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STEM teachers' beliefs about the relevance and use of evidence-based information in practice: a case study using thematic analysis

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The term *evidence-based practice* has gained importance in teacher education as well as in everyday school life. Calls from policymakers, academics, and society have become increasingly apparent that teachers' professional actions should not exclusively be based on subjective experiential knowledge but also on empirical evidence from research studies. However, the use of evidence comes along with several challenges for teachers such as often lacking applicability of available sources or limited time resources. This case study explores how teachers (n = 12) at secondary schools think about the relevance and usage of evidence-based information in practice as well as the barriers associated with it. As we see a particular need for evidence-based teaching in STEM disciplines, we focus on these subjects. A thematic analysis of the data indicates that the teachers generally rate relevance highly, for instance seeing opportunities for support and guidance. However, the actual use of evidence-based information in the classroom is rather low. The teachers most frequently mentioned the feasibility of implementation in class as a quality indicator of evidence-based information. Based on the data, we discuss possible conclusions to promote evidence-based practice at schools. Furthermore, the study opens up directions for further research studies with representative teacher samples in various disciplines.

KEYWORDS

evidence-based information, STEM teachers, secondary school, thematic analysis, case study

1 Introduction

Mathematical as well as science literacy are important for social participation in modern society, as literacy refers to the "ability to use mathematics [or science] to solve problems in real situations" (Wang, 2021, p. 2). It can emerge from learning processes, "including conceptual understanding, strategic ability, process fluency, reasonable reasoning awareness, and positive inclinations" (Wang, 2021, p. 2). Today, qualified employees are needed in the field of technology and sciences (OECD, 2016), however, many students worldwide have difficulties in solving mathematical problems or tasks in natural sciences as, for example, the

results of the PISA study show (OECD, 2016, 2019). Thus, it seems crucial to support student learning through excellent teaching in these disciplines, which, ideally, increases the learners' understanding and motivational aspects such as the perceived relevance of STEM-specific content (Stuckey et al., 2013). Evidence-based teaching can enhance teaching effectiveness and, hence, students' learning outcomes (e.g., Bathgate et al., 2019).

According to Bromme et al. (2014), empirical evidence provides different types of knowledge such as description as well as explication knowledge that enable the implementation and evaluation of state-of-the-art teaching. Particularly practical implications from current relevant research studies have the potential to improve the teaching quality at school. According to Whitehurst (2004), evidence-based practice means that decision-makers "routinely seek out the best available research and data before adopting programs or practices that will affect significant numbers of students" (p. 1). Evidence-based practice in STEM teaching therefore means that teachers use the best available evidence—for example studies on effective teaching strategies (Knogler et al., 2022)—regardless of whether the results are presented in primary or secondary studies of scientific journals or in formats that have already been specifically prepared for practitioners. So far, however, the transfer of educational research findings can rather be observed on the system level than on the classroom level. One example is the consideration of the PISA results which, for example, led to the expansion of full-day schools in Germany (Barnat, 2019). In contrast, there is little direct influence of evidence on explicit classroom practice of individual teachers. It can be assumed, however, that this promotes student outcomes in mathematics and science subjects (Schiepe-Tiska et al., 2021). Appropriate evidence-based information can support teachers in selecting, implementing, and reflecting on the most effective teaching strategies and thus also in achieving targets in educational standards (e.g., Knogler et al., 2022, p. 135).

However, there seems to be a gap between evidence and practice, especially regarding teaching in STEM disciplines (Bathgate et al., 2019). An example of this gap between evidence and practice becomes also clear when we look at the use of digital tools in secondary school teaching. Whereas numerous studies yield evidence that using digital tools in science and mathematics teaching can significantly enhance learning outcomes of secondary school students (Steenbergen-Hu and Cooper, 2013; Hillmayr et al., 2020), a substantial amount of teachers think that using digital tools can impede concept formation or distract from learning (Fraillon et al., 2019, p. 185). As a result, the potential of using digital tools in teaching and learning STEM is not being fully exploited. This example illustrates the need for more evidence-based practice by teachers.

2 Evidence and theoretical perspectives

As Mosteller et al. (2004) stated, "findings from educational research may be our greatest resource for supporting and improving educational practice" (p. 29). Generally speaking, evidence-based practice in education has become a much-discussed topic among politicians, researchers, and practitioners in recent years (e.g., Dagenais et al., 2012; Schiepe-Tiska et al., 2021). Using evidence as the basis for decision-making and professional actions instead of exclusively subjective beliefs and experiential knowledge became an even more prominent demand (Bromme et al., 2014). Of course, the aim is not to replace the teacher's experiential knowledge entirely with evidence. Newton et al. (2020) propose a more pragmatic approach with their decision-making model for applying research evidence in educational practice: "The most useful research evidence is combined with practitioner judgment about how and why to apply it in a specific context, with specific questions for each aspect. At the intersection of these three factors [useful evidence, educator judgment, local context], is pragmatic evidence-based education" (p. 5). But how can all the associated requirements be accomplished—especially as research does not always yield clear results? It is well-known that there are several fundamental prerequisites for using evidence-based information, such as access to sources, skills to understand as well as adapt evidence, and enough time resources for both obtaining, interpreting, and finally applying relevant information (Lysenko et al., 2014; Thomm et al., 2021a). However, although these prerequisites might be necessary tools, they are not a sufficient predictor for the actual use. Controversial discussions on appropriate measures to control the situation with COVID-19 recently showed the challenge of making evidence-based decisions or judgments for non-scientists.

The use of empirical methods in educational research has a long tradition. However, teachers acquire little knowledge during their studies about how to use and critically assess potentially relevant research findings (Wenglein et al., 2015). Teacher educators can be seen "as central agents in terms of the dissemination and implementation of evidence-based practice" (Diery et al., 2021, p. 3). However, recent studies showed that teacher educators face several challenges when it comes to translating research evidence into teaching practice (Diery et al., 2021; Georgiou et al., 2023). Moreover, van Schaik et al. (2018) identified various barriers regarding the usage of evidence-based information, such as skills in finding, interpreting, and applying research findings as well as limited accessibility and lack of time resources. Although several innovative interventions aim at enhancing access to adequate resources in general (e.g., Diery et al., 2020a), it seems that educational research findings need to be specifically processed (Fleischman, 2009; Hetmanek et al., 2015) and distributed so that teachers can make use of these valuable knowledge sources in their everyday school practice. Yet, it is little explored which type of information or source best meets practitioners' needs (Demski and Racherbäumer, 2015; Gräsel, 2019). Regardless of how they are processed, teachers' beliefs, appreciation, or attitudes toward educational research findings and evidence-based practice can be a crucial factor when it comes to using evidence in the school context (van Schaik et al., 2018; Thomm et al., 2021a).

The evidence base on STEM teaching and learning is relatively large compared to other subjects (e.g., Cheung and Slavin, 2013; Steenbergen-Hu and Cooper, 2013; Belland et al., 2017; Higgins et al., 2019) and provides a sound starting point for further exploring teachers claims and needs toward evidence-based practice. According to Bathgate et al. (2019), "the need for evidence-based teaching in college classrooms" primarily applies to STEM subjects, where research "shows a rigid and traditional (e.g., purely lecture-based) classroom approach," which "can systematically marginalize students, even unintentionally, through the structure and assessments used in the classroom and the cultural norms of science" (p. 1).

Therefore, this case study focuses on STEM teachers' beliefs about the *relevance* of evidence-based information in school practice.

We define evidence-based information as any content based on research findings (e.g., official in-service teacher education or journal articles). We further explored to what extent teachers *use* evidence-based information, what kind of *barriers* they face, and what *quality indicators* they use to assess evidence-based information. Based on our data, we discuss conclusions to promote evidence-based classroom instruction and for the practice of science communication.

2.1 Do teachers use evidence-based information—and why (not)?

Based on a literature review, Dagenais et al. (2012) concluded "that the use of research-based information is hardly a significant part of the school-practice scenario" (p. 296). According to Barnat (2019), teachers are more likely to actively search for information when faced with a problem, which is probably why their use of current evidence is not a daily routine. In addition, seeking out the best available sources of research can be a complex and time-consuming task (Thomm et al., 2021a) which also might hinder teachers from using evidence.

There is a variety of individual reasons that might be responsible for the limited use of educational research findings in teaching practice. National and international research has until now identified some specific factors that can be considered as necessary prerequisites for teachers to make use of evidence-based information that can help improve teaching and learning. So motivational variables and subjective beliefs are crucial when it comes to performing specific actions (Bandura, 1993; Liljedahl, 2011). More specifically, teachers' beliefs influence their perceptions and judgments, which will affect their behavior in the classroom (Pajares, 1992, p. 307). This link between attitude and behavior can be explained by the theory of planned behavior, "designed to predict and explain human behavior in specific contexts" (Ajzen, 1991, p. 181) and postulating "that behavior is a function of salient information, or beliefs, relevant to the behavior" (p. 189). According to that, Kiemer and Kollar (2021, p. 13) showed in their study that negative beliefs about the utility of educational evidence play an important role. They have a negative effect on the use of evidence-based information. Thus, when teachers are using evidence in their daily activities, their beliefs about the relevance of evidence are at least as important as their skills to do so (e.g., Thomm et al., 2021b). Previous studies show that teachers' beliefs about the relevance of educational evidence vary considerably (Hemsley-Brown and Sharp, 2003; Dagenais et al., 2012; van Schaik et al., 2018). Thus it is not possible to paint a uniform picture (Thomm et al., 2021b).

Relevance can be seen as "a personally meaningful connection to the individual" (Priniski et al., 2018, p. 2). Thus, the more likely a topic or activity, such as using educational evidence, plays a meaningful role for an individual, the higher the perceived relevance. According to the relevance continuum of Priniski et al. (2018), a teacher might perceive a study on the topic of *flipped classroom* as relevant because the teacher has long wanted to try out the concept in the classroom, but not necessarily because the reading of educational evidence *per se* is of relevance, which is an example of the lowest level of personal meaningfulness (*personal association*). The next level on the relevance continuum is *personal usefulness*: a teacher, for example, might consider reading educational studies to be relevant because scientific findings can help to prepare lessons and ultimately improve student learning as an essential target of the teacher's work. An example of the highest level of relevance (*identification*) is that a teacher might consider reading educational studies to be relevant because orientation to scientific knowledge is perceived as an essential part of professional responsibility.

Stuckey et al. (2013) offer a broader perspective on the meaning of relevance by focusing more strongly on the consideration of consequences. Applying their theory to the present issue, evidence-based information becomes relevant if its use has (positive) consequences for the teachers. These positive consequences can be both intrinsic and extrinsic and they can relate to current situations and decisions or the future. The intrinsic components relate to personal motives and the teacher's interest, while the extrinsic components relate to expectations from their personal and professional environment as well as from society (Stuckey et al., 2013). Following this idea, appropriate evidence-based information can support the teacher in lesson planning and thus be perceived by the teacher personally as a reduced workload. Another example of the intrinsic component is that the use of evidence on effective teaching strategies can increase the learning outcomes of students and thus contribute to the achievement of predetermined competence goals (e.g., KMK, 2022). The political and social demands for evidence-based practice in schools, and the related expectations of politicians or parents "that educational research will make a difference in what students learn, what teachers know, and what they teach" (Greenwood and Mabeady, 2001, p. 334), are an example of an extrinsic component. Regarding consequences that relate more to the future, the development of the teaching profession toward a scientifically based profession and the associated greater effectiveness as well as recognition can also serve as an extrinsic example here (Knogler et al., 2022).

However, even if a teacher considers the use of evidence to be relevant, various conditions must be met to successfully utilize evidence, which is, for example, a supporting environment at the school (Brown and Zhang, 2016), access to sources as well as the skills to read and interpret educational research findings (e.g., Bauer and Prenzel, 2012; Lysenko et al., 2014), or adequate time resources (Mosteller et al., 2004). Thomm et al. (2021a) examined the relations between such conditions and showed that better source access had no significant effect on the perceived irrelevance of results from education research. A plausible reason for this is, that teachers often miss clear and applicable implications of educational research studies (e.g., Lysenko et al., 2014). Finally, teachers are primarily interested in answers to typical everyday problems in the school context and practical applicability (Beelmann, 2014). This lack of applicability as well as the various challenges they face when using evidence stresses that specifically processed information has the potential to support evidence-based practice. Hence, specific ways of communicating and disseminating relevant evidence-based information to teachers are required that are appropriate for the target group and which according to Fleischman (2009) encompasses in particular an adequate format and a reasonable language. Regarding the use of educational research findings as an essential prerequisite for establishing an efficient evidence-based practice, researchers are assigned a key role in implementing change (Fleischman, 2009).

In short, to understand the claims and needs of teachers, it is therefore not only important to what extent teachers use evidence in

their everyday work but also, as an essential prerequisite for this, to what extent and why they see evidence as relevant to themselves and their work as teachers.

2.2 How is evidence-based information provided for practitioners?

Teachers begin to deal with the concept of evidence during their coursework at university, e.g., by reading scientific studies. However, teacher educators are still confronted with various challenges when it comes to translating evidence into their practice (Georgiou et al., 2023). Moreover, the demand for evidence-based practice goes beyond higher education, and teachers themselves should be able to bring it into their daily work routine.

To date, there has been little research on how teachers select different sources of information (Kiemer and Kollar, 2021) as well as on ways of transferring scientific knowledge into practice (e.g., Gräsel, 2019). Thus, not much is known about how relevant knowledge must be prepared for teachers so that they can use and implement it in classroom practice.

So far, different formats have been developed which aim to promote the use of evidence-based information by practitioners in the field of education. For example, Wenglein et al. (2015) examined how specific training can enhance the argumentative use of evidence by pre-service teachers. In addition to such formats, efforts are made to promote evidence-based practice through science communication. According to Burns et al. (2003), science communication can be defined as "the use of appropriate skills, media, activities, and dialogue" (p. 191) to produce personal responses to science such as awareness as well as the familiarity and understanding of (new) research findings. Practitioners could thus be directly and regularly informed about school-relevant research findings based on primary studies (Fuchs et al., 2021) or research syntheses such as meta-analyses or systematic reviews (Hillmayr et al., 2017; Diery et al., 2020a). Intermediary organizations such as clearing houses (e.g., the What Works Clearinghouse in the US) deal with the question of *what works* and aim to bridge the research-practice gap in education by using the method of research synthesis (e.g., Joyce and Cartwright, 2020). This method allows the existing evidence to be summarized based on an overall balance and thus improves the generalizability of the findings (Beelmann, 2014). The pyramid of evidence (e.g., Bromme et al., 2014) shows different sources of evidence-based information, which helps to assess their quality. Systematic reviews and meta-analyses are presented at the top of the pyramid, as they yield the most valid research findings for evidence-based practice and, at the same time, are less error-prone than individual experimental studies. Case studies or practice guidelines represent the lowest level of the pyramid, as their results are not generalizable, and confounding variables cannot be controlled.

Short reviews and plain language summaries are specific formats to provide summaries and ratings of current meta-analyses for practitioners (Diery et al., 2020a; Benz et al., 2021). Some formats focus on the specific target group and prepare scientific content directly for school practice (Hillmayr et al., 2017). Regarding the teachers' request for better applicability of evidence (e.g., Beelmann, 2014), the combination of specifically processed information with evidence that is based on research syntheses seems promising to strengthen evidence-based practice. In all of these rather long-term endeavors, it is important to "involve educators at every step of the way" (Fleischman, 2009, p. 80) and to "consider how evidence is currently used in education" (Fleischman, 2009, p. 72).

3 The present study

Although the importance of evidence-based practice may apply to all school subjects, we see a particular need for evidence-based teaching in STEM disciplines (e.g., Bathgate et al., 2019). Hence, in the present case study, we focus on mathematics, chemistry, biology, and physics teachers. These teachers tend to be more similar in their beliefs and approach than teachers of, for example, subjects like arts, music, or languages (Grossman and Stodolsky, 1995).

According to prior research, the extent to which teachers use evidence-based information is generally quite low (Dagenais et al., 2012; Hetmanek et al., 2015). At the same time, the extent, as well as the way of using evidence, can vary considerably among teachers (e.g., Thomm et al., 2021b). This can be traced back to diverse factors such as personal beliefs (van Schaik et al., 2018; Kiemer and Kollar, 2021)—which are also connected with the perception of relevance—or external conditions such as the availability of relevant sources (Thomm et al., 2021a). Reviewing research on teachers' utilization of evidence since 2001, van Schaik et al. (2018) concluded that "collaborations between schools and research institutes could be a way to counter barriers and create favorable conditions for teachers" to use academic knowledge (p. 59). Reciprocal partnerships between researchers and teachers can improve the use of evidence-based knowledge because of its close connection to the teachers' everyday practice. However, according to the authors, little is known about what teachers actually do when using evidence.

Thomm et al. (2021a) examined "the complex interplay of factors contributing to teachers' sourcing and reception of educational research" (p. 7) in a quantitative study and concluded that further in-depth studies on this topic are needed. According to the authors, it is important to address both external conditions of the teachers' environment as well as individual aspects such as personal beliefs in future studies.

To gain insight into context-specific factors, Joyce and Cartwright (2020) suggest supplementing quantitative studies with other, for example, qualitative research methods. Thus, to broaden the prevailing perspective of *what works* regarding current research efforts to foster evidence-based practice (Joyce and Cartwright, 2020), we address the question of *what works here*, in a more specific context by using a qualitative approach in this case study.

Whereas Georgiou et al. (2023) explored teacher educators' attitudes regarding their own evidence-based practice—as "the successful implementation of evidence-based teaching practices is a complex and multifaceted process, and it involves various stakeholders in education" (p. 7)—the present study addresses these issues on the teacher level.

Thus, the present case study explores mathematics and science teachers' beliefs about the relevance as well as their thoughts about the use of evidence-based information. To investigate possible reasons for the rather uncommon use of evidence, we asked teachers which kind of sources they used to obtain evidence-based information and what barriers they faced when using it. To gain insights into their needs when

processing evidence-based information, teachers were asked about quality indicators they used to evaluate evidence-based information.

The following research questions guided our case study:

1. What are STEM teachers' beliefs about the relevance of evidence-based information?
2. How do STEM teachers use evidence-based information?
3. What barriers do STEM teachers face when using evidence-based information?

4 Methods

We followed a case study approach (Cohen et al., 2007), as this approach allows us "to catch the complexity and situatedness of behavior" (p. 85), to understand the specific situation of a group—here the STEM teacher group—and to find out what we can learn from this particular case.

To analyze the interview data, we used the qualitative method of thematic analysis, which is widely used in psychology as well as in other fields (Braun and Clarke, 2006), for example, within case studies on evidence-based teaching (Georgiou et al., 2023).

Because of their complex interplay, the questions of how, to what extent, and why teachers engage with evidence should each be considered in context. Concerning the aims of our study, we agree with Chowdhury (2015, p. 1,139) that a qualitative approach allows a more flexible exploration of phenomena than, for example, a questionnaire. As teachers might have experienced contradictory behaviors and beliefs regarding evidence-based practice, this approach allows us to get more in-depth information on this. The use of open-ended questions in our interviews enables teachers to raise issues that might not have been considered in closed-ended formats.

4.1 Sample

The teacher sample was compiled in cooperation with the *Bavarian State Institute for School Quality and Educational Research* (*ISB*), an institution commissioned by the Bavarian Ministry of Education to contribute to the qualitative improvement of the school system in Bavaria. We used purposive sampling (Cohen et al., 2007) to access a group of teachers who are expected to have a similar understanding of the concept of *evidence* due to their teaching subjects (STEM). Moreover, they have a high level of teaching routine because of their teaching experience (13.17 years on average).

The teachers were notified by email of the planned interview and invited to participate.

Twelve teachers (three of them were male) agreed to take part in the interview study. Since the sample was chosen regarding the focus on teaching mathematics and science within the present study, all of the interviewees taught at least one science subject (i.e., biology, chemistry, physics, or natural sciences in general) or mathematics at a secondary school in Bavaria, Germany. Seven of them taught at a *Gymnasium* (highest track), three of them at a *Realschule* (middle track), and two at a *Mittelschule* (lower track, where students receive a basic general education). Additional background information on the teacher sample is presented in Table 1.

4.2 Data collection

In the written request, teachers were informed that the interview was about the relevance of research from the perspective of practitioners. To ensure comparable interview conditions, all interviews were conducted by the first author—who did not know the interviewees beforehand—using a pre-developed semi-structured guideline. The interviews were carried out between March and July 2020. Due to the conditions during the COVID-19 pandemic, all interviews had to be conducted via telephone. The interviews were recorded as audio files and transcribed afterward.

The interview consisted of the following questions, divided into three parts:

(1) Relevance of evidence in practice:

- *To what extent are research findings relevant for you as a teacher?*

(2) Use of evidence in practice:

- *To what extent does research influence your work?*

TABLE 1 Background information on teacher sample.

Interview ID	Type of school	Subjects taught	Teaching experience (in years)
I1	Gymnasium (highest track)	Biology/Chemistry	17
I2	Gymnasium (highest track)	Physics/Mathematics	19
I3	Gymnasium (highest track)	Physics/Mathematics/Informatics	14
I4	Realschule (middle track)	Chemistry/Mathematics	18
I5	Realschule (middle track)	Physics/Mathematics	2
I6	Realschule (middle track)	Chemistry/Mathematics	27
I7	Mittelschule (lower track)	Science/Mathematics/Informatics/Languages	13
I8	Gymnasium (highest track)	Physics/Ethics or Religious Education	10
I9	Mittelschule (lower track)	Physics/Chemistry	11
I10	Gymnasium (highest track)	Mathematics/Informatics	9
I11	Gymnasium (highest track)	Physics/Mathematics	12
I12	Gymnasium (highest track)	Mathematics/Ethics or Religious Education/Languages	6

- *Can you give a specific example of when you have integrated research-based information into your teaching or daily work?*
- *How did you learn about new research findings so far?*
- *How do you evaluate the quality of research-based information that is available to you?*

(3) Barriers to evidence use in practice:

- *What challenges do you face when it comes to using research or research-based information?*

For the present study, we were interested in anything that teachers considered to be evidence or evidence-based. To avoid misunderstandings and ensure a consistent understanding among the teachers, the more commonly known terms *research findings* or *research-based information* were used as forms of evidence. Explanations regarding our understanding of evidence were given if needed. Whether the respective basis to which the teachers referred was generated according to the usual standards of scientific practice cannot be verified in detail, and is not initially relevant to the purpose of the present study.

4.3 Data analysis

The average duration of the interviews was 25.67 min ($SD = 10.23$). First, the audio records of all interviews were transcribed verbatim. The text material was then analyzed following the method of thematic analysis (Braun and Clarke, 2006). This method is primarily intended to gain insight into the complexity of teachers' beliefs and behavior, as it is "a flexible and useful research tool, which can potentially provide a rich and detailed, yet complex, account of data" (Braun and Clarke, 2006, p. 78). It allows us to identify, analyze, and report (different or similar) themes within our data. A theme "captures something important about the data in relation to the research question" (p. 82).

While the main themes (beliefs about relevance, usage behavior, barriers) were identified theory-driven (Diery et al., 2020b; Kiemer and Kollar, 2021; Thomm et al., 2021b), the detailed data analysis was carried out inductively, so that sub-themes could be identified primarily based on the available data material, i.e., on the specific content expressed by this individual group of teachers (Braun and Clarke, 2006).

According to the method of thematic analysis (Braun and Clarke, 2006), the analysis process consisted of the six following phases:

1. Familiarizing oneself with the data: After all interviews were transcribed verbatim, the first author read all transcripts at least two times to get familiar with the entire data set and wrote down initial ideas.
2. Generating initial codes: Keeping the research questions in mind, interesting passages were marked. Due to the complex database, the qualitative analysis software *MaxQDA* was used, which facilitated a structured and systematic process.
3. Searching for themes: In this step of intense examination, similar content was collected in common (main) themes, and further sub-themes were identified. This step was supported by a second coder. All discrepancies between the two coders were discussed until a consensus was reached, and potential sub-themes were jointly identified. The focus here was on the dialog between co-researchers and thus on the comprehensibility and confirmability of coding (Graneheim and Lundman, 2004).
4. Reviewing themes: We checked whether the identified themes worked for the entire data set and the collated passages per (sub-)theme formed a coherent pattern.
5. Defining and naming themes: All themes relevant to the research questions were defined and named concisely.
6. Producing a report: The analysis was described in the present article, using vivid interview extracts as examples for the identified themes.

5 Findings

In the following section, we present our findings along the research questions and the corresponding themes. First, we report on the main theme *relevance of use* and the sub-theme *potentials of evidence*, which both relate to research question 1. We then continue with the findings regarding the *extent of use*, *specific examples*, *sources of evidence*, and *quality indicators*, which are all themes relating to research question 2. Finally, we present our findings regarding research question 3, which relates to the perceived *barriers*. For a better overview of the distribution of specific codes, we additionally report their frequencies of mention (Vaismoradi and Snelgrove, 2019), which were measured once per teacher even if the content was mentioned more than one time during the interview. At the end of this section, we briefly summarize our findings from the interviews.

5.1 Relevance of use

Overall, the teachers rated an orientation toward evidence in practice as *very important* ($n = 10$). One teacher said:

> *"I think it's very important for my work, especially as you can only develop further in this way and then you can also, yes, gain new insights. You do not always do things the old way."*

Another teacher said:

> *"I cannot imagine that anyone doubts that this makes sense. The findings in science and research are, of course, extremely important for society and practice."*

In several cases, however, the relevance was seen depending on the *feasibility* and applicability ($n = 4$). One answer was:

> *"So most of what I learned during my studies, I could not apply in practice."*

Accordingly, three teachers added:

> *"In my opinion, it is not possible to give a definitive answer. It depends definitely on what it is specifically, especially how detailed and how practice-oriented the whole story is."*

> *"I believe that the findings would actually be incredibly important for teachers if we were able to implement them and had the freedom to do so."*

> *"Research findings should definitely be taken into account. The extent to which this can then be implemented is, in the end, a different question."*

In one case, the gap between theory and practice was strongly emphasized: conditions of everyday school life seemed to be insufficiently considered in research and thus findings were claimed to be not beneficial for practice. One teacher also emphasized the importance of orientation toward evidence in the context of teacher training—but then the feasibility of the content was decisive.

Three teachers stated that relevance and the orientation toward evidence depended on *individual needs*. If an existing concept—from the teachers' perspective—had been successful so far, it should not be completely modified even if this was recommended based on scientific findings. In this case, selectively changing concepts that have proven successful was more sensible.

Whereas several teachers regarded teaching experience as at least equivalent to scientific findings, one of the interviewed teachers mentioned that experience and initiative should always be consistent with current research findings. Another interviewee saw it as an obligation of teachers to place their trust in science.

In two cases, the relevance was seen as dependent on the type of school. These teachers stated a great need for orientation toward scientific knowledge especially for the lower track *Mittelschule*: *"At the Mittelschule, of course, research results are not as present, as perhaps at the Gymnasium."*

5.2 Potentials of evidence

Four of the interviewees justified the relevance of evidence for practice with the associated opportunity for *personal and school development*. They argued that schools are subject to permanent change and need to constantly adapt to the lives of their students. To enhance student learning, instruction must be continuously improved. Only by knowing relevant prerequisites, high-quality teaching can be guaranteed. A lack of orientation toward evidence may thus risk a standstill of development.

In seven cases, the potential of orientation toward evidence was seen in the fact that it offered *support and guidance* to teachers: specifically, lesson planning and design were mentioned here, as well as the interaction with students. In two cases, a special need for the *Mittelschule* was addressed, since these teachers usually also teach subjects for which they have not completed a university degree. Additional subject-specific knowledge in a form suitable for the target group would therefore be helpful to the respondents.

Moreover, it was mentioned that a scientific basis could facilitate the acceptance and attractiveness of *innovations* and enable *objective discussions, decisions, and conclusions*. In one case, the added value of an orientation toward evidence was seen in the fact that different federal states of Germany or school systems could be compared with one another, and thus successful concepts could be adopted.

5.3 Extent of use

Four of the interviewees stated that their teaching was influenced by evidence-based information, from strongly to selectively:

> *"Research has had quite an influence on my work over the years."*

> *"Again and again, I would say. In the short term and very selectively. So I would not say that I read large research reports and can then put them into practice one-to-one, but simply in small things. Of course, it's also about the subject."*

In three cases, the influence was more indirect, for example, via the curriculum or subject-oriented educational teacher training. In these cases, research did not directly influence teaching. Regarding teacher training, however, one teacher said:

> *"I would really like teacher training to be more research-based than it is now. There is often too little input from outside, so in my view, there's often not enough that's really well-founded."*

Another teacher said:

> *"I believe that teachers benefit from educational research, even if only indirectly, because they hear about these methods in relevant journals or something like that and then implement them."*

Five other respondents stated that their everyday work was hardly or not at all influenced by evidence-based information, for example:

> *"Very little. There is very little immediate, direct influence, simply because you do not really get to engage with research in everyday life."*

Another answer was:

> *"At the moment, we are really relying more on subjective theories and sometimes trying out things that have proved successful elsewhere. That's empiricism on a very small scale. But I cannot say that I have the time or the opportunity to think about what would be a current contribution from educational research that would help me with this or that topic, I have to be honest."*

This was supported by another teacher:

> *"The everyday life of teachers can be influenced to the extent that they have the capacity to attend appropriate training courses. So if the teacher has the time resources to deal with this, then I think it can be incorporated into everyday teaching."*

5.4 Specific examples

When asked for specific examples of when teachers used research-based information, the topic of using digital tools was mentioned most frequently ($n = 8$), and two teachers referred specifically to the handling of digital tools:

> *"There is evidence, for example, that explainer videos that are too long have high dropout rates, and therefore it is recommended that explainer videos for students should be no longer than five minutes, then that directly influences my work, because then I know, okay, my videos have been too long so far, I'll just make them shorter" (I8).*

Evidence for the purpose of individual support and differentiation of students was mentioned five times, for example, regarding learning difficulties or gender-specific support:

> *"If you have children with autistic traits, for example, it's important to find out from time to time how best to deal with them" (I12).*

Evidence was also taken into account in lesson planning and design ($n = 3$), more specifically, teachers incorporated student feedback, flipped classroom, or learning goal-oriented basic models:

> *"Flipped Classroom, for example. I was initially made aware of it* via *recommendations and tips […]. Then I got more information about it […]. And I thought, oh, I can try that out, too, and then I implemented it and used it, and made my own experience" (I8).*

Three times, students were reported to engage in research-based learning themselves, such as experimenting in research labs:

> *"The students always found it very positive to visit a research lab, even if it was only to see how a PCR is done in practice" (I1).*

The curriculum itself and its competency-based nature were mentioned by three teachers as an evidence-based example:

> *"Regarding the new state-wide curriculum, many aspects that come from educational research were considered, […] and in fact, these are approaches that I am trying to take into account more and more in my lessons" (I7).*

Only one teacher did not have any specific example of using or considering evidence.

5.5 Sources of evidence

The majority of the respondents stated that they obtained evidence-based information in *magazines*, such as subject-oriented educational journals, some of which contained practical examples ($n = 9$). Eight teachers gained their knowledge from *teacher training*. In seven cases, the teachers used the *Internet* for information retrieval, with three of the respondents citing specific *social media* channels in which they regularly and actively obtained information. Six teachers reported that they obtained information from their *school environment*—for example, by exchanging ideas with the teaching staff or via relevant information portals. In five cases, *higher education institutions* were named as sources of evidence-based information. For example, these teachers took part in specially offered lectures or acquired their knowledge through collaboration with the university. Two teachers also used offers from the *state institutes* as well as classical *news formats*. One of the teachers regularly visited *education fairs*.

5.6 Quality indicators

The most frequently mentioned quality indicator of research-based information was its direct *feasibility* in the classroom ($n = 10$). The interviewees attached importance to the fact that the effort required for appropriate preparation and practical implementation should not be too high. One teacher stated that evidence-based information should always be aligned with the curriculum to better assess advantages and disadvantages. Three of the teachers considered the *conciseness* of evidence-based information to be an important characteristic: information should be available in a bundled manner. It was also important to the respondents that the research-based information offered concrete ideas or subject-specific examples that could be implemented directly in the classroom. Two of the interviewees stated that the top criterion was the *subject specificity* of the material. Practical feasibility should be given not only in terms of content. Relevant information should have the potential to be implemented according to the respective situation (federal state, type of school). In four cases, the *expected learning success of the students* was mentioned as the top quality indicator. Evidence-based information should help to ensure learning success and to convey the subject matter in such a way that the students remain motivated and interested. In addition, the teachers' own experience played a role in the assessment of the evidence: for three of the respondents, the material should be *plausible based on their own experience*. In five cases, the *source* played a role in the assessment of quality. Various indicators were named here that can be assigned to the common scientific quality criteria (e.g., generalizability, validity). One of the interviewees stated not to use any specific indicator for assessing the quality of sources.

5.7 Perceived barriers

Nine of the respondents saw *time resources* as a barrier to using evidence-based information in the classroom. There seemed to be a lack of time and resources for preparation as well as a lack of available teaching time. For the implementation, for example, the search for suitable material, the examination of scientific knowledge, the weighing of advantages and disadvantages within the individual conditions as well as the adaptation to the learning environment of the students were required and seemed to be too time-consuming.

Also, nine of the 12 teachers mentioned *organizational conditions* as a barrier to using evidence-based information. Most of the time, teachers mentioned constraints regarding the technical equipment or the curriculum. Especially teachers of the *Mittelschule*, due to the heterogeneous student body, saw little capacity to use evidence-based information in class.

Further, the question of accessibility of scientific findings was raised. Half of the teachers mentioned a *lack of usable material* as a barrier to integrating evidence-based information in their classroom work. On the one hand, the particular development of suitable evidence-based material was seen as enormously time-consuming, therefore the teachers used to rely on existing material. However, they claimed that adequate material was difficult to find and available material—such as scientific papers or research summaries—in most cases was too unspecific in terms of both the subject and individual teaching conditions. They noted a lack of concrete examples as well as subject-specific information in the material, so it was not directly applicable in the classroom.

In several cases, teachers called for more consideration of scientific findings, especially in in-service teacher training, which should

convey relevant findings more practically. According to the interviewees, teacher training was often rather based on experience and is not sufficiently scientifically sound.

5.8 Summary of findings

Although most teachers state that evidence-based teaching is important, our data put this into perspective and suggest a certain reluctance of teachers to adopt evidence-based practices in their classrooms. Several teachers emphasized the significance of aspects related to the particular teaching situation.

Although an orientation toward evidence in practice turned out to be of personal meaningfulness for some of the interviewed teachers, the actual relevance seemed to depend on the feasibility in the classroom as well as on individual situations of the teacher and school. The greatest potential of evidence was seen in its offer of support and guidance, specifically for lesson planning and design. However, only a few teachers intentionally used evidence in their work routines. According to most of the teachers, their work was either indirectly—for example, via the curricula—or hardly, or not at all influenced by evidence. Specific examples of the use of evidence were mostly related to teaching methods such as the use of digital tools or differentiation of learners. Subject-specific content was rarely mentioned. The teachers mainly gained new research insights from magazines, teacher training, or the internet including social media channels. Barriers regarding the use of evidence that teachers faced were organizational conditions such as inadequate technical equipment at school or the curriculum. Moreover, a lack of (subject-)specific material seemed to be problematic. The comment that limited time resources were responsible for the rather rare use of evidence-based information is a quite general aspect that is known from other contexts as well (e.g., Diery et al., 2020b). The most important quality indicator of evidence-based material was its feasibility in the classroom followed by the type of source itself and the expected learning success of students. Furthermore, the conciseness of information, as well as subject-specific examples, were considered crucial.

Particular demands for additional subject-specific knowledge for the lower track *Mittelschule* were mentioned several times throughout the interviews since these teachers often did not have a sufficiently content-related qualification in all subjects they teach. Because of various difficult conditions in these low-track schools, increased support for teachers should be provided to allow the use of evidence-based practices.

6 Discussion

With the present case study, we aimed to get deeper insights into STEM teachers' beliefs about the relevance of evidence-based practice as well as their usage behavior and perceived barriers when it comes to using evidence in practice. Although the majority of the interviewed teachers perceived important potentials in an orientation toward evidence—which is in line with the findings of Thomm et al. (2021b) or Georgiou et al. (2023) who focused on the level of teacher educators—its application in school practice was generally low. According to prior research and the decision-making model according to Newton et al. (2020), experiential knowledge—such as teachers' own experience or the experience of other teachers—played a crucial role when using evidence (Hetmanek et al., 2015) as well as assessing the usability of evidence-based information sources (Kiemer and Kollar, 2021). The data from the present case study also show that teachers used their own experiences to evaluate the quality of evidence-based material. This may be regarded as a critical finding concerning Thomm et al. (2021b) who fear a "devaluation of educational research when scientific evidence contradicts preservice teachers' prior beliefs" (p. 1,069). However, this is one possible explanation for the infrequent use of evidence-based information by teachers. As a result, research should probably make an even greater effort to incorporate the knowledge of practitioners and to disseminate and communicate research findings about the opportunities and constraints in the classroom. In terms of relevance, it can be implied that teachers see both personal associations and personal benefits in evidence, but relevance at the level of personal identification is not apparent in the responses (see Priniski et al., 2018). Moreover, primarily intrinsic aspects, such as support and orientation as well as personal development, were mentioned here rather than extrinsic aspects that would motivate teachers to use evidence (see Stuckey et al., 2013).

Most of the interviewed teachers obtained scientific information from common subject-oriented educational magazines or in the context of teacher training, however, more innovative formats with specifically processed evidence are not sufficiently available. In general, teachers are interested in practice-oriented answers to everyday problems (Beelmann, 2014), which is confirmed by this study, but it also shows that readily at hand and useful material is difficult to find.

The challenges that the interviewed teachers are confronted with can be categorized into resource-related challenges and practice-related challenges, analogous to the study of Georgiou et al. (2023): most of the interviewees mentioned a lack of time resources as well as the lack of sources containing evidence-based material that can be directly incorporated into lessons. Further, problematic organizational framework conditions were mentioned by most teachers, as also found by Brown and Zhang (2016). As a conclusion, they stated that schools should "promote the vision for evidence-use (i.e., actively encourage its use)" and "establish effective learning environments, in which learning conversations around the use of evidence, can flourish." (p. 780).

What can we conclude from the present findings for science communication efforts to promote evidence-based practice? According to the results, the feasibility of the content, information about the expected learning success of students, and subject-specific aspects should be taken into account in relevant formats. One possibility to address these aspects is the format user-oriented practice brochures, for example, a brochure about the use of digital tools in mathematics and science subjects as a current topic in need of evidence-based information (Hillmayr et al., 2017). In this brochure, relevant information based on current research findings from meta-analyses (Hillmayr et al., 2020) is specifically processed for mathematics and science teachers at the secondary school level. To strengthen the feasibility of the evidence two subject-oriented examples are elaborated, which refer to the evidence and offer suggestions for implementation in class. As the need for feasibility is mentioned very frequently throughout the interviews, this aspect seems pivotal concerning the use of evidence-based information. Moreover, the brochure yields

information about the effects of using digital tools on student learning outcomes in mathematics and science subjects. According to one-third of the interviewees, the expected learning success of students is an important quality indicator regarding evidence-based material. In line with the finding that common scientific quality criteria seem to play an important role for some of the interviewees, the brochure yields concise information about characteristics and the method regarding the underlying research studies as well as theoretical background knowledge toward learning with digital tools. Such formats can thus potentially serve to raise teachers' awareness, familiarity, and understanding of (new) research findings while addressing their specific demands and needs in concrete ways.

6.1 Prospects and limitations of the study

Whereas the use of evidence-based information by teachers as well as the development of appropriate formats to enhance evidence-based practice is still under-explored (e.g., Dagenais et al., 2012; Gräsel, 2019; Georgiou et al., 2023), the present case study provides insights into mathematics and science teachers' views on the relevance as well as the use of evidence-based information by a thematic analysis of the current interview data. The aim of our constructivist approach was not to generalize the findings, but to highlight the individual beliefs and thoughts of the specific group of STEM teachers. To find out, if the findings may be transferable to teachers in other disciplines, further studies should be conducted.

There are several limitations of this study. As the teachers participated voluntarily, the findings might rather represent the claims and needs of an upper bound, and thus the perceived relevance, as well as the usage of evidence, could be substantially lower regarding other teachers on the secondary school level. Although we addressed our interview request to several teachers through various communication channels, only 12 teachers attended. This may indicate that evidence-based teaching is not yet the focus of teachers although evidence is considered an important criterion in the classroom, studies on student performance provide concrete results, and—at least partly—curricula have included this aspect.

Furthermore, the method of thematic analysis is assigned to hermeneutics (Devi Prasad, 2019) and thus in this case aims to understand what teachers think whereas possible explanations for their behavior and beliefs might be better analyzed within other study designs. Finally, the responses from our interviewees might have been biased by social desirability since the demands for evidence-based practice in the school context are commonly known these days (Bromme et al., 2014). As already stated by Thomm et al. (2021a) future studies should therefore consider "process data that mirrors teachers' actual behavior when engaging with educational research" (p. 7). In this way, the appropriateness of different science communication formats could also be examined more directly.

6.2 Implications and conclusion

The interview data show that—according to the answers of most of the teachers—the use of currently available evidence-based information seems to go along with an *additional effort* regarding lesson planning as well as teaching time. Moreover, a lack of appropriate material is problematic. Thus, it seems crucial to provide specifically processed evidence-based material for teachers (Thomm et al., 2021a). As feasibility was the most mentioned aspect regarding quality indicators of evidence-based material, formats such as the mentioned user-oriented practice brochure (Hillmayr et al., 2017) can potentially support the use of evidence-based information. The fact that respondents rarely use evidence concerning specific subject content may be related to a lack of available material. Such formats should therefore contain subject-specific examples that can be implemented directly in the classroom (Hetmanek et al., 2015).

Furthermore, the subjective experiential knowledge of teachers seems to play an important role when it comes to using evidence. The theory of conceptual change describes that subjective beliefs may be based primarily on a person's experience and do not necessarily consider accepted scientific theories (Liljedahl, 2011, p. 103), which sometimes leads to robust misconceptions. As "conflicts between prior beliefs and scientific evidence may foster and stabilize a strong preference for experiential over scientific sources" (Thomm et al., 2021b, p. 1,058), it is essential to fundamentally change inaccurate beliefs—ideally during pre-service teacher training. Therefore the theory of conceptual change should be considered in interventions to change beliefs regarding teaching (Liljedahl, 2011).

As organizational conditions were mentioned as one of the two most significant barriers to the use of evidence-based information, the implications of further studies should be more closely aligned with the curricula. School-related factors such as the implementation of a culture of using evidence to improve practice (Thomm et al., 2021a) seem pivotal and implications of studies should therefore offer concrete guidelines for different types of schools to optimize their current framework conditions—regarding special needs particularly for the lower track *Mittelschule*. According to Brown and Zhang (2016), "evidence use will never be fully or meaningfully realized unless school leaders prioritize evidence-informed practice as a school commitment" (p. 780). In line with that, Bathgate et al. (2019) suggest that stakeholders should pay more attention to identifying and strengthening conditions that promote evidence-based practice while reducing challenging factors.

Besides the mentioned challenges, the interviewed teachers also identified potentials regarding the use of evidence-based information, namely the opportunity for support and guidance in terms of their daily work. Typical everyday problems in the school context should hence be the subject of future studies. Therefore, it is necessary to get teachers more involved in the research process (Fleischman, 2009) and to consider their specific and current needs when planning and designing research studies. Stronger collaboration between researchers and practitioners could also help to illustrate the importance of scientific information—even if it conflicts with experiential knowledge—and that evidence is primarily intended to *support* as well as *optimize* existing teaching and learning processes instead of requiring additional efforts. To promote a user-driven research culture, teachers' awareness should be raised that not only scientific input is important for practice, but also vice versa. The problem that practitioners often see teaching and research as two unrelated activities (Medgyes, 2017) could be addressed in dialogic formats of science communication (Burns et al., 2003). Here, teachers could work with researchers to promote evidence-based practice through the generation of practice-based evidence (Bryk, 2015). This may also increase teachers' sense of relevance by being part of an evidence-generating practice.

Evidence-based practice is not a sure-fire success (Bromme et al., 2014), and thus more research on the topic of using, processing, and finally sharing evidence-based information is needed, and with it, more collaboration between interdisciplinary-oriented and subject-oriented researchers as well as practitioners (van Schaik et al., 2018). The themes identified within this case study can offer directions for further research questions which should be examined based on representative samples as well as samples of teachers from other disciplines to find out under which conditions evidence-based practice and hence ultimately learning and teaching processes in school can best be strengthened.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

DHi: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Writing – original draft. FR: Writing – review & editing, Conceptualization, DHo: Writing – review & editing, Conceptualization. KR: Supervision, Writing – review & editing, Conceptualization.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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