an overall (medium-sized) positive effect of using digital tools on students' academic performance in mathematics and science and a smaller positive effect regarding students' attitudes toward the subject taught. The study thus confirms prior findings on an updated and broad database (e.g., Cheung & Slavin, 2013; Steenbergen-Hu & Cooper, 2014; Sung et al., 2017; Van der Kleij et al., 2015) and can reduce existing uncertainties concerning the use of digital tools by teachers (Fraillon et al., 2019)—especially since the expected learning success of the students proved to be an essential aspect for the teachers regarding the quality of evidence-based information (Hillmayr et al., 2024). Moreover, the moderator analyses show that external conditions of learning environments can influence the students' learning success (substantially). The analyses show greater effects when digital tools were used in addition to non-digital material and did not completely replace other methods (Hillmayr et al., 2020). In general, however, according to

Clark (1994) and Kozma (1994), the relevant learning content should always take center stage, not the considerations of possible methods or media. Practitioners should thus assess if and how the use of digital tools can support teaching and learning regarding the specific situation or the context in which they want to use it. The practice-relevant findings of the present research synthesis can support teachers in such assessments.

Empirical studies on the use of evidence-based information in school practice are rare (e.g., Gräsel, 2019; Kiemer & Kollar, 2021). Georgiou et al. (2023) approached the topic with an interview study on the attitudes of teacher educators as important multipliers, whereas the present interview study addressed the issue of evidence-based teaching more directly at the teacher level.

Like prior studies (e.g., Georgiou et al., 2023; Thomm et al., 2021b), the present interview study (Publication B) showed that teachers see potential in the use of evidence-based information, although the actual use of relevant information in practice is comparatively low (Williams & Coles, 2007). Furthermore, the interview data confirmed that teachers are primarily looking for answers to practical everyday problems (Beelmann, 2014)—but the study also shows that necessary information and material are hardly available.

Further, the interview study showed that teachers face several challenges when it comes to using evidence-based information. The main barriers were identified in previous studies several years ago (van Schaik et al., 2018; Williams & Coles, 2007) and apparently still exist. Confirming the findings of Georgiou et al. (2023), the data showed that the challenges teachers face when using evidence-based information can be categorized into the following types: resource-related challenges and practice-related challenges. That limited time resources or problematic organizational framework conditions, in general, can lead to a rather rare use of evidence is known from other contexts, too (e.g., Brown & Zhang, 2016; Diery et al., 2020b).

7.2 Insights for Processing Evidence-Based Information and the Contribution of Research Synthesis

As prior studies (e.g., Dagenais et al., 2012; Hetmanek et al., 2015; Kiemer & Kollar, 2021), the present work shows that using or applying evidence-based information in the classroom is not yet very common, despite the numerous efforts to promote evidence-based educational practice in the recent past (e.g., Diery et al., 2020a; Seidel et al., 2017; Wenglein et al., 2015). Greater consideration of research synthesis as a systematic, comprehensive, and well-founded source of information could help to reduce this research-practice gap: For example, as it can be a challenging task—not only for practitioners but also for scientists—to get an

overview of a wide variety of research results, especially concerning controversial issues such as computer-supported learning and teaching, a systematic review of relevant findings has the potential to support evidence-based decision-making (Cumming, 2012).

Brown and Zhang (2016) recommended that schools should "promote the vision for evidence-use (i.e., actively encourage its use)" as well as "establish effective learning environments, in which learning conversations around the use of evidence, can flourish" (Brown & Zhang, 2016, p. 780). To create an effective environment, it is crucial to understand and consider teachers' individual needs and challenges. The analysis of the interview data (Publication B) showed some aspects that seem to be of particular importance for the teachers, namely the feasibility of evidence-based material in the classroom as well as the expected learning success of students. Taking a look at the content and objectives of scientific studies, it can be seen that questions are often aimed at making teaching and learning more effective, but direct application of the findings in schools and lessons, on the other hand, are usually neither part of the study (e.g., Lysenko et al., 2014) nor possible without further processing of the findings. Relevant scientific findings should, therefore, be processed for teachers in a suitable form to promote evidence-based practice. The main issue of the present dissertation, which relates on the one hand to the relevance of the topic of teaching and learning with digital tools and the resulting need for evidence-based information, and on the other hand to the challenges faced by teachers when using evidence-based information, was addressed by processing the findings from the meta-analysis (Publication A) in a practice brochure (Hillmayr et al., 2017) that was made available to teachers in an appropriate language and with concrete suggestions for application. The main barriers mentioned by the teachers (lack of time and access to relevant sources; Hillmayr et al., 2024) can be addressed by appropriately and systematically processing and providing teachers with such relevant evidence-based content.

Although meta-analyses have a stronger significance than individual studies (e.g., Bromme et al., 2014), it is particularly important to consider the results in the respective context—both concerning the conditions of the study, for example, by looking at moderator analyses and the scope of application such as the specific conditions in school practice when processing evidence for practitioners (e.g., Hillmayr et al., 2017). Particularly in the context of teaching and learning at school, the respective framework conditions, as well as the people involved, can vary significantly. As demonstrated in this dissertation, the comprehensive data basis of research syntheses often allows several research questions on a specific topic but with different aspects in focus to be analyzed (e.g., Hillmayr et al., 2023). Exploiting the potential of such data can particularly be used to meet individual circumstances and different needs in the context of teaching and learning. Regarding the use of digital tools, for example, practice brochures could be supplemented by the provision of continuous (e.g., school-type specific)

teacher training as "digital technologies are ever-changing, not always predictable, and can take on many forms" (Hamilton et al., 2016, p. 2). This might also apply to other teaching and learning methods, as knowledge about them constantly evolves in our fast-paced world. Generally, a combination of text-based formats and accompanying teacher training that regularly provides information on new scientific findings and enables a direct dialog between research and practice can make an essential contribution to closing the research-practice gap in a dynamic way (see Brown & Zhang, 2016).

It is emphasized that there is no universal recipe for success, which makes it all the more important to sensitize teachers by providing different suitable evidence-based formats. Whereas research syntheses can make an essential contribution to generating evidence-based information, it is crucial to consider the individual circumstances (e.g., different types of schools) and address the various needs of the target group when designing and implementing (diverse) formats to support practitioners.

7.3 Methodological Considerations and Limitations of the Studies

Over the last few decades, mixed methods have been increasingly used in social science studies (e.g., Schreier & Odağ, 2020). As the combination of different approaches and different perspectives on a topic enables a deeper understanding of human phenomena, for example, in the field of teaching and learning, a mixed-method design was used for this dissertation examining a complex as well as still under-explored issue in educational research (e.g., Dagenais et al., 2012; Georgiou et al., 2023; Gräsel, 2019). To approach the overarching research question, a research synthesis was first carried out to create an empirical basis on the effects of using digital tools in STEM subjects as a topic in need of evidence-based information. Since previous meta-studies were usually limited to a specific digital tool or a single subject (e.g., Cheung & Slavin, 2013; Ma et al., 2014; Steenbergen-Hu & Cooper, 2014), the present study addressed a gap in a comprehensive analysis by looking at both different types of digital tools and different subjects as well as considering a variety of contextual factors. Systematic reviews and meta-analyses form the top of the evidence pyramid (e.g., Bromme et al., 2014) and thus provide valid and reliable evidence for practice.

As so far mainly used in the medical field, research syntheses are still little used to promote evidence-based practice in the school sector. In the second part of the dissertation, a qualitative approach was therefore chosen to gain deeper insights into STEM teachers' beliefs about the relevance and use of evidence-based information in practice—as a specific group acting in a particular context. This allows initial conclusions to be drawn about more or less effective ways of obtaining and processing evidence-based information, such as that

generated by research syntheses. The present interview study thus focused on the question of “what works here” with a context-specific focus and broadened the prevailing question in prior studies concerning evidence-based practice of “what works” in a more general sense (e.g., Joyce & Cartwright, 2020), which often has little significance for specific practical applications.

First, the main methodological limitation of the present study is that the effects of using digital tools in the meta-analysis are primarily correlative in nature and do not reveal any clear causalities. Moreover, the findings should always be seen in the respective (practical) context, as the database consists of primary studies in which confounding variables cannot be completely controlled.

Second, the qualitative interview study is a case study with a group of twelve STEM teachers and does not allow the findings to be generalized. Nevertheless, this dissertation illustrates how practice-related research questions can be addressed with holistic approaches in an area still under-researched by involving important stakeholders in practice, such as STEM teachers, in the research process. This is an essential step towards bridging the research-practice gap sustainably and effectively.

7.4 Implications for Practice and Future Research

Even if the results of the present meta-analysis show significant positive effects when using digital tools across all grade levels and all subjects considered, this should not lead to premature decisions in practice. In the case of digital teaching and learning, it becomes clear that learning success depends on external conditions (e.g., Hillmayr et al., 2020) and can also lead to adverse effects in unfavorable circumstances. Therefore, contextualizing scientific findings in appropriate formats focusing on practical use and application is necessary and helpful in promoting evidence-based practice. For this purpose, context-specific meta-analyses and other research syntheses can provide a reliable and valid empirical basis, as the present dissertation shows.

Moreover, the analysis of the present interview data revealed that most teachers associate using evidence with additional effort. Further, the feasibility of the results seems to be decisive for actual use by the teachers. This also indicates that evidence-based formats for practitioners should contain concrete suggestions and applicable subject-specific examples, ideally developed through cooperation between researchers, didactics experts, and practitioners (e.g., Hillmayr et al., 2017)—as successful transfer of research findings requires a reciprocal process between actors from science and practice (see Sackett et al., 1996).

As has become apparent in both the study selection process for the meta-analysis and the interviews with the teachers, research questions or methods of educational studies often do not match the concrete and current needs of practice. Therefore, the design and conduction of future studies should take greater account of practical needs—not least by involving practitioners such as teachers throughout the entire research process (e.g., Fleischman, 2009). Promoting collaborations between researchers and practitioners could also have a positive impact on teachers' (often skeptical) attitudes (e.g., Thomm et al., 2021b) toward (educational) research in general.

Overall, there should be a stronger focus on practical implications in research studies and corresponding publications to highlight the practical relevance and promote the practitioners' awareness of important interdependences, possibilities, and limitations. Contextualizing the results is even more important if studies can only show correlative relationships. In addition to considerations regarding specific formats to promote evidence-based practice, the structure and language of scientific publications themselves should be adapted more to the target group of practitioners, with a particular focus on practical implications.

As mentioned in Section 7.2, the comprehensive data basis generated during the selection of studies for research syntheses can potentially be used to address different research questions, possibly in additional practice-related publications, as demonstrated in this dissertation. Because of the current demand for evidence-based information in various educational sectors with different individual needs and to promote a sustainable research practice, the potential of data should be assessed by the researcher in all conscience. In addition, the framework conditions in science should be improved so that researchers (can) focus more strongly on transferring their results into practice (see Sinell, 2017). For example, the latter could be addressed by increased funding of corresponding efforts.

Last but not least, the present findings should be expanded through further studies, for example, by updating the database of the meta-analysis regarding the effects of digital tools in mathematics and science subjects and examining the use of evidence-based information in practice in greater depth using representative samples.

8 Conclusion

Discussions about evidence-based practice in education have been present in Germany for about three decades. Politicians are hoping for an improved basis for the decision-making of educational practitioners and, thus, claim user-oriented evidence-based information for relevant educational issues (e.g., Hartmann et al., 2016).

In this relatively young field of research, numerous attempts exist to promote evidence-based educational practice. The present dissertation addresses the current demands and supplements prior efforts by examining different research questions with a holistic and mixed-method approach.

The publications of this cumulative dissertation project provide insights into ways of generating practice-oriented evidence and allow conclusions regarding more or less beneficial aspects in processing scientific findings for practitioners, in this case, specifically for STEM teachers. The main conclusions from the present studies can be summarized as follows: While research syntheses such as meta-analyses can technically provide a suitable and valuable data basis for evidence-based decision-making in education, teachers often face several challenges when using evidence-based information. Examples include a lack of directly applicable evidence-based information or limited time resources to search for and make use of available material. Also, the demands from policymakers to make decisions based on scientific findings require a more or less direct applicability of evidence in practice (e.g., Hartmann et al., 2016).

Thus, these factors should be considered early in the research process so that the results can be used in practice later. As research questions in scientific studies are often *not* tailored to the practice's needs, relevant stakeholders of educational practice, such as teachers, should be more involved in the research process—starting with the planning, conception, and design of future (primary and secondary) research studies. The present dissertation illustrates how practitioners can be involved in complex research projects and thus contributes to bridging the still-existing gap between science and (educational) practice. Bringing researchers and practitioners closer together is a necessary step towards a well-established and effective evidence-based practice.

References

Al-Balushi, S. M., Al-Musawi, A. S., Ambusaidi, A. K., & Al-Hajri, F. H. (2017). The Effectiveness of Interacting with Scientific Animations in Chemistry Using Mobile Devices on Grade 12 Students' Spatial Ability and Scientific Reasoning Skills. *Journal of Science Education and Technology, 26*(1), S. 70–81. doi:10.1007/s10956-016-9652-2

Barnat, M. (2019). Die Nutzung von Forschungsergebnissen in der Lehrpraxis von Schule und Hochschule. In N. Buchholtz, M. Barnat, E. Bosse, T. Heemsoth, K. Vorhölter and J. Wibowo (Eds.), *Praxistransfer in der tertiären Bildungs-forschung: Modelle, Gelingensbedingungen und Nachhaltigkeit* (pp. 17–27). Hamburg, Germany: Hamburg University Press. doi: 10.15460/HUP.198

Bauer, J., and Prenzel, M. (2012). Science Education. European teacher training reforms. *Science, 336*(6089), 1642–1643. doi: 10.1126/science.1218387

Bauer, J., Prenzel, M. & Renkl, A. (2015). Evidenzbasierte Praxis - im Lehrerberuf?! Einführung in den Thementeil. *Unterrichtswissenschaft, 43*, 188-192. doi: 10.3262/UW1503188

Bauer, J., Berthold, K., Hefter, M. H., Prenzel, M., & Renkl, A. (2017). Wie können Lehrkräfte und ihre Schülerinnen und Schüler lernen, fragile Evidenz zu verstehen und zu nutzen? *Psychologische Rundschau, 68*(3), 188–192. doi: 10.1026/0033-3042/a000363.

Baumert, J., Kunter, M., Blum, W., Klusmann, U., Krauss, S., & Neubrand, M. (2011). Professionelle Kompetenz von Lehrkräften, kognitiv aktivierender Unterricht und die mathematische Kompetenz von Schülerinnen und Schülern (COACTIV) – ein Forschungsprogramm. In M. Kunter, J. Baumert, W. Blum, U. Klusmann, S. Krauss, & M. Neubrand (Eds.), *Professionelle Kompetenz von Lehrkräften Ergebnisse des Forschungsprogramms COACTIV* (pp. 7–25). Münster: Waxmann.

Bathgate, M. E., Aragón, O. R., Cavanagh, A. J., Waterhouse, J. K., Frederick, J., & Graham, M. J. (2019). Perceived supports and evidence-based teaching in college STEM. *Int J STEM Educ 6*, 11–14. doi: 10.1186/s40594-019-0166-3

Bayraktar, S. (2001/2002). A Meta-analysis of the Effectiveness of Computer-Assisted Instruction in Science Education. *Journal of Research on Technology in Education, 34*(2), 173–188. doi:10.1080/15391523.2001.10782344

Beelmann, A. (2014). Möglichkeiten und Grenzen systematischer Evidenzkumulation durch Forschungssynthesen in der Bildungsforschung. *Zeitschrift für Erziehungswissenschaft, 17,* 55–78. doi: 10.1007/s11618-014-0509-2

Belland, B. R. et al. (2017). Synthesizing results from empirical research on computer-based scaffolding in STEM education: A meta-analysis. *Review of Educational Research, 87*(2), 309–344.

Benz, G. et al. (2021). PLan Psy - Interessenkatalog: Eine empirisch fundierte Klassifikation psychologiebezogener Interessen in der Allgemeinbevölkerung: Entscheidungshilfe zur Selektion KLARtext-relevanter Meta-Analysen in PSYNDEX. *PsychArchives.* doi: 10.23668/psycharchives.5034

Bhagat, K. K., & Chang, C.-Y. (2015). Incorporating GeoGebra into Geometry learning—A lesson from India. *Eurasia J. Math. Sci. Tech. Ed. (Eurasia Journal of Mathematics, Science & Technology Education), 11*(1), 77–86. doi:10.12973/eurasia.2015.1307a

Borenstein, M., Hedges, L. V., Higgins, J. P. T., & Rothstein, H. R. (2009). Introduction to meta-analysis. Chichester U.K.: John Wiley & Sons.

Braun, V., and Clarke, V. (2006). Using thematic analysis in psychology. *Qual. Res. Psychol. 3*, 77–101. doi: 10.1191/1478088706qp063oa

Bromme, R. et al. (2014). Empirische Bildungsforschung und evidenzbasierte Bildungspolitik. *Zeitschrift für Erziehungswissenschaft, 17 (Special Issue 27)*, 3-54. doi: 10.1007/s11618-014-0514-5

Brown, C., & Zhang, D. (2016). Is engaging in evidence-informed practice in education rational? What accounts for discrepancies in teachers' attitudes towards evidence use and actual instances of evidence use in schools? *Br. Educ. Res. J. 42*, 780–801. doi: 10.1002/berj.3239

Chen, J., Wang, M., Kirschner, P. A., & Tsai, C. C. (2018). The role of collaboration, computer use, learning environments, and supporting strategies in CSCL: A meta-analysis. *Review of Educational Research, 88*(6), 799-843.

Cheung, A. C. K., and Slavin, R. E. (2013). The effectiveness of educational technology applications for enhancing mathematics achievement in K-12 classrooms: A meta-analysis. *Educational Research Review, 9*, 88–113. doi: 10.1016/j.edurev.2013.01.001

Clark, R. E. (1983). Reconsidering research on learning from media. *Review of educational research, 53*(4), 445–459.

Clark, R. E. (1994). Media will never influence learning. *Educational Technology Research and Development, 42*(2), 21–29. doi:10.1007/BF02299088

Clark, D. B., Tanner-Smith, E. E., & Killingsworth, S. S. (2016). Digital games, design, and learning: A systematic review and meta-analysis. *Review of educational research, 86*(1), 79–122.

Cumming, G. (2012). Understanding the new Statistics: Effect Sizes, Confidence Intervals, and Meta-analysis. New York, NY: Routledge.

Dagenais, C. et al. (2012). Use of research-based information by school practitioners and determinants of use: A review of empirical research. *Evidence & Policy: A Journal of Research, Debate and Practice, 8*(3), 285–309. doi: 10.1332/174426412X654031

Demski, D., and Racherbäumer, K. (2015). Principals' evidence-based practice –findings from German schools. *International Journal of Educational Management, 29(6), 735-748*. doi: 10.1108/IJEM-06-2014-0086

Diery, A. et al. (2020a). Das Clearing House Unterricht. Ein Service für die Lehrer*innenbildung?! *Journal für LehrerInnenbildung, 20*(2), 42-51. doi: 10.35468/jlb-02-2020_03

Diery, A. et al. (2020b). Evidence-based practice in higher education: Teacher educators' attitudes, challenges, and uses. *Frontiers in Education, 5*(62). doi: 10.3389/feduc.2020.00062

Farley-Ripple, E., May, H., Karpyn, A., Tilley, K., & McDonough, K. (2018). Rethinking connections between research and practice in education: A conceptual framework. *Educational Researcher, 47*(4), 235–245.

Fauth, B., & Leuders, T. (2018). *Kognitive Aktivierung im Unterricht*. Landesinstitut für Schulentwicklung Stuttgart (LS).

Fleischman, S. (2009). User-driven research in education: A key element promoting evidence-based education. In W. Böttcher, J. N. Dicke, and H. Ziegler (Eds.), *Evidenzbasierte Bildung. Wirkungsevaluation in Bildungspolitik und pädagogischer Praxis* (pp. 69-82). Münster, Germany: Waxmann.

Franke, U., & Wecker, C. (2019, February). Das mache ich eigentlich immer so – Erfahrungsbasiertes Alltagswissen als Begründung von unterrichtsmethodischen Entscheidungen. Paper presented at the Konferenz der Gesellschaft für Empirische Bildungsforschung (GEBF), Cologne, Germany.

Fuchs, L.S. et al. (2021). *Assisting Students Struggling with Mathematics: Intervention in the Elementary Grades (WWC 2021006).* Washington, DC: National Center for Education Evaluation and Regional Assistance (NCEE), Institute of Education Sciences, U.S. Department of Education.

Fraillon, J., Ainley, J., Schulz, W., Friedman, T., & Duckworth, D. (2019*). Preparing for life in a digital world: the IEA International Computer and Information Literacy Study 2018 International Report.* Melbourne, Australia: Australian Council for Educational Research (ACER).

Georgiou, D., Diery, A., Mok, S. Y., Fischer, F., and Seidel, T. (2023). Turning research evidence into teaching action: Teacher educators' attitudes toward evidence-based teaching. Int J Educ Res Open 4:100240. doi: 10.1016/j.ijedro.2023.100240

Gogolin, I., Hannover, B., & Scheunpflug, A. (2020). Evidenzbasierung als leitendes Prinzip in der Ausbildung von Lehrerinnen und Lehrern–Editorial. In I. Gogolin, B. Hannover, and A. Scheunpflug (Eds.), *Evidenzbasierung in der Lehrkräftebildung*, *Edition ZfE 4* (pp. 1-9). Wiedsbaden: Springer. doi: 10.1007/978-3-658-22460-8_1

Gräsel, C. (2019). Transfer von Forschungsergebnissen in die Praxis. In C. Donie, F. Foerster, M. Obermayr, A. Deckwerth, G. Kammermeyer, G. Lenske, M. Leuchter, and A. Wildemann (Eds.), *Grundschulpädagogik zwischen Wissenschaft und Transfer* (Jahrbuch Grundschulforschung, 23, pp. 2-11). Wiesbaden, Germany: Springer VS.

Hamilton, E. R., Rosenberg, J. M., & Akcaoglu, M. (2016). Examining the Substitution Augmentation Modification Redefinition (SAMR) model for technology integration. *Tech Trends, 60*, 433-441. doi:10.1007/s11528-016-0091-y

Hartmann, U., Decristan, J., & Klieme, E. (2016). Unterricht als Feld evidenzbasierter Bildungspraxis? *Zeitschrift für Erziehungswissenschaft, 1*(19), 179-199.

Haynes, R. B. (2001). Of studies, syntheses, synopses, and systems: the "4S" evolution of services for finding current best evidence. *BMJ Evidence-Based Medicine, 6*(2), 36–38.

Hattie, J. (2009). Visible learning: A synthesis of over 800 meta-analyses relating to achievement. New York, NY: Routledge.

Hattie, J., & Timperley, H. (2007). The Power of Feedback. *Review of Educational Research, 77*(1), 81–112. doi:10.3102/003465430298487

Hetmanek, A. et al. (2015). Wozu nutzen Lehrkräfte welche Ressourcen? *Unterrichtswissenschaft, 43*(3), 193–208.

Higgins, K. et al. (2019). Effects of technology in mathematics on achievement, motivation, and attitude: A meta-analysis. *Journal of Educational Computing Research, 57*(2), 283–319.

Hillmayr, D., Reinhold, F., Ziernwald, L., and Reiss, K. (2017). *Digitale Medien im mathematisch-naturwissenschaftlichen Unterricht der Sekundarstufe. Einsatzmöglichkeiten. Umsetzung und Wirksamkeit*. Münster: Waxmann. https://waxmann.com/buch3766

Hillmayr, D., Ziernwald, L., Reinhold, F., Hofer, S. I., Reiss, K. M. (2020). The potential of digital tools to enhance mathematics and science learning in secondary schools: A context-specific meta-analysis. *Computers & Education 153*, 103897. doi: g/10.1016/j.compedu.2020.103897

Hillmayr, D., Reinhold, F. & Reiss, K. (2022). Das Potenzial digitaler Tools für einen qualitätsvollen Unterricht: Ein Blick auf aktuelle Forschungsbefunde. *SchulVerwaltung spezial, 1*, 34-36.

Hillmayr, D., Reinhold, F., Ziernwald, L., Hofer, S. I., & Reiss, K. (2023). Zum Zusammenhang zwischen Leistungs-und Motivationseffekten beim Einsatz digitaler Tools im mathematisch-naturwissenschaftlichen Unterricht der Sekundarstufe. Eine Forschungssynthese. In K. Scheiter & I. Gogolin (Eds.), *Bildung für eine digitale Zukunft, Edition ZfE 15* (pp. 103-123). Wiesbaden: Springer. doi: 10.1007/978-3-658-37895-0_5

Hillmayr, D., Reinhold, F., Holzberger, D., & Reiss, K. (2024). STEM teachers' beliefs about the relevance and use of evidence-based information in practice: a case study using thematic analysis. *Frontiers in Education, 8*, 1261086. doi: 10.3389/feduc.2023.1261086

Joyce, K. E., & Cartwright, N. (2020). Bridging the Gap Between Research and Practice: Predicting What Will Work Locally. *American Educational Research Journal, 57*(3), 1045–1082. doi: 10.3102/0002831219866687

Kiemer, K., and Kollar, I. (2021). Source selection and source use as a basis for evidence-informed teaching. *Zeitschrift für Pädagogische Psychologie, 35*, 1–15. doi: 10.1024/1010-0652/a000302

KMK (2004). Standards für die Lehrerbildung: Bildungswissenschaften. Beschluss der Kultusministerkonferenz.

Kozma, R. B. (1994). Will media influence learning? Reframing the debate. Educational *Technology Research and Development, 42*(2), 7–19. doi:10.1007/BF02299087

Köller, O. (2017). Theoria cum praxi – hilft Bildungsforschung für die pädagogische Praxis? Vortrag beim Post-Doc Symposium Praxistransfer an der Universität Hamburg vom 23.–24.11.2017.

Landrum, T. J., Cook, B. G., Tankersley, M., & Fitzgerald, S. (2002). Teacher perceptions of the trustworthiness, usability, and accessibility of information from different sources. *Remedial and Special Education, 23*(1), 42–48.

Lewalter D., Kastorff, T. & Moser, S. (2023) Digitalisierungsbezogene Lerngelegenheiten und -aktivitäten in Schule und Freizeit. In D. Lewalter, J. Diedrich, F. Goldhammer, O. Köller, & K. Reiss, (Eds.), *PISA 2022: Analyse der Bildungsergebnisse in Deutschland* (pp. 237-271). Münster; New York: Waxmann.

Lichti, M., & Roth, J. (2018). How to foster functional thinking in learning environments using computer-based simulations or real materials. *Journal for STEM Education Research*, 1, 148-172.

Littell, J. H., & White, H. (2018). The Campbell Collaboration: Providing better evidence for a better world. *Research on Social Work Practice, 28*(1), 6-12.

Lysenko, L. V. et al. (2014). Educational research in educational practice: Predictors of use. *Canadian Journal of Education, 37*(2), 1–26.

Mayer, R. E. (2014). Cognitive Theory of Multimedia Learning. In R. E. Mayer (Ed.), *The Cambridge Handbook of Multimedia Learning* (2nd ed., pp. 31–48). New York, NY: Cambridge University Press.

Mayer, R. E., & Chandler, P. (2001). When learning is just a click away: Does simple user interaction foster deeper understanding of multimedia messages? *Journal of Educational Psychology, 93*(2), 390.

Ma, W., Adesope, O. O., Nesbit, J. C., & Liu, Q. (2014). Intelligent tutoring systems and learning outcomes: A meta-analysis. *Journal of Educational Psychology, 106*(4), 901–918. doi:10.1037/a0037123

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & The PRISMA Group. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLoS Medicine, 6*(7). doi:10.1371/journal.pmed.1000097

Moreno, R., & Mayer, R. (2007). Interactive Multimodal Learning Environments: Special Issue on Interactive Learning Environments: Contemporary Issues and Trends. *Educational Psychology Review, 19*(3), 309–326. doi:10.1007/s10648-007-9047-2

Mosteller, F., Nave, B., and Miech, E. J. (2004). Why we need a structured abstract in education research. *Educational Researcher, 33*(1), 29-34.

Nattland, A., & Kerres, M. (2009). Computerbasierte Methoden im Unterricht [Computer-based Methods in Class]. In K.-H. Arnold, U. Sandfuch, & J. Wiechmann (Eds.), *Handbuch Unterricht* (2nd ed., pp. 317–324). Bad Heilbrunn, Germany: Julius Klinkhardt.

OECD (2001). *Knowledge and Skills for Life: First Results from PISA 2000*. Paris: Organisation for Economic Co-operation and Development (OECD). doi: 10.1787/9789264195905-en

OECD (2013). *PISA 2015: Draft Science Framework*. Paris: Organisation for Economic Co-operation and Development (OECD).

OECD. (2019). *PISA 2018 results (volume I): What students know and can do*. Paris: Organisation for Economic Co-operation and Development (OECD). doi: 10.1787/5f07c754-en

OECD (2016a). *PISA 2015: Results in Focus. PISA in Focus, No. 67*. Paris: Organisation for Economic Co-operation and Development (OECD). doi:10.1787/aa9237e6-en

OECD (2016b). *PISA 2015 Results (Volume I): Excellence and Equity in Education*. Paris: Organisation for Economic Co-operation and Development (OECD). doi:10.1787/9789264266490-en

Özyurt, Ö., Özyurt, H., Güven, B., & Baki, A. (2014). The effects of UZWEBMAT on the probability unit achievement of Turkish eleventh grade students and the reasons for such effects. *Computers & Education, 75*, 1–18. doi:10.1016/j.compedu.2014.02.005

Perry, D. R., & Steck, A. K. (2015). Increasing Student Engagement, Self-Efficacy, and Meta-Cognitive Self-Regulation in the High School Geometry Classroom: Do iPads Help? *Computers in the Schools, 32*(2), 122–143. doi:10.1080/07380569.2015.1036650

Petrosino, A., Boruch, R. F., Soydan, H., Duggan, L., & Sanchez-Meca, J. (2001). Meeting the challenges of evidence-based policy: The Campbell Collaboration. *The ANNALS of the American academy of political and social science, 578*(1), 14–34.

Reinhold, F., Diedrich, J., Strohmaier, A., & Reiss, K. (2023) Mathematikkompetenz in einer durch Digitalisierung geprägten Welt: Die Rahmenkonzeption in PISA 2022. In D. Lewalter, J. Diedrich, F. Goldhammer, O. Köller, & K. Reiss, (Eds.), *PISA 2022: Analyse der Bildungsergebnisse in Deutschland* (pp. 27-51). Münster; New York: Waxmann.

Reiss, K. & Hillmayr, D. (2018). Wirksamkeit digitaler Medien im mathematisch-naturwissenschaftlichen Unterricht: Eine Analyse des aktuellen Forschungsstands. *SchulVerwaltung spezial, 4*, 178-180.

Schreier, M., & Odağ, Ö. (2020). Mixed methods. In G. Mey, K. Mruck (Eds.), *Handbuch qualitative Forschung in der Psychologie*, 263-277. Wiesbaden: Springer. doi: 10.1007/978-3-658-18387-5_22-2

Sackett D. L. et al. (1996). Evidence based medicine: what it is and what it isn't. *The BMJ, 312*(7023), 71–72. doi: 10.1136/bmj.312.7023.71.

Schiepe-Tiska, A. et al. (2021). Achieving Multidimensional Educational Goals Through Standard-Oriented Teaching. An Application to STEM Education. *Frontiers in Education*, *6*, 592165. doi: 10.3389/feduc.2021.592165

Seidel, T., Mok, S. Y., Hetmanek, A., & Knogler, M. (2017). Meta-analysen zur unterrichtsforschung und ihr beitrag für die realisierung eines clearing house unterricht für die lehrerbildung. *Zeitschrift für Bildungsforschung, 7*(3), 311-325.

Shadaan, P., & Leong, K. E. (2013). Effectiveness of Using GeoGebra on Students' Understanding in Learning Circles. *Malaysian Online Journal of Educational Technology, 1*(4), 1-11.

Sinell, A. (2017). Das Transfer Strategy Framework. Ein Tool zur Entwicklung passgenauer Transferstrategien. *Wissenschaftsmanagement, 23*(4), 36–41.

Sliwka, A., & Klopsch, B. (2019). Redefining school: Educational spaces for Adolescents' engagement in learning. In H. Jahnke, C. Kramer & P. Meusburger (Eds.), *Geographies of schooling*, 321-332. Cham, Switzerland: Springer.

Sung, Y.-T., Yang, J.-M., & Lee, H.-Y. (2017). The Effects of Mobile-Computer-Supported Collaborative Leaning: Meta-analysis and Critical Synthesis. *Review of Educational Research, 87*(4), 768–805.

Thomm, E. et al. (2021a). Predictors of teachers‘ appreciation of evidence-based practice and educational research findings. *Zeitschrift für Pädagogische Psychologie, 35*, 1–12. doi: 10.1024/1010-0652/a000301

Thomm, E. et al. (2021b). When preservice teachers’ prior beliefs contradict evidence from educational research. *British Journal of Educational Psychology*, *91*(3), 1055–1072. doi: 10.1111/bjep.12407

Schmich, J., & Itzlinger-Bruneforth, U. (2019). *TALIS 2018. Rahmenbedingungen des schulischen Lehrens und Lernens aus Sicht von Lehrkräften und Schulleitungen im internationalen Vergleich* (Vol. 1). Graz: Leykam.

Steenbergen-Hu, S., and Cooper, H. (2013). A meta-analysis of the effectiveness of intelligent tutoring systems on K–12 students’ mathematical learning. *Journal of Educational Psychology, 105*(4), 970–987.

Steenbergen-Hu, S., & Cooper, H. (2014). A meta-analysis of the effectiveness of intelligent tutoring systems on college students’ academic learning. *Journal of Educational Psychology, 106*(2), 331–347. doi:10.1037/a0034752

Van der Kleij, F. M., Feskens, R. C., & Eggen, T. J. (2015). Effects of feedback in a computer-based learning environment on students’ learning outcomes: A meta-analysis. *Review of educational research, 85*(4), 475-511.

Van Schaik, P. et al. (2018). Barriers and conditions for teachers' utilisation of academic knowledge. *International Journal of Educational Research, 90*, 50–63. doi: 10.1016/j.ijer.2018.05.003

Vygotsky, L.S. (1978). Mind in Society: The development of higher mental processes. Cambridge: Harvard University Press.

Wang, L. H., Chen, B., Hwang, G. J., Guan, J. Q., & Wang, Y. Q. (2022). Effects of digital game-based STEM education on students’ learning achievement: a meta-analysis. *International Journal of STEM Education, 9*(1), 26.

Wenglein, S. et al. (2015). Kompetenz angehender Lehrkräfte zum Argumentieren mit Evidenz: Erhöht ein Training von Heuristiken die Argumentationsqualität? *Unterrichtswissenschaft, 43*(3), 209-224.

Whitehurst, G. J. (2004). Making education evidence-based: Premises, principles, pragmatics, and politics. *Evanston, IL: Institute for Policy Research, Northwestern University*.

Williams, D., & Coles, L. (2007). Teachers’ approaches to finding and using research evidence: An information literacy perspective. *Educational Research, 49*(2), 185–206. doi: 10.1080/00131880701369719

What Works Clearinghouse (2012). WWC Practice Guide for Educators: Development Guidelines. U.S. Department of Education: Institute of Education Sciences. https://ies.ed.gov/ncee/wwc/Docs/ReferenceResources/wwc_pg_manual.pdf

Zierer, K. (2020). Die Wirkung digitaler Medien im Schulunterricht–Chancen und Risiken der Digitalisierung aus erziehungswissenschaftlicher Sicht. In R. A. Fürst (Ed.), *Digitale Bildung und Künstliche Intelligenz in Deutschland: Nachhaltige Wettbewerbsfähigkeit und Zukunftsagenda,* 373-386. Wiesbaden: Springer.

Appendix

Note:
For copyright reasons, the full texts are not included in this publication of the dissertation.

Appendix A - Publication A

Hillmayr, D., Ziernwald, L., Reinhold, F., Hofer, S. I. & Reiss, K. M. (2020). The potential of digital tools to enhance mathematics and science learning in secondary schools: A context-specific meta-analysis. *Computers & Education, 153*, 103897.
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Appendix B - Publication B

Hillmayr, D., Reinhold, F., Holzberger, D., & Reiss, K. (2024). STEM teachers' beliefs about the relevance and use of evidence-based information in practice: a case study using thematic analysis. *Frontiers in Education, 8*, 1261086.
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