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Design-based research–Tension between practical relevance and knowledge generation–What can we learn from projects?

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Abstract

Researchers often develop teaching-learning solutions to improve the quality of instruction. Some of these solutions are developed in the paradigm of design-based research (DBR). The output of DBR projects goes beyond design products for practice and includes contributions to local theories about teaching-learning in specific subject areas and contexts as well as knowledge about how to design and implement these processes. Design knowledge and contributions to local theories are intended to construct a cumulative, content-specific body of knowledge about teaching and learning that is transferable to related subject areas or contexts. To make this process work, dimensions of DBR need to be systematically reported. However, DBR projects are sometimes criticized for focusing more on practical output than on reports about research output and the form of cooperation with practitioners. To empirically investigate these presumed voids, we examined DBR projects conducted by the German-speaking physics education research community during the past 20 years.

Keywords: design-based research, theory-practice gap, curriculum development

INTRODUCTION

Physics education research (PER) aims to generate knowledge that contributes to the theoretical understanding of content-related teaching and learning processes as well as to improve teaching and learning practices. While PER has produced a wealth of empirical findings and theoretical insights into teaching and learning processes during the last 50 years, the implementation of these findings in teaching practice has only partially been successful. On the one hand, "there is still a large gap between what is known about effective teaching and learning science […] and the reality of instructional practice" (Duit et al., 2013, p. 487). On the other hand, "science education research is frequently viewed as irrelevant by policy makers, curriculum developers, and science teachers" (Duit & Treagust, 2003, p. 682).

This gap between theory and practice may at least partly result from traditional views on research. As expressed by Stokes (1997), while "basic research seeks to extend the area of fundamental understanding, applied research is directed toward some individual or group or societal need or use." (p. 8). In their pure forms, basic research is often associated with rigor and knowledge generation, and applied research is associated with relevance and practical use. This dichotomous view on scientific research creates tension and does not meet the needs of educational research as knowledge generating discipline that informs practice.

The limited impact of (physics) education research on teaching practices has led authors to question the traditional dichotomous view on science. Moving away from the idea of two incompatible poles–applied and basic research–Stokes (2011) proposes a view of knowledge generation in two dimensions. The dimensions "quest for fundamental understanding" and "considerations of use" form a coordinate system with four quadrants in which the opposing poles are realized simultaneously in various gradations (Smith et al., 2013, p. 151). In this model, the "use-inspired basic research" quadrant combines rigorous, scientific research and real-world applications, offering a way to bridge the gaps between knowledge and utility and between research and practice.

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Contribution to the literature

- This study discusses common characteristics of DBR based on primary literature on DBR and possible ways of framing theoretical contributions of DBR projects. It reveals the need to clarify the understanding of the theoretical contributions of DBR projects.
- Results of this study provide suggestions for future DBR projects and their documentation and reporting.
- This study portrays evolution and advancement of DBR in the German-speaking PER over the past 20 years and the formation of genuine science education research approaches to DBR.

The German-speaking science and mathematics didactics community has a long tradition of curriculum development (Niedderer & van Aufschnaiter, 2008; Prediger et al., 2013; Schecker & Hopf, 2021) within which different approaches have emerged. In recent years, particularly approaches with a strong focus on research- and evidence-based curriculum development have often been framed within the design-based research (DBR) paradigm (Mikelskis & Mikelskis, 2010; Niedderer & van Aufschnaiter, 2008; Shah et al., 2015; Stokes, 2011). However, DBR projects are sometimes criticized for focusing more on practical output, leaving the research output, the form of cooperation between research and practice, and the design process blurred. This is problematic, given the desideratum for cumulative knowledge generation and, subsequently, the intended synergistic use of this knowledge by other researchers, developers, or practitioners.

In our study, we want to shed light on how the German-speaking PER community deals with the tension between knowledge generation and developing products for practice in DBR projects. We investigate how this issue is addressed in DBR projects and which dimensions of DBR projects are reported to the scientific community. To empirically explore presumed voids, we systematically analyze reports on DBR projects available in conference proceedings of the German physical society (DPG) and the Gesellschaft der Didaktik für Physik und Chemie (GDCP) as well as related PhD theses published in the last 20 years.

DESIGN-BASED RESEARCH AS A PARADIGM FOR BRIDGING THE THEORY-PRACTICE GAP

DBR emerged in general education research at the beginning of the 1990s. This paradigm, which embodied the ideas of use-inspired basic research, was seen as having the potential to bridge the gap between research and practice by improving the translation of research into teaching practice (Haagen-Schützenhöfer & Hopf, 2020). Shah et al. (2015) claim that DBR is "serving theoretical and practical needs in education, addressing the complexity of education by informing immediate practice while simultaneously contributing to theoretical understandings in the field of education" (p. 152). The Design-Based Research Collective (2003) identifies four major benefits of DBR in education research:

1. exploring possibilities for creating novel learning and teaching environments,
2. developing theories of learning and instruction that are contextually based,
3. advancing and consolidating design knowledge, and
4. increasing our capacity for educational innovation.

There are different approaches within the design movement: design research, DBR, design experiments, design theories, educational design research, and developmental research (Prediger et al., 2015). Although these approaches have sometimes different foci and properties, they share similar goals and characteristics. We use the term DBR as a generic term for a methodological frame that incorporates a pragmatic dimension, which seeks to solve local, real-world problems, and a scientific dimension, which generates and accumulates knowledge about teaching and learning. In this context, design is understood not only as a product but also as a process–a problem-solving activity that leads to the generation of novel insights, knowledge, practices, or products (Bakker, 2018; Reinmann, 2022; Roggema, 2016). In the following section, we will discuss the common characteristics of DBR and how the tradition of German curriculum development adopted the ideas and characteristics of DBR.

What Characterizes Design-Based Research

DBR emerged as a paradigm of use-inspired basic research that combined two dimensions: knowledge generation (pure basic research) and utility in real-world situations (pure applied research). The nature of this paradigm is best illustrated by relating DBR to these two dimensions. As the ecology of learning is complex, controlled experiments, such as those performed in pure basic research, cannot fully capture the essence of teaching and learning in real-life contexts (Brown, 1992). DBR contributes to our understanding of this complexity by focusing on specific processes in specific contexts. In contrast, pure basic research emphasizes isolated variables (Confrey, 2005; The Design-Based Research Collective, 2003; diSessa & Cobb, 2004; Reinmann, 2005; van den Akker et al., 2006). In addition, DBR goes beyond simple design solutions for real-world problems, which are common in applied research (Edelson, 2002). In DBR, the design process is research-driven and systematically documented. Formative evaluation helps to identify shortcomings and obstacles. Then, lessons learned are generalized beyond the specific context to contribute to theory components. Three levels of theory contributions can be distinguished (Edelson, 2002; Reinmann, 2005). Domain theories generalize aspects of problem analysis; design frameworks provide prescriptive guidelines for achieving learning goals in a specific context; and design methodologies offer procedural guidance for the design process and describe the required tasks, objectives, and expertise. Thus, DBR aims to combine both dimensions.

Linking applied and basic research offers several benefits. McKenney and Reeves (2018) emphasize that "through such a synergistic process, educational design research stands to increase both the robustness of its theoretical implications and the relevance of its innovative products." (p. 9). DBR projects adopt a dual perspective that includes both epistemic and design goals. Likewise, the research objects are both epistemic and design objects. Additionally, DBR is contextualized in both current scientific knowledge and specific practical conditions. This generates contextualized theories of teaching and learning and insights into the design process (theoretical output) as well as concrete improvements for practice (practical output).

A wide range of preliminary work has identified a number of characteristics that are common to different DBR approaches (Cobb et al., 2003; The Design-Based Research Collective, 2003; Edelson, 2002; Prediger et al., 2015; Reinmann, 2005; van den Akker et al., 2006):

1. Discrepancies experienced in educational practice are the starting point for a DBR project (real-world problem).
2. Interventions (e.g., course formats, teaching-learning environments, teacher guides, student materials) for authentic settings are designed to overcome this discrepancy.
3. Iterations of design, implementation, formative evaluation, and re-design ensure continuous improvement and new insights.
4. Cooperation between researchers and practitioners ensures that the research is grounded in real-world contexts, addresses practical needs, and is successfully implemented in practice with integration of theoretical knowledge and practical insights.
5. Design has both process and product dimensions. Design assumptions about how the design product can best achieve the goal are constantly reviewed and refined.
6. Theories are the prospective basis for design assumptions (theory-based perspective) and function as the reference for review. Theories about domain-specific teaching and learning are generated (theory-generative perspective) and refined retrospectively.
7. Empirical findings play a central role in analysis of the initial state of the real-world problem, in the formative evaluation of the iterations, and in the summative study of mature designs.
8. The complexity of real school settings is reflected in the research and development process, offering ecological validity and practice orientation. Contextualized theories provide answers to practical real-world problems and serve as guidelines for the design of learning processes.

These characteristics may vary across approaches due to different foci and methodological groundings. However, these differences are fine-grained since the presented characteristics are linked to the aims that are common to all approaches, namely, to provide design products for practice and contribute to theories (Prediger et al., 2015).

The Tradition of Curriculum Development in the German-Speaking Physics Education Research Community and Role of Design-Based Research

The development of curricula for science education has a long tradition dating back to the 1950s. In response to the so-called "Sputnik shock," many curriculum development projects were funded in the Western world, including Germany. These initiatives aimed to achieve innovations in science and technology teaching in schools in order to increase students' interest, ambition, and competency in these subjects.

In Germany, early physics curriculum development projects were mainly initiated by physicists at universities. These projects mainly focused on content and neglected educational perspectives. In the 1970s, when PER chairs were established in Germany, empirical research was introduced to strengthen the scientific basis of curriculum development at some places. As a consequence, developmental research communities emerged in the field of science and mathematics education in German-speaking countries (Mikelskis-Seifert et al., 2008; Prediger et al., 2015; Schecker & Hopf, 2021).

The origins of these curriculum development traditions can be traced back to different research groups. The movement initiated by Walter Jung at the University of Frankfurt at the beginning of the 1970s can be seen as a forerunner of DBR in the German-speaking PER community (Schecker & Hopf, 2021). Jung (1992) stressed that two perspectives must be intertwined to solve practical learning problems: one rooted in physics and its content structure, and one that considers the learning of physics from a psychological point of view. Following this idea, Jung (1992) developed instructional elements and refined them based on analysis of the learning processes they triggered in teaching experiments (named "Akzeptanzbefragungen [acceptance surveys]", Jung, 1992). Later, this approach was systematically related to DBR frameworks and has meanwhile spread as the Frankfurt DBR tradition and has informed numerous DBR projects in the German-speaking PER community.

The IPN physics curriculum can be mentioned as another important German curriculum development. It emerged in the late 1970s with the intent of "improving physics instruction in schools in co-operation with science schoolteachers and science education experts at universities" (Mikelskis-Seifert et al., 2008, p. 5f). The trial-based IPN strategy was characterized by "iterative development in several trials [and] pre- and post-test developed and used for evaluation" (Niedderer & van Aufschnaiter, 2008, p. 13f). In addition to a subject-specific focus, the IPN strategy has a concept orientation; some central physical concepts are repeatedly used throughout the 17 units of the IPN physics curriculum in class 5 to class 10.

A third movement called "fachdidaktische Entwicklungsforschung [didactic development research]" (Prediger & Zwetzschler, 2013) was established at the University of Dortmund. The ideas of this movement are explicitly based in DBR. Recently, the Dortmund tradition was further developed through a systematic emphasis on empirical inquiry and theory building, which take place in a framework that pays particular attention to specifying and re-structuring content. This tradition has informed several disciplines of content-specific education research and has yielded many empirical insights, particularly in the field of mathematics and science education (Prediger & Link, 2012; Prediger & Zwetzschler, 2013).

The three aforementioned movements show the long and active tradition of curriculum development in Germany. Though they vary in their focus and underpinnings, they have strong, explicit ties to characteristics of DBR, as outlined before.

RESEARCH AIMS

A long-term aim of DBR is to generate a coherent body of knowledge from individual DBR projects that is accessible for researchers and directly informs and influences practice (Collins, 1992; Shah et al., 2015). Consequently, it is necessary to document relevant dimensions of DBR projects, such as how a DBR project is methodologically grounded, how design processes are carried out, what kind of products for practice are designed, how a DBR project contributes to local theories and design knowledge, and what strategies for cooperation with practitioners and for dissemination are chosen by the researchers. As outlined in the introduction, DBR projects are sometimes criticized for focusing on practical output, while other dimensions of DBR projects, such as the theoretical and research-related outputs, the form of research-practice cooperation and the design process remain blurred–creating a tension between practical relevance and knowledge generation. We want to shed light on this tension in our own research community and examine how DBR has flourished in the German-speaking PER community over the past two decades.

In doing so, we will help to identify potential future advancements in DBR and how it is reported. Therefore, we do not synthesize the findings reported in the conference papers and theses of our data corpus to a coherent body of knowledge. We rather analyze what kind of findings and which other dimensions of DBR projects are reported in order to stimulate a more coherent and thus more comparable documentation of DBR projects. Such a documentation should eventually support the process of synthesizing a coherent body of knowledge. So, we primarily take a DBR perspective and try to find out how the paradigm of DBR is realized, and how the potential of DBR has been exploited so far. Our analysis is guided by the following research aims.

Research Aim 1: Methodological Groundings

Many different approaches can be used to incorporate the idea of DBR in education research. Identifying which literature on DBR is referenced when reporting on DBR projects reveals the methodological groundings and underlying assumptions of the researchers about DBR as a paradigm. Additionally, doing so provides an overview of trends and approaches of conducting DBR that influence the German-speaking PER community.

Research Aim 2: Practical & Research-Related Output

DBR produces different types of outputs, including design products for practice–such as intervention designs, curricula, learning materials–and research findings. These outputs are essential for accumulating a body of knowledge about content-related learning and design processes that is transferable to related subject areas or contexts. Researchers need to know the empirical findings and contributions to local theories of a project, and also exactly what a design product is like to be able to interpret and transfer results properly to similar contexts. Local theories often have a narrow scope of application to a specific subject domain or context. For example, the implementation of a design product on optics in secondary school in an urban area shows that a certain strategy supports students in developing a concept of light propagation. Other researchers may further explore if the local theory might be applicable to their problem or might further expand the local theory to different contexts. Therefore, we want to find out which types of outputs are reported back to the scientific community for knowledge generation.

Doing so, will shed light on the role of DBR in addressing the theory-practice gap.

Research Aim 3: Cooperation

Cooperation between researchers and practitioners is a central characteristic of DBR. On the one hand, cooperation enables the integration of knowledge and practical insights in the design process, resulting in more relevant and effective designs. On the other hand, cooperation contributes to a better understanding of the local contexts of real-world problems, as multiple different perspectives are considered. Furthermore, cooperation can improve practitioners' acceptance of practical design products. Therefore, we want to find out which role practitioners play in DBR projects of the German-speaking PER community and how practitioners' perspectives are considered. To understand the role of practitioners, we also need to know what type of practitioners are in the focus (e.g., teachers at school, lecturers at university, science educators in science centers). Therefore, we also investigate which groups of learners–and consequently practitioners–are in the focus of DBR projects and addressed by the design products.

METHODS

In our review, we systematically analyze which of the above-mentioned dimensions have been reported in research reports about DBR projects within the German-speaking PER community. For our review, we decided to analyze first conference proceedings for an overview and then theses for more extensive insights into DBR projects in our community. In the following subsections we explain the decision for choosing two different data sources, the selection process and the analysis of the data.

Conference Proceedings as Data Source

A systematic literature review is typically a method to identify, evaluate and summarize the findings of individual studies on certain issues (Newman & Gough, 2020). We initially planned to align the procedure of our review to the process suggested by PRISMA (Page et al., 2021). As a search tool we determined FIS-Bildung datenbank [education database]–a web portal operated by Informationszentrum Bildung [Education Information Center] (IZB) of the Leibniz Institute for Educational Research (Germany). The focus of this web portal is the topic-related compilation of relevant internet resources for and about research and research data in the field of education and didactics/content-related educational research. FIS does not only access the network of German-speaking libraries but also databases such as ERIC or EbscoHost, among others. When conducting literature searches (PRISMA–step 3) we only found a small number of DBR projects, and the hits lacked several DBR projects we had encountered at different occasions like conferences of our community. At this point, we had to rethink our strategy to avoid such blind spots and followed the suggestion of PRISMA to "perform other searching methods".

The goal of our review is to reveal how DBR projects are reported in the German-speaking community. Conferences are the platform where a scientific community professionally interacts and communicates about current research, and thus conferences constitute a scientific community. For German-speaking physics education researchers such typical occasions of professional interaction and communication are the two trinational (Austria, Germany, and Switzerland) conferences taking place each year: the spring meeting of DPG and the conference of GDCP. Since both conferences have conference proceedings and a slightly different focus within PER, we opted for them as data sources to get an overview of DBR projects conducted in the German-speaking PER community.

Selection process & selection criteria of conference papers

First, we systematically searched for contributions about DBR projects in the digital conference proceedings of the two biggest conferences in the German-speaking PER community: the spring meetings of DPG and the annual conferences of GDCP. While digital DPG conference proceedings have only been available since 2010, we do have digital access to GDCP conference proceedings since 2002.

We searched the conference proceedings for several variations of the term DBR, including "design(-)based(-) research," "design research," and "design-based research." We also used the generic term "Entwicklungsforschung [development research]" that is commonly used in German as a translation or synonym for DBR. In a next step, we excluded hits, where the search term only occurred in the reference section of the paper but not in the main text. After excluding these cases, the first selection phase yielded 148 papers.

Then, we analyzed these papers and excluded, for example, theoretical papers about DBR in general and papers referencing future DBR projects in their outlook section. The remaining 133 projects reported some kind of design product for practice in terms of solutions designed to overcome discrepancies identified in educational practice. We decided to exclude the 6 conference papers of GDCP published before 2010 to have a better comparability between the two conferences.

Finally, we checked for duplicates published in both proceedings. We classified conference papers as duplicates when they were either identical or when they reported the same aspects of a DBR project with the same findings. There were no duplicates. Thus, the final number of conference papers was 127.

Table 1. Main (deductive) categories used for analysis of 127 conference papers

Main category	Description of category	Prototypical text passage (translated from German)
Research aim 1		
Methodological groundings	This category includes all references to methodological foundations of DBR in literature that serve as basis for the DBR project.	*The intervention was designed following a DBR approach (Reinman, 2005).*
Research aim 2		
Type of design product to overcome a practical discrepancy	This category refers to text passages that mention & describe output that directly aims to support practice.	*We developed and evaluated a curriculum with corresponding learning materials.*
Research-related output	This category refers to text passages that mention & describe output that supports knowledge generation, such as statements on collected data.	*The majority of students in this study had difficulties with concept of voltage.*
Research aim 3		
Group of learners	This category refers to text passages that explicitly name group of learners for whom design products are developed in DBR project.	*Intervention was developed for secondary schools.*
Role of practitioners	This category refers to text passages that explicitly describe the role of practitioners in the DBR project.	*Teachers who enacted the intervention in a classroom were interviewed.*

Analysis procedure of conference papers

We performed a structuring content analysis according to Mayring (2014) to systematically analyze the 127 conference papers using MAXQDA plus 2022 (release 22.0.1). The context units were the full papers. For the analysis of the 127 conference papers, we developed a deductive category system (**Table 1**) as suggested by Mayring (2014). The categories were based on our research aims. One main category focused on the methodological groundings (research aim 1), two main categories on the two dimensions of output (research aim 2), and two main categories on the group of learners and the role of practitioners (research aim 3).

In a next step, one author–a research assistant of our research group–analyzed the full data corpus. The research assistant had more than a year of experience in PER and had been trained in how to conduct a content analysis with the code manual and was familiar with DBR and its characteristics. The other two authors–a professor and an experienced PhD student-supervised the coding process by regular meetings and discussions, and coded parts of the data corpus themselves for discursive validation. In these meetings we merged, fine-tuned and added further inductive subcategories to the category system.

Theses as Data Source

After analyzing the 127 conference papers, we presented the initial results at the 2023 DPG conference to reveal blind spots and discuss limitations of our approach. The feedback and the discussions encouraged us to use an additional data source, because conference papers are very limited in space, usually only report selected findings of a project and often report work in progress. Without any doubt, the analysis of these conference papers provides a good basis for an overview of DBR activities within the community. But conference papers, like other publication formats are hardly able to draw the full picture of the different dimensions of DBR projects we are interested in and that are relevant for accomplishing the goal of generating a coherent and transferable body of knowledge. On the other hand, in the German-speaking PER community, monographs are typically written in the context of PhD projects. Cumulative theses in the sense of a collection of research papers are the exception. The publication type thesis, however, supports our endeavor, since it is not strictly limited in length. That makes it easier for authors to report on different dimensions of DBR projects in a more comprehensive way than research articles and conference papers allow. On the other hand, theses usually also refer to findings of related master's theses, papers or reports that may have been written in the context of the DBR project.

Selection process & selection criteria of theses

We split the selection process into two parts. First, we started from the identified DBR-projects in the conference proceedings, searching for corresponding PhD or postdoctoral theses by the authors of the conference papers. Second, we used the FIS database to find additional theses that had not been presented at a conference.

For the first approach, we clustered the 127 conference papers that report findings for one and the same DBR project. Thereby, we could identify 74 projects. Then we systematically searched for theses written by the authors of the conference papers on the Internet by google and the webpages of the working groups. This search resulted in 13 PhD theses and one post-doctoral thesis.

In our second approach, we followed PRIMSA suggestion "to search multiple data bases" by using FIS database. We searched for the same terms as in the conference proceedings–namely "design(-)based(-) research", "design research," and "Entwicklungsforschung [development research]"–and additionally filtered for theses. We eliminated theses that were not submitted to any German-speaking university. We categorized the remaining theses according to research areas. This way we could identify four theses from the area of PER that were published between 2002 and 2022 and two of them had not been identified by our first approach via theses related to DBR projects identified in conference proceedings. On the other hand, in our first approach we found 12 additional theses compared to our second approach via the FIS database search. This shows that our first strategy–to start from contributions at conferences–was very fruitful to trace relevant theses.

Analysis procedure of theses

We analyzed the 16 theses–14 identified by DBR projects reported in conference papers and two additional by a FIS-search following the same structuring content analysis procedure suggested by Mayring (2014) as with the conference papers. Though we used the same deductive main categories (see **Table 1**), we added new inductive subcategories at some points to get a more detailed picture of the data. With the theses, we adapted the coding process. The research assistant only coded the categories "methodological groundings", "group of learners" and "role of practitioner", because the research assistant struggled with the length of the theses and the grain size of details we wanted to extract. The other two authors decided to choose one thesis they both coded separately in detail using all main categories deriving new inductive subcategories. In a next step, the results were compared by discussing mismatches. In this discursive validation, subcategories were reorganized or merged. Afterwards, professor and PhD candidate coded half of the remaining theses. In several meetings, selected text passages were discussed to support intersubjectivity.

Limitation of Selection Process

As limitation of our study, it is important to stress that the above-described procedure cannot exhaustively portray DBR trends in the German-speaking PER community since it excludes DBR projects that were not presented at one of these conferences or were presented without submission of a paper for the proceedings or is not connected to a thesis listed in the FIS database. However, we assume that our strategy to "perform other searching methods" than conventional searching engines, namely, to search in community specific conference proceedings, plus to search for DBR theses in the field of PER on a relevant search engine like FIS and to "locate grey literature" as (unpublished) theses related to the identified DBR projects, covers DBR activities within the German-speaking PER community in a good extent.

RESULTS

A central goal of this study is to shed light on the reported dimensions of DBR projects in order to portray the application of DBR in the German-speaking PER community and the role of DBR in addressing dimensions such as design products for practice, the involvement of practitioners and research-related output. Additionally, the study reveals the potential for future advancements in reporting results of DBR projects. At this point, it is important to mention that the dimensions of DBR projects reported in this section may not provide a full picture of DBR projects, but only give an overview of what is reported about them. Consequently, we do not claim that the results of our study elucidate how DBR projects are actually conducted.

Conference Papers

We first provide an overview of the 127 conference papers that report certain dimensions of DBR projects, and we then analyze these dimensions in more detail. In general, we report conference papers starting with 2010 since DPG started publishing conference proceedings online in 2010. In 2010, only one of the 155 papers in the GCDP proceedings was related to a DBR project, and four of the 83 papers in DPG proceedings of the same year. In 2015, the number of papers in the proceedings of both conferences exceeded 10 in total. In 2022, nearly twice as many papers were published than in prior years. A comparison of the number of DBR conference papers to the number of all papers in conference proceedings clearly shows DBR has become successively more common over the last 20 years (**Figure 1**).

However, there are digital GDCP conference proceedings before 2010, starting from 2002. In our opinion, analyzing the number of papers related to DBR in GDCP proceedings before 2010 can provide an idea when DBR became an issue in conferences of the German-speaking PER community. We did not find any conference papers related to DBR published in the conference proceedings of GDCP before 2007. Between 2007 and 2010, the relative number of conference papers about DBR projects was less than 1.5% (six out of the 464 papers of the three conferences). We conclude, that using DBR as a paradigm for developing research-based solutions for practice reached the German-speaking PER community during this period. Of course, other approaches for development of such solutions, with similar ideas, but under different names existed in the German-speaking community before that.

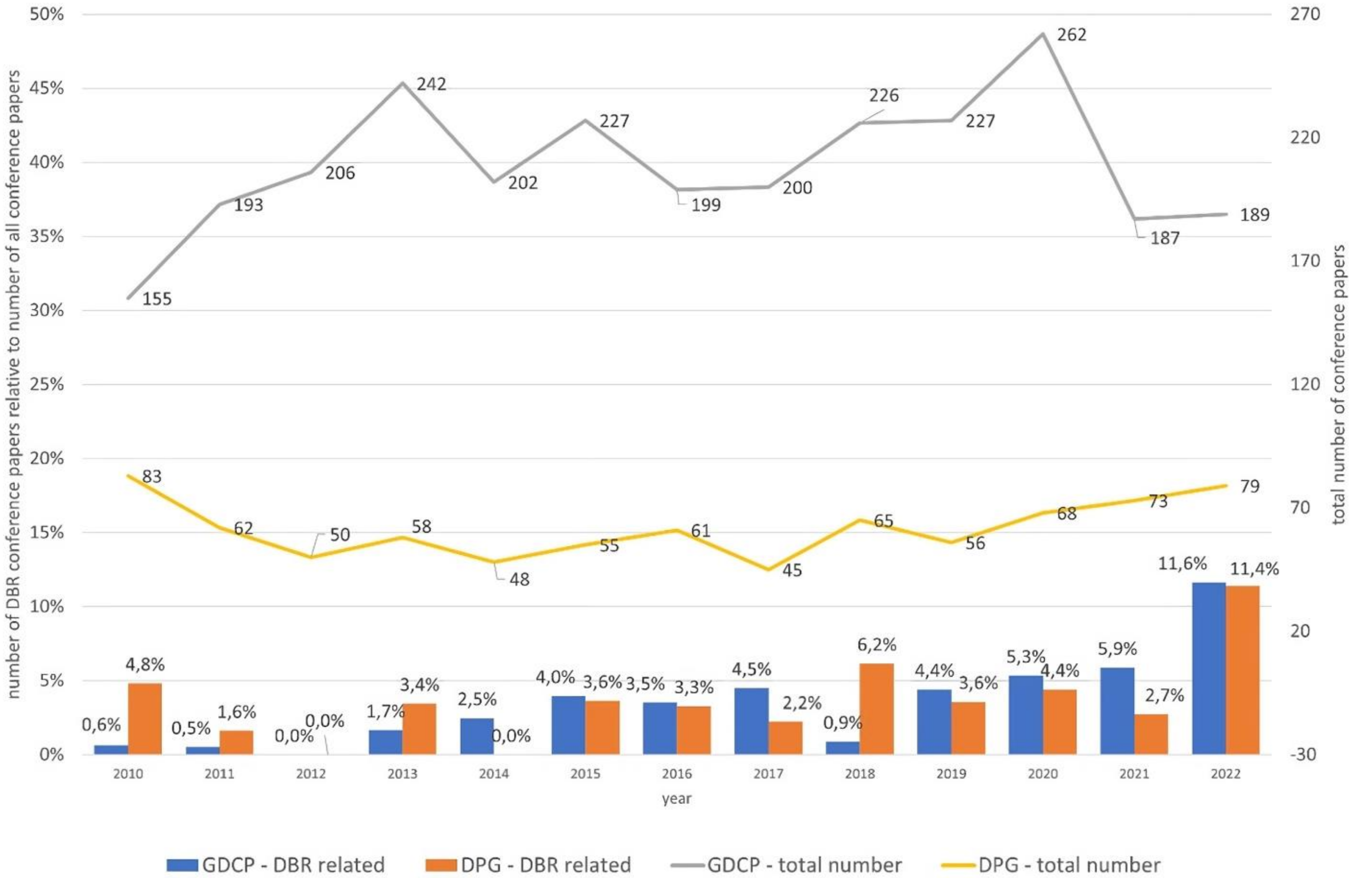

Figure 1. Relative number of conference papers about DBR projects in DPG & GDCP from 2010 to 2022 (development of total number of GDCP [grey] & DPG [yellow] conference papers) (Source: Authors' own representation, based on DPG & GDCP proceedings from 2010 to 2022)

In the 127 conference papers, we identified 74 different DBR project clusters. However, the amount of conference papers reporting the status quo or findings of a project varies tremendously. For example, several researchers of a project consortium present different aspects of their long-term project in 18 conference papers over a time span of seven years. While on the other side of the spectrum, there are projects that are only represented in one conference paper. For a better picture of DBR projects, we will always present the number of conference papers as well as the number of project clusters.

Research aim 1: Methodological groundings

We identified methodological groundings of DBR in literature that serve as a basis for the reported DBR projects. Surprisingly, most DBR projects ground their methodological approaches in two articles from the field of general education research. Thirty-one conference papers cite Reinmann (2005), and 25 conference papers cite The Design-Based Research Collective (2003) when describing DBR. When taking project clusters instead of individual conference papers as basis, 18 projects refer to Reinmann (2005), and 16 to The Design-Based Research Collective (2003) when describing DBR. Both are theoretical articles that argue for DBR approaches in education research and emphasize the potential of DBR for addressing the theory-practice gap. Reinmann (2005) pleads for research to focus on innovation rather than solely on evaluation of innovative educational approaches. She sees a central goal of DBR as generating knowledge about how DBR approaches work. Similarly, The Design-Based Research Collective (2003) locates the potential of DBR for developing contextualized theories of teaching and learning and increasing the human capacity for innovations. Nine conference papers (six projects) refer to Prediger and Link (2012) and four conference papers (four projects) refer to Hußmann et al. (2013). The authors of both articles are representatives of the Dortmund movement and rooted in the field of mathematics didactics. Eight conference papers (six projects) refer to Wilhelm and Hopf (2014)–who introduce the idea of DBR in a handbook for methods in science education research–and six conference papers (five projects) refer to Haagen-Schützenhöfer and Hopf (2020)–who outline the development and research processes of DBR, illustrated by the development of a curriculum on introductory optics for secondary school. The authors of both articles are representatives of the Frankfurt tradition. Several other articles were cited by three or fewer conference papers. Thirty-six conference papers (14 projects) do not provide any references for their understanding of DBR.

We were interested whether the methodological groundings are rather located in general education or if our community has already developed a discipline specific/generic interpretation of DBR. We clustered the cited articles from the field of the German-speaking science education research to reveal trends in German-speaking PER community. We found 23 conference papers, which cite articles related to the Frankfurt tradition, and 16 papers, which cite articles related to the Dortmund approach.

Research aim 2: Practical & research-related output

The conference papers describe a broad variety of design solutions as a practical output of DBR projects. We clustered these design solutions in five categories. The majority of 86 papers (61 projects) describe the development of some kind of teaching-learning sequences such as teaching and learning concepts or curricula (42 papers and 21 projects), learning environments (12 papers and nine projects), university-level courses (six papers and five projects), or teaching or learning units (six papers and six projects). Thirty papers (27 projects) report on the development of specific instructional materials, such as learning materials (13 papers and 10 projects) or multimedia applications (five papers and four projects). Thirteen papers (11 projects) mention the development of physical learning environments, such as out-of-school student laboratories (five papers and three projects) or science center exhibits (three papers and three projects). Two papers (one project) describe the development of different measures for supporting university students in the beginning of their studies. These categories are not disjoint, as, for example, a conference paper can simultaneously report the development of an instructional concept and the development of associated materials.

Most of the conference papers also report research-related output of DBR projects, that is empirical findings. However, 39 papers (31 projects) do not report any empirical findings. These projects usually either provide an overview of the study design or describe the design solution. We clustered the empirical findings into seven categories. Forty-seven papers (33 projects) report findings on content-specific learning processes, such as identified learning obstacles, student conceptions, or strategies to support learning. These findings tend to be based on qualitative data from intervention studies. Thirty papers (20 projects) report findings of evaluations of the design products in an intervention study, for example, measuring the impact of an intervention on various variables. These findings tend to be based on quantitative data from pre-post-tests. Twenty papers (11 projects) report findings on practitioners' perspectives on the design products, such as the practitioners' acceptance of and attitudes towards a design product. Twelve papers (11 projects) report on findings about the empirical analysis of the problem context, such as revealing practitioners' attitudes by interviews, students' competence using test instruments or potential learning opportunities by curriculum analysis. Such an empirical analysis is usually carried out prior to the development of a design product. Eight papers (eight projects) describe the development of test instruments for evaluation or data collection, one paper reports on the fidelity of implementation of an intervention, and one paper reports on the validity of a test instrument.

Research aim 3: Cooperation

The conference papers present solutions to real-world educational problems by developing design products for practice. These real-world problems involve different groups, such as learners, practitioners, or stakeholders. We analyzed for which group of learners the design products are developed to get a better idea of the type of practitioners involved. We also analyzed what is reported about the role of the practitioners involved in the analyzed DBR projects.

The design products were developed for learners of different ages and for different settings. The main target audience of these design products of 89 papers (50 projects) are students in a school environment (primary and secondary school). Thirty papers (21 projects) focus on teacher students, and seven (six projects) focus on students at university level other than teacher students. Few papers focus on other target groups, such as visitors of science centers (three papers and three projects), children in kindergarten (two papers and two projects), or in-service teachers (three papers and three projects).

The practitioners were involved in DBR projects–according to the conference papers–in different ways and to a different extent. Thirty-four papers (20 projects) report involving practitioners in the design or research process by interviews, logbooks, or questionnaires. Three papers (three projects) define the role of practitioners as co-developers, and in two of these papers the teachers are also involved in the evaluation process. Only 23 papers make the role of the practitioners in the process of implementation explicit in formulations like "teachers implemented the teaching and learning sequence in classroom". We, however, assume that in all projects, where the design product was implemented in practice, practitioners were involved in this implementation to some degree, even if this was not explicitly mentioned. What also remains open is how frequently the roles of researcher and practitioner are merged, for example in cases, where the researcher is at the same time the lecturer at the university course designed, or a PhD researcher who is at the same time a schoolteacher, implementing a DBR project in her or his school class.

Table 2. Overview of solutions designed in theses to overcome educational discrepancies

	Thesis	Solutions designed to overcome educational discrepancies
1	Bitzenbauer (2020)	Adjustment of a curriculum on quantum optics for secondary schools
2	Burde (2018)	Development of a curriculum on introductory electricity for secondary schools with corresponding curriculum materials
3	Tobias (2010)	Development of an evidence-based learning environment on Newtonian mechanics for secondary schools with corresponding learning materials for students
4	Wiener (2017)	Development of a learning unit on particle physics for secondary schools with corresponding typographic illustrations
5	Laumann (2017)	Development of a new, self-consistent, and compatible curriculum on magnetism for university students
6	Küpper (2021)	Development of a learning environment on optics for inclusive physics classes
7	Bliesmer (2020)	Development of a prototypical content structure on the physics of coastlines in out-of-school learning contexts
8	Roskam (2020)	Development of an exhibition on physics on coastlines for visitor centers of national parks
9	Heran-Dörr (2006)	Development of a concept for a context-sensitive teacher training program for primary school science teachers
10	Behrens (2018)	Development of learning materials in an instructional design approach for school practice for an exemplary topic in physics
11	Jannack (2017)	Adjustment/development of projects for school practice following a problem-based learning approach
12	Smoor (2018)	Development of a curriculum for teaching and learning laboratories and a concept for a modular structure for teacher education programs
13	Haak (2017)	Development and adjustment of measures for the introductory phase of physics studies at universities
14	Sajons (2020)	Adjustment of out-of-school learning opportunities in science centers for school students
15	Skorsetz (2019)	Two learning environments for testing a theory (the design products are not primarily for overcoming educational discrepancies in practice)
Postdoctoral thesis		
16	Haagen-Schützenhöfer (2016)	Development and advancement of a curriculum on introductory optics for secondary schools with corresponding learning materials for students

Theses

Our analysis of the 16 theses shall provide a more thorough insight of different dimensions of DBR projects in the German-speaking community. Though a thesis holds the opportunity to report more of a DBR project than conference papers or articles in research journals, we cannot assume that we really get a full picture of the corresponding DBR project, and that all relevant dimensions of DBR projects are reported. As with the conference papers we only analyze what is reported in the thesis and not how the DBR project was actually conducted. Thus, to answer the question of what is reported on DBR projects in this second data source, we first describe the aims explicated by the authors of the theses to get an overview of the different DBR projects. Then, we present the findings of our structured content analysis.

All authors of the theses aim to develop or adjust a design solution for a practical problem, with the exception of Skorsetz (2019). This author aims to test an alternative explanatory approach for gender differences in motivation when learning science content. To this end, she iteratively develops two learning environments based on a DBR approach. The majority of the remaining 15 theses aim to develop or refine a curriculum on a specific physics-related topic. **Table 2** provides an overview of the practical goals of the analyzed theses.

The research goals concerning knowledge generation vary among the theses. Ten theses explicitly aim to gain insight into learning processes or contribute to theories about teaching and learning certain content in a certain context. Eight theses want to investigate the influence of an intervention on a variable, such as a learning outcome. Five theses aim to investigate teachers' acceptance of particular aspects of an intervention, such as the perceived feasibility of implementing the intervention in school. Three publications explore students' acceptance of, for example, instructional explanations. One thesis wants to investigate how learning materials can be developed and evaluated for use in school practice using an instructional design approach. The subject matter addressed, and related learning processes are explicitly not focus of the study.

Research aim 1: Methodological groundings

We also identified methodological groundings of DBR in literature that serve as a methodological basis for DBR projects reported in the 16 theses. Similarly to the conference papers, the most cited articles on DBR are The Design-Based Research Collective (2003) and Reinmann (2005). 13 of the 16 theses refer to the first article and 10 to the second one. Eight theses refer to Prediger and Link's (2012) article about the Dortmund approach and seven theses to Wilhelm and Hopf (2014) who are related to the Frankfurt tradition. Six theses refer to Cobb et al. (2003) and five to Bereiter (2002). Both articles are about the general idea and potential of DBR for educational research, the first focusing on related methodological questions and the second emphasizing the important role of DBR for sustained innovation. Five theses refer to Stokes' (1997) article about Pasteur's quadrant, we described before in the introduction.

Three theses refer to Hußmann et al. (2013)–also describing the Dortmund approach–and Wilhelm et al. (2012)–describing the Frankfurt tradition. Also, three theses refer to an article on DBR by Brown (1992), which is often seen as a central starting point of DBR. Four theses refer to an article by Edelson (2002) about different types of theories DBR contributes to. Many more articles are cited by two or less theses. However, two theses do not refer to articles on DBR or "fachdidaktische Entwicklungsforschung [didactic development research]".

Research aim 2: Practical & research-related output

We first analyzed which practical outputs of DBR projects are reported in the 16 theses. We identified different types of design products. In contrast to the analysis of conference papers, we can provide more details on the design products, because of the more detailed descriptions in theses. Seven authors present a concept for practice that is curricular in nature, such as a teaching-learning environment (Tobias, 2010), a learning environment (Küpper, 2021), a teaching-learning arrangement (Haagen-Schützenhöfer, 2016), a concept for instruction (Bitzenbauer, 2020; Burde, 2018), or a learning unit (Wiener, 2017). All of these authors provide teaching and learning materials as well as a content structure, except for Wiener (2017), who primarily suggests typographical illustrations and how to implement them. Beyond the delivery of teaching and learning materials, Laumann (2017) designed a video and interactive animations, Tobias (2010) and Wiener (2017) suggest a concept for teacher training, and Haagen-Schützenhöfer (2016) reports dissemination measures in teacher education. Though Behrens (2018) also provides learning materials on optics for secondary school–similar to Haagen-Schützenhöfer (2016)–she does not provide a new content structure, or a curriculum on optics. The main focus of her project was to develop exemplary learning materials using an instructional design approach.

The remaining theses have other practical outputs that cannot be clustered in a meaningful way, because they are different on many levels. Heran-Dörr (2006) provides a concept for a teacher training program with a corresponding Internet platform. Sajons (2020) reports on out-of-school laboratories for students, guidelines for laboratory operators to design such laboratories, and guidelines for self-evaluation and corresponding trainings. In their complementary projects, Bliesmer (2020) and Roskam (2020) provide a prototypical exhibition for national parks, experiments for an exhibition with corresponding materials, and a handbook and guidelines for exhibition managers. Smoor (2018) implements teaching and learning laboratories for teacher students in modules of a teacher education program. Jannack (2017) adjusts selected out-of-school lab projects for implementation in school practice and provides corresponding teaching and learning materials. Haak (2017) provides various measures for the introductory phase of physics students at university, such as workshops, tutorials, advertising, and learning assistance. As mentioned previously, Skorsetz (2019) develops two learning environments to answer a basic research question. She explicitly mentions that these two learning environments have only limited applications for further use in practice.

Next, we want to describe our findings on the level of research-related output. The goal of a research study is to go beyond the study and produce findings that are applicable to other contexts (Polit & Beck, 2010). Firestone (1993) writes, "[w]hen researchers generalize, they really make claims about the applicability of their findings to other settings." (p. 16). In quantitative research, statistical generalizations from a sample to a population are often easy to grasp, though not unproblematic because of the difficulty to sample in social studies (see Polit & Beck, 2010). Firestone (1993) suggests two additional forms of generalization that are applicable for and relevant to both quantitative research and qualitative research: analytical generalizations (i.e., when cases are generalized to a theoretical contribution) and case-to-case translations (i.e., when a case is generalized to a similar case). Especially for case-to-case translations, the researcher needs to document a so-called thick description of the context so that the reader can transfer findings to their case.

Based on these ideas, we distinguished two epistemological categories of research-related output of DBR projects when analyzing the theses. The output was either at the level of statements, which are based on data providing evidence for other researchers to be translated to similar contexts, or at the level of analytical generalizations (Firestone, 1993). In other words, we determine whether authors explicitly formulate generalizations or remain on the level of describing their findings. This distinction should provide insights into how researchers in DBR projects in our community may understand the role of DBR in contributing to theories and thus, in generating knowledge. For the endeavor of knowledge generation, it is generally important what research-related output is reported back to the community.

First, we describe which analytical generalizations are made by the authors based on their findings. We identified five different subcategories of analytical generalizations. The first three subcategories are in alignment with the idea of Edelson (2002) that DBR draws generalizations at three levels. Six theses explicitly generalize their findings to contribute to domain theories about teaching and learning. Nine theses provide design frameworks, that is guidelines for designing a solution for a similar problem. Three theses outline design methodologies, that is guidelines for the design process itself. Only two of the analyzed theses do not explicitly generalize on any of these five levels.

In addition to Edelson's three levels of generalization, we identified two theses that present guidelines for the development of test instruments and five theses that contribute to general teaching and learning theories. Three theses do not analytically generalize their results to actively contribute to some kind of theory. They stay on a descriptive level of their results.

All of the analyzed theses provide some kind of empirical findings that can be used by other researchers in similar contexts. Fourteen theses portray learning processes, obstacles, or student conceptions. Eleven theses provide evaluative results for different variables in the interventions. Five theses provide insights into practitioners' acceptance of the practical solution. Four theses empirically analyze existing initiatives to address a problem.

Research aim 3: Cooperation

The practitioners involved in the 16 analyzed thesis play different roles in the design and research processes. Solutions in DBR are designed for real-world educational settings, which include learners, practitioners and sometimes other persons. Thus, a central characteristic of DBR is the cooperation with practitioners to design relevant solutions for practice and furthermore support the sustainability and dissemination of the solution in practice. While all 16 theses involve learners in their research by either implementing a design product in an intervention study or interviewing learners, only 12 theses explicitly mention the role of practitioners in empirical investigations. In eight of these theses, the practitioners implement the design product in an intervention. Also, in eight theses the practitioners are involved in other empirical assessments, such as interviews, or feedback questionnaires. In three theses the researcher takes on the role of the practitioner and in one thesis a pre-service practitioner carries out an intervention. In none of the theses the practitioners are actively involved in design or research processes. In two theses other persons are involved: One thesis uses questionnaires for parents to assess their children's brain type and one thesis validates a test instrument for assessing conceptual understanding by PER experts.

DISCUSSION & CONCLUSIONS

DBR has emerged as a paradigm of use-inspired basic research in the past 30 years. About 20 years ago, DBR has reached the German-speaking PER community. However, DBR projects are sometimes criticized for focusing on practical output, such as designed materials or interventions, rather than on research-related output or research-practice cooperations to support practical relevance and dissemination of these design products in practice.

The goal of this study is to shed light on this criticism by analyzing which dimensions of DBR projects are reported upon and how the German-speaking PER community deals with the challenge of DBR realizing both knowledge generation and the development of design products for educational practice. To accomplish this goal, we analyzed conference proceedings of DPG and GDCP from the past 20 years to get an overview of reported dimensions of DBR projects, as well as corresponding PhD and postdoctoral theses to get as complete a picture of DBR projects as possible.

This study is not without limitations. First, the data collection process can only provide a limited picture of DBR projects in the German-speaking PER community. Not all DBR projects may have been reported in conference proceedings, or projects may have been labeled with other terms as we searched for. Second, we can only analyze what is reported in the conference papers and theses. Therefore, we do not claim to reveal how DBR projects are actually conducted. Third, due to the huge variety of terms in DBR projects (e.g., terms for design products), it was sometimes difficult to relate text passages to categories. Additionally, we had to translate German terms into English.

In our discussion, we focus on the tension between designing products for practice that are relevant and usable for practitioners and at the same time generate knowledge about how these products support learning processes in a realistic setting (The Design-Based Research Collective, 2003; Reinmann, 2005). We are interested in how this tension is reflected in publications on German-speaking DBR projects. We structured the following paragraphs in alignment with our research aims.

We found that most of the identified DBR projects refer to a small amount of basic literature on DBR, when methodologically grounding their approach (research aim 1). We identified three main strands of literature for methodological groundings, one strand of general education research articles and two strands of articles describing content-specific approaches of DBR-projects in science and mathematics education research. Most

DBR projects refer to general education literature on DBR that adopts a paradigmatic perspective and does not specifically discuss processes within DBR. The two most cited articles of this strand (The Design-Based Research Collective, 2003; Reinmann, 2005) especially emphasize the role of DBR for knowledge generation. From this we infer that a majority of DBR projects analyzed have a similar understanding and thus may share similar goals: To generate knowledge about teaching and learning by designing solutions for real-world problems. However, these paradigmatic articles from general education do not suggest a specific procedure for achieving these goals. One reason for this may be their time of origin, which coincides with the beginnings of DBR movements, as diSessa and Cobb (2004) put it:

> "Design research is a relatively new and still evolving methodology. The community of researchers has not had time to filter and share reflections on the phenomenology of 'doing science' in this way. As a consequence, the delineation of agreed upon practices and the development of a grounded language for describing them is very much in progress." (p. 78)

The other two strands of articles we identified relate to content-specific approaches for implementing the idea of DBR in specific projects of physics or science education: an approach based on the Frankfurt tradition (Wilhelm & Hopf, 2014), which is genuine to the German-speaking PER community (see 2.2), and the Dortmund approach (Prediger & Link, 2012), which emerged in the German-speaking science and mathematics education research community. Both approaches have a strong focus on content-specific teaching and learning processes and the development of a content structure. In addition, both discipline-specific strands framed their content-specific approaches within the paradigm of DBR, thereby creating generic approaches to DBR in the German-speaking science and mathematics education research community. This demonstrates that new methodologies for DBR have evolved within the German-speaking PER community, guiding other projects in conducting DBR and thus might contribute to the advancement of DBR on an international level. Though there seems to be a similar understanding of DBR and the development of own methodologies and a grounded language within the German-speaking PER community, in 36 of 127 conference papers (14 of the 74 projects) and two of 17 theses, the authors do not refer to any article, when mentioning DBR as methodological framework for their project. This can be viewed critically because on the one hand, it fails to convey the authors' understanding of DBR to the recipient and on the other hand, it may fuel the criticism that DBR is methodologically volatile (Kelly, 2004).

DBR aims to produce output on both a practical and a research-related level (Reinmann, 2005). The analysis of the output of DBR projects in the German-speaking PER community reveals that the majority of these projects report theoretical outputs. On the other hand, it also shows that there is a need for a shared understanding of what is subsumed as theoretical output (research aim 2). Contrary to assumption that DBR projects predominantly report practical outputs, our findings show that most of them provide research findings, such as insights into students' conceptions, learning processes, or evaluation results. However, it is important to note that 39 conference papers (31 projects) do not report research-related outputs. This finding might be attributed to the inherent constraints of conference papers and journal articles. Their restrictions in length are often limiting the in-depth exploration of theoretical contributions, such as the provision of 'thick descriptions' as advocated by scholars like Firestone (1993).

> "Thick description refers to rich, thorough descriptive information about the research setting, study participants, and observed transactions and processes. Readers can make good judgments about the proximal similarity of study contexts and their own environments only if researchers provide high-quality descriptive information." (Polit & Beck 2010, p. 1453)

The challenge of thick descriptions in certain publication formats has also been acknowledged in the existing literature (e.g., Polit & Beck, 2010). To address the argument that conference papers may lack theoretical output due to length limitations, we also considered theses. Theses in the German-speaking PER community often take the form of monographs, providing the necessary length to thoroughly discuss theoretical contributions and offer detailed 'thick descriptions'. Our analysis of theses as data source contradicts the criticism that theoretical output is neglected in corresponding DBR projects, since 14 of the 16 theses explicitly incorporate theoretical output. However, theoretical output is framed and reported in different ways. We assume that this variability is due to different conceptualizations of theoretical output within the community. This poses a challenge for the desideratum of DBR to build a cohesive body of knowledge. Consequently, developing a shared understanding of theoretical output of DBR within the German-speaking PER community and beyond becomes desirable.

For reporting theoretical output, we propose to take two different perspectives on theoretical outputs of DBR, namely in which way are results generalized and to what kind of theory are they generalized. Firestone (1993) outlines three types of generalization: statistically from a sample to a population, analytically from specific results to a theory, and case-to-case translation by providing thick descriptions that facilitate transfer of results to other contexts. Statistical generalization, often favored in more quantitatively driven research communities (Polit & Beck, 2010), is challenging in real-world educational contexts because of the quasi-experimental nature of intervention studies and the difficulty to control variables in educational real-world setting (Brown, 1992). In DBR, the focus typically lies in investigating domain-specific teaching and learning processes in realistic settings, leading to the development of local theories (Prediger et al., 2015) or domain theories (Edelson, 2002). This emphasis allows for analytical generalizations, exploring a theory's applicability and boundaries in real-world contexts. For instance, our analysis of theses revealed the identification of new student conceptions, learning obstacles, and support mechanisms. Edelson (2002) also introduces two additional types of theories that researchers in DBR may generalize to: design frameworks, which represent generalized design solutions, and design methodologies, which encompass generalized design procedures. Additionally, the provision of thick descriptions of the research setting, observed interactions and real-world contexts of DBR projects becomes crucial for readers to gauge the applicability of results, such as design products or local theories, to their own contexts of interest (cf. 'storied truths' by Barab, 2014). Such descriptions are also valuable for practitioners or other researchers, planning DBR projects in similar contexts to extend domain theories, design frameworks or design methodologies.

The practical output of DBR projects is typically some kind of design product. In all the analyzed papers and theses, we encountered various design products. However, identifying the specific design product can be challenging, as they are often ambiguously specified or labeled differently. For example, terms such as 'learning unit [Lerneinheit]', 'learning environment [Lernumgebung]', 'learning arrangement [Lernarrangement]', 'curriculum/teaching concept [Unterrichtskonzept]', and many others were often used without clear definition. In some cases, it was unclear whether a design product on a conceptual level also included corresponding materials. Future DBR projects would greatly benefit from providing clear and concise descriptions of practical outputs. Additionally, the diversity in products may signify DBR's potential for fostering innovation (Bereiter, 2002).

DBR is commonly seen as an approach to link research and practice through cooperation between practitioners and researchers (research aim 3). Our analysis reveals that the learner's role is consistently addressed in publications, focusing on the empirical findings of DBR projects. However, especially in the case of conference papers, the practitioner's role in DBR projects is hardly mentioned. Though in most conference papers data was collected in interventions, that implement a design product in practice with learners, it sometimes remained unclear whether a practitioner or a researcher had carried out this intervention. The role of practitioners in DBR projects seems frequently to be limited to that of an implementer of the design product, at least according to the conference papers. An equal cooperation between researchers and practitioners in terms of collaboration was very rarely reported in the conference papers. Nearly a quarter of the conference papers explicitly mention the involvement of practitioners through, for example, interviews, logbooks, and questionnaires. On the contrary, about two thirds of the theses report such an involvement of practitioners. Notably, in three theses, researchers themselves took both the roles of researchers and practitioners, personally implementing the design product in practice. In four theses, the role of the practitioner in the DBR project was not reported at all.

Our findings suggest that, at least, the implementation in practice seems to be relevant for DBR researchers. Though the perspectives and experiences of practitioners seems to be considered in many theses in some way, this perspective plays a minor role in conference papers. This may indicate that the empirical findings concerning learners are more likely to be presented on conferences and may be seen as more important than findings concerning practitioners. However, we do not have any proof for this assumption. Collaboration between researchers and practitioners is essential in finding real-world solutions, as emphasized by Buhl et al. (2022), but such collaborations could be hardly identified in our analysis. We believe that DBR projects in teacher education may inherently involve collaboration due to researchers also being practitioners as lecturers. This assumption is however not reflected in our data sources. Furthermore, according to our data sources, practitioners seldom seem to be involved in the definition of the problem, or the design process itself. Thus, we recommend for future DBR projects that the role of the practitioners should be explicitly reported, and collaborations between practitioners and researchers be strengthened.

Additionally, another goal of DBR is to bring about sustainable changes in practice, as proposed by Bereiter (2002). Achieving this change necessitates measures for disseminating design products. However, our analysis could not uncover any reports detailing how design products have been disseminated in practice.

We can learn several things from DBR projects in the German-speaking PER community. Over the past two decades, the number of these projects has noticeable increased. DBR seems to provide a paradigmatic foundation for the long curriculum development tradition in our community (as discussed before), offering a systematic framework equipped with terminology for communication and methodologies to guide the design and research processes. Our analysis has revealed two systematic approaches for DBR projects that are generic to our community and that are at least partially introduced into the international discourse in the form of publications. Moreover, we have observed that researchers within our community report on various dimensions of DBR projects, albeit in diverse ways and at different levels of granularity. This diversity makes it challenging to generate a comprehensive body of knowledge about teaching and learning processes, design processes or design methodologies. Furthermore, practitioners seem to play a role in DBR projects, although they are often viewed as part of the context rather than active collaborators.

Contrary to criticism that DBR projects lack theoretical output, our findings suggest that theoretical output plays a more significant role than previously assumed. However, there is a need to clarify the understanding of what constitutes theoretical output. In this article, we propose an approach to foster a shared understanding of theoretical output.

To achieve a comprehensive and robust body of knowledge, our community will ultimately need to assemble the numerous small theoretical building blocks–which to some extent is limited to local contexts–into more overarching theories about teaching and learning physics.

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