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Theory genesis in the design-based research process – a subject didactic view on theory application, verification and development by using design principles

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Abstract

This article intends to provide answers to the overarching question of how theories, which are transferred into concrete design principles, develop in a DBR process. Theories from three completed DBR projects in geography didactics will be examined regarding their genesis in the research process and their function in individual phases of a DBR cycle. The chosen theories differ in scope, depth and empirical saturation. The aim is to analyse the role that these theories take in the DBR research process and to discuss them in terms of their contribution to the output of DBR projects and a possible generalisability of the findings. Finally, the results of the analyses are synthesised into a model for theory genesis in DBR projects.

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Keywords design principles, subject didactics, theory genesis, theoretical outcome, operationalisation of design principles

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Theory genesis in the design-based research process – a subject didactic view on theory application, verification and development by using design principles

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1.0 Introduction

The article aims to examine the development of theories that are translated into concrete design principles (DP) within the context of design-based research (DBR) processes. Therefore, theories from three completed DBR projects in geography didactics will be examined and the genesis of these theories and their function in different phases of a DBR cycle will be analysed.

The article is structured as follows:

Firstly, based on existing literature, the role and function of theories in subject didactic research are reviewed (section 2.1). Subsequently, the specific application and emergence of theories within the DBR cycle are discussed (section 2.2), with particular attention given to the significance and contribution of design principles to theory development. The core of the article consists of analysing selected theories and theory elements from the authors' three projects, which differ in terms of scope, depth and empirical saturation (section 3). The analysis follows a consistent procedure in which specific key points in the research process are examined in detail. Thereafter the theoretical outcome of the research process for the school context and the subject didactic community is discussed. Finally, the results of the analyses are synthesised into a model for theory genesis in DBR projects (section 4).

2.0 On the role of theories in DBR projects

2.1 Theories in subject didactic research

Theories serve the general purpose of systematising and integrating scientific knowledge. Thus, theories provide a foundation for practical applications, they enable communication about knowledge and the construction of understanding (Eisend & Kuß, 2021, p. 33). In science the nature of theories is inconsistent, which is also reflected in subject didactic research (Eisend & Kuß, 2021, p. 33.; Gryl, 2020, p. 365). Theories are initially linguistic constructs that make numerous statements about the relationship between concepts and phenomena (Jaccard & Jacoby, 2020, p. 28). The systematic and justified presentation of the relationships between phenomena and concepts is of great relevance, as the acceptance of a theory is particularly measured by the argumentatively comprehensible statements about the interaction between individual concepts.

Consequently, elements of a theory include systematic relationships between concepts, statements about justified regularities of these relationships and the empirical verifiability of the correspondence between theory and reality[1] (Eisend & Kuß, 2021, p. 40). Thus, theories are evolving constructs and not products that are completed (Lamnek & Krell, 2016, p. 91). The results of empirical research can weaken or strengthen theories in their fundamental acceptance and in their application to specific subjects. Moreover, theories can be developed (further) or differentiated through empirical research. A differentiation of a theory can occur with regard to interconnected concepts and terms, the scope of validity and the application to new subject areas (Prediger, 2015, p. 645).

Theories serve various functions in the context of subject didactics. On the one hand, they contribute to the foundation and development of diverse instructional designs, thus playing a crucial role in the planning and implementation of teaching (Gryl, 2020, p. 366; Porsch, 2020, p. 207). Theories provide the basis on which teachers can theoretically and conceptually plan their lessons and actions. In this context, theories are important for the transmission of subject content (Gryl, 2020, p. 366). On the other hand, theories themselves can be the subject of instruction. For example, the theory of plate tectonics (geography) and the theory of evolution (biology) are subjects of learning in all German framework curricula. Therefore, students need to understand these theories as instruments for analysing subject-specific phenomena and their interconnections (Gryl, 2020, p. 378).

The goal of subject didactic research is the development and improvement of theories, their application to teaching and the empirical examination of their utility (Gryl, 2020, p. 378). Despite the increasing emphasis on theoretical approaches in subject didactic research, there is a lack of clarity in the use of the term "theory", to the extent that the term is avoided and substitutive terms such as models, concepts, theoretical references, principles and thought patterns are employed (Gryl, 2020, p. 367; Hemmer et al., 2018, p. 11). However, theories are not only products but also the basis of empirical subject didactic research. They are applied from various domains, such as subject disciplines (e.g., geographical cluster theory), educational psychology, general didactics (e.g., self-efficacy theory, theory of

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[1] The term "reality" used by Eisend and Kuß (2021, p. 40) requires further elaboration, especially with regard to different perspectives such as realism or constructivism. We align ourselves with the constructivist perspective and agree with Renkl's statement (2023, p. 45): Most researchers would likely say that they adopt a constructivist perspective insofar as they assume that learning ultimately occurs through mental construction processes of the learners. However, in design-based research, real contexts are necessary to examine the intended effects of a design. Each of these contexts is unique and individual, as are the perspectives and practices of the actors involved (researchers, teachers, learners). It is important to acknowledge that and consider this diversity in the research process and reflect upon it.

situated learning) and geographical subject didactics (e.g., geographical key concepts). These theories differ in terms of scope, empirical saturation and analytical-theoretical depth (Porsch, 2020; Prediger, 2015). The distinguishing characteristics of theories mentioned here are only a selection from the aspects described in the academic literature[2] (Lamnek & Krell, 2016).

An example of a theory with broad scope is the critical-constructive didactics according to Wolfgang Klafki (1958). It has a general didactic claim and is societally accepted. However, it lacks empirical saturation in its development process, as this theory was formulated based on practical classroom experience rather than incorporating empirical findings (Porsch, 2020, p. 207). The "Conceptual Change Approach" can be seen as a theory with high empirical saturation (Posner et al., 1982; Schnotz, 2006; Reinfried, 2010). Numerous empirical studies from various domains support this theory (including biology education, geography education and physics education). Based on insights gained in multiple disciplinary fields, it has become a theory that holds validity in general didactics. The "Systems Theory" by Luhmann (1997) can be characterised as a theory with analytical-theoretical depth. Although it was not heavily underpinned by empirical research during its development, that theory achieved a wide reach nevertheless. That was due to its application and further development in a variety of subject-specific contexts which resulted in societal acceptance. Theories with narrower scope are typically domain-specific, such as the Ludwigsburg model for the competence of map interpretation (in German: "Ludwigsburger Modell zur Kartenauswertekompetenz") (Hemmer et al., 2010). This theory finds particular application in geography didactics, in competence-oriented geography lessons and the specific field of working with maps.

The theories applied in subject didactics essentially demonstrate two paths of theory development. On the one hand, theories are empirically derived by starting from verifiable hypotheses; the concepts that have to be tested are then examined empirically. On this basis theories or theory elements are developed (Prediger, 2015; Harant & Thomas, 2020, p. 22). They have an empirical-analytical basis of formation. On the other hand, theory formation can be described as a logical-deductive or theoretical-conceptual path, followed by empirical testing and saturation. In this case, theories or theory elements are formed by argumentatively connecting existing theoretical approaches (Prediger, 2015). Especially theories that have a logical-deductive context of origin are rarely awarded the status of theories within subject-didactic research. In these cases, researchers often use theory-related terms such as models, concepts or

[2] For example, in Grounded Theory (Glaser & Strauss, 1967) theories are differentiated based on their level of generalisation into subject areas (facts), subject related theories and formal theories (Lamnek & Krell, 2016, p. 104 ff.). The purpose of this distinction is to differentiate the degree of generalisation of theories. Another classification of theories is discussed by von Werthern (2020), who distinguishes between everyday life theories, theories with medium range, "grand" theories and program theories.

conceptual frameworks (Gryl, 2020) because these constructs do not have the same high level of requirement standards as a theory (Porsch, 2020, p. 216).

2.2 Application and development of theories in DBR projects

The role theories play in DBR processes is complex, as they permanently accompany the research process and serve various functions. For example, during the design phase it is necessary to identify relevant theories from different reference disciplines and incorporate them into the research and development process (Euler, 2014b, p. 17). That is why the selected theories significantly influence the design of a teaching and learning environment. In the analysis phase, the (further) development and elaboration of design principles occur with continuous reference to the theoretical framework. Thereby theories serve both as anchors and frameworks that are continuously further differentiated. Thus, in DBR projects, theories are not only the starting point and outcome of research but also integral to the process and undergo changes through the cyclical nature of the DBR research process.

In DBR projects, the "initial theories" (Prediger, 2015, p. 657) not only serve as a justification for the research but they also need to be applied and interconnected through a creative act of their own. Prediger (2015, p. 644) uses the terms of theory reception and theory production to denote the function of theories and theory elements in subject didactic research. Theory reception marks the beginning of a research process, where theories are utilised to identify research gaps and legitimise research projects. The task is to categorise theories and theoretical elements in order to integrate them into an overarching classification, highlighting relationships and boundaries and weaving a new network of theories (Prediger, 2015, p. 644). In DBR projects theory reception goes beyond the descriptive and analytical level. Both individual theoretical elements and the created network of theories are translated into teaching practices during the design of the prototypical learning environment. This process typically involves transforming the constructed theoretical framework into design principles, which are then operationalised through multiple stages[3] and lead to a prototypical learning environment (Feulner et al., 2021, p. 8 ff.).

Resulting from that process, the development of the instructional design is always guided by theory (Feulner et al., 2021, p. 8 ff.). Prediger (2015, p. 657) distinguishes between different paths of adopting initial theories in the beginning of the DBR research process:

[3] A detailed explanation of the operationalisation process of DP can be found in Feulner et al. (2021), visualised in Figure 7.

- path 0: complete adoption from literaturek
- path 1: abstraction or generalisation of practical knowledge regarding phenomena to be researched as well as solution approaches
- path 2: area-specific clarification or adaptation of general theories from neighbouring disciplines
- path 3: further development or generalisation or transfer of empirically reasoned theories and theory elements to new or expanded areas of study
- path 4: interconnection of existing theories through integrating, synthesising or combining theories and theory elements

According to Prediger (2015, p. 657), the enumeration is chronological and traces the historical development of mathematics education as a scientific discipline, with all strands currently coexisting. Especially concerning the integration of theories and practices, which is also reflected in the collaboration between practitioners and researchers in DBR projects, path 1 (see paths above) is highly relevant as a starting point for the conception of the learning environment (Serwene, 2023).

One central aim of research is the formation of theories and theory elements through their advancement and development. The process of theory formation is therefore understood as a continuous development, in which existing theories are refined and new theories are formed in order to explain phenomena and to make predictions. This process also includes the empirical validation of theories through research studies and the testing of theory predictions (Prediger, 2015, p. 653).

2.3 Design principles as active elements for connecting theory and design

In the DBR process, the interplay between theories and design principles plays a central role, as the transfer of theories into DP forms the basis for the formation of design products. In DBR projects, theories are not only seen as predetermined frameworks but also as active elements of design that help to understand the impact and effectiveness of practice products.

We understand DP as points of crystallisation for practical design and scientific knowledge acquisition and consider them as a crucial part of the design phase (Euler, 2014a, p. 97). DP are continuously revised in the context of evaluation and interpretation in the design cycles, eventually constituting a central product of the DBR project (Feulner et al., 2021, p. 7).

Meanwhile, they can be formulated at various levels of abstraction. The formulation of DP varies, among other factors, depending on whether they are based on theoretically or empirically derived plausibility assumptions, overarching guiding ideas, teaching and learning theoretical assumptions, or interpretations of these in the specific application context (Euler, 2014a, p. 102, 108 f.). Thus, DP can range from very specific statements about instructional designs with an "if-then logic" in the so-called alphabet-sentence by van den Akker (1999) (van den Akker, 1999 cited in Bakker, 2018) to general design principles that simply provide orientation and direction (Plomp, 2010, p. 22).

Although the DP within the operationalisation process are increasingly formulated in a more practice-oriented manner, influenced by designers' own conceptual considerations (Feulner et al., 2021), the design decisions remain theory-based. Consequently, the implementation of a design results in a theory-oriented process for solving specific practical problems (Wilhelm & Hopf, 2014, p. 32). Through the close connection between theory and practice, DBR enables the adaptation and modification of theoretical concepts to meet the specific needs and requirements of the educational context.

DBR aims to achieve the (further) development of theories in terms of context-specific theories in the field of education and to enable the generalisability of this theoretical knowledge (Tulodziecki et al., 2013, p. 211 referring to DBRC, 2003, p. 5 ff.). Thus, theory development goes hand in hand with the development of learning environments in the research process and is accompanied by research methods (Tulodziecki et al., 2013, p. 211 referring to DBRC, 2003, p. 5 ff., among others).

However, since subject didactic theory-building is an ongoing process, it is inevitable that the design process can also be based on incomplete theories (Feulner et al., 2015, p. 209). This is partly due to the fact that DBR specifically aims at the development and testing of innovations for which there are no sufficient practical solutions yet. Nevertheless, theories form the basis for the design of interventions (based on DP), as this is the only way to thoroughly examine their impact and effectiveness and derive justified consequences for redesigns.

The processes of theory application, verification and development, as proposed by Euler (2014a), are an approach to illustrate different aspects of the genesis of DP, particularly in DBR research processes.

In the process of designing teaching-learning concepts, the terms theory application and theory verification are referred to when the DP are primarily derived from didactic theories that are already existing (Euler, 2014a, p. 107). This process initially pertains to the transfer of existing theories into DP and subsequently to the empirical verification of these theories. Selected theories are intended to guide the design of products for specific phenomena or situations, with the aim of achieving theory-based effects, enabling research-based explanations of observations and deriving instructional guidance. During the implementation, testing and verification are conducted to check if they align with the observed data. Theory verification serves to assess the validity and explanatory power of a theory concerning the developed design, allowing for adjustments or improvements if necessary. Theory application is crucial to demonstrate the relevance of the theories, their relevance in real contexts and to verify them in practical settings.

When further knowledge is gained through the practical testing and is then incorporated into the DP, the term theory development can be used (Euler, 2014a, p. 107). New insights and research findings lead to the development of explanatory approaches for new phenomena or the expansion of existing explanations. This process involves expanding, improving or modifying existing theories in relation to the studied subject, which narrows the scope of theory development (see section 4; criticism by Renkl, 2023). After going through multiple cycles, the DP increasingly incorporate differentiated theoretical and empirically underpinned insights.

The concepts of theory application, verification and development are not only co-existing processes but can also follow each other chronologically: An existing theory can initially be applied (design phase), then verified (application and analysis phase) and subsequently becoming more differentiated, further developed or refined (through the redesign in the cyclical process). Within the stages of operationalisation, a DP can thus represent theory application at the beginning of the research process; based on this it can then be verified and/or undergo theory development on the same basis. The different contexts of origin also explain the dual function of design principles as a basis for instructional practice and as a result of scientific knowledge acquisition (Euler, 2014a, p. 107).

If DP (which were derived from theory and then operationalised) prove to be effective, this theory application and verification can already represent a result (in the sense of "this design principle proves to be effective for my design" or "this design principle can be used for the conception of XY"). When new insights emerge (e.g., during the operationalisation of the design principles, which are then tested and evaluated), this constitutes theory development. With regard to the operationalisation process of design principles (Feulner et al., 2021, p. 9 f.) it is therefore possible that theory application and verification are primarily found in the formulations of the first two stages, insights contributing to theory development mainly in the wording of the second and third stages (Feulner 2021, p. 409). Subsequently, at the end of a research process, it can be discussed whether a result constitutes theory application, verification or development, thus categorising the scope of the respective insight (Feulner, 2021, p. 430).

To identify and operationalise design principles is one form of bridging the gap between theory and design. Within the Design-Based Research literature, conjecture mapping (Sandoval, 2014) and hypothetical learning trajectories (Bakker, 2018; Bakker & Smit, 2017) are frequently discussed in relation to the conceptualisation of actionable knowledge for design (Bakker, 2018). All three approaches possess a hypothetical nature (Bakker, 2018). Sandoval (2014, p. 20) defines conjecture mapping as "a method for articulating the joint design and theoretical ideas embodied in a learning environment in a way that supports choices about the means for testing them."[4]. Conjecture maps thereby elucidate how the learning environment can be empirically evaluated. Both DP and conjecture maps serve as valuable tools at the inception and conclusion of a DBR project (Bakker, 2018). The third frequently mentioned method for linking theories and design decisions is through hypothetical learning trajectories (HLT), which encompass "(a) an overall learning goal, (b) students' anticipated starting point, (c) instructional activities (typically for one lesson), and (d) assumptions about how the instructional activities would support mental activities that lead to the overall learning goal" (Bakker & Smit, 2017, p. 120). HLT appear particularly beneficial when content and learning activities necessitate sequencing (Bakker, 2019). In Smit's dissertation project, a HLT was formulated for each lesson to structure the session; consequently, the hypothetical learning trajectories were augmented by hypothetical teaching trajectories (Bakker & Smit, 2017). In the following, we will use operationalised design principles to connect initial theories, deductively and inductively chosen design decisions and revision mechanisms.

Answers to how theories can be developed in a DBR-specific manner through theory genesis can be found in Edelson (2002). According to Edelson, there are three basic possibilities for theory development in DBR projects: (1) domain theories, (2) design frameworks and (3) design methodologies.

(1) A domain theory is the generalisation of a part of the problem analysis. According to Edelson (2002), this type of theory building is always descriptive. An example of a domain theory could be statements about learners and their individual learning paths. Domain theories can be further divided into context theories and outcomes theories. Characteristically context theories make statements about challenges and opportunities that arise from various design contexts. Whereas outcomes theories describe results associated with an intervention.

(2) A design framework is a generalised design solution. Unlike domain theories, design frameworks always have a prescriptive character. They include statements about the features of developed artifacts and how these features work. Edelson (2002, p. 114) describes design frameworks as a "collection of coherent design guidelines". Design frameworks are therefore closely related to the developed design principles.

(3) According to Edelson (2002), the third way to formulate a theory is through design methodologies. These also have a prescriptive character, as they should provide guidelines for the design process. Design methodologies, commonly used in various fields beyond didactics (e.g., engineering, software development), can be employed to develop procedures that consider all essential problems and apply the necessary knowledge within the design process. Typically, such a

[4] For a more detailed explanations on conjecture maps refer to Sandoval (2014) and Bakker (2018).

design methodology specifies a defined sequence of tasks and describes the goals and processes of the designers for each step.

These three types correspond to the three different sets of decisions that designers make during the design process:

(a) The problem analysis “characterizes the goals, need, or opportunity that a design is intended to address together with the challenges, constraints, and opportunities presented by the design context" (Edelson, 2002, p. 109).

(b) The design solution “describes the resulting design. It is the result of the designers' efforts to address the challenges, satisfy the constraints, exploit the opportunities, and balance the tradeoffs that were identified in the problem analysis" (Edelson, 2002, p. 109).

(c) The design procedure “specifies the processes and the people that are involved in the development of a design" (Edelson, 2002, p. 108).

Once a theory or a theory element has been developed within a DBR project, it becomes part of the dual outcome (Feulner et al., 2021, p. 17). While the practical output generally provides solutions to the initial problem, the addressed theory or developed theory contributes to the didactic discourse (Wilhelm & Hopf, 2014, p. 31). Usually, theories are introduced into the discourse through publications, following the practices of the scientific community. The situation is different for the practical output, as a successful transfer must be understood not merely as a one-dimensional mechanism but rather as a dialogical process between two reference systems (Jakobs, 2021). It requires additional supportive measures. In this context, the formulation of DP at different levels of complexity and the implementation of DBR projects in theory-practice tandems (Serwene, forthcoming) provide a beneficial foundation for a "symbiotic implementation" (Gräsel, 2011) of the results.

The high contextual nature of theories developed in DBR projects is often subject to criticism (Renkl, 2023), which leads to a limitation in the degree of generalisation of the (further) developed theories. This limitation is also evident in the selection of terminology. Terms such as local, context-specific or proto-theories are used in the DBR literature to denote this contextual specificity (Hiller, 2017, p. 104). The FUNKEN research group for example, uses the term "local theories," emphasising that the theory cannot completely exceed its context of origin. Moreover, the term deliberately states that the theories remain subject-specific and that they have limited applicability to other learning objects (Prediger et al., 2012, p. 458). The DBRC (2003, p. 8) uses the term "prototheories" and explicitly refers to contextualised theories of teaching and learning. Euler (2014b, p. 18) describes the theories generated from DBR studies as "area-specific." According to Euler, these theories should be relevant for specific educational practices while also extending beyond the specific case and being transferable to larger contexts (Euler, 2014b, p. 18).

3.0 Analysis of three theories/theory elements from DBR projects

In section 3, selected theories and theory elements from three DBR projects conducted by the authors are analysed. These chosen theories and theory elements differ in terms of scope, depth and empirical saturation (Gryl, 2020).

Analysis 1 (section 3.1) examines the application of the "Self-Determination Theory" (SDT) (an empirically underpinned and scientifically recognized theory) in a DBR process. The case study is drawn from the dissertation project "SpielRäume – A DBR study on mobile location-based learning with Geogames"[5] by Feulner (2021). This project involves the design, testing, evaluation and iterative development of an innovative learning environment by using a so-called "Geogame", with the aim of promoting a differentiated spatial perception among students through active processes of spatial exploration and with the aim of generating insights into the specific game design.

The consolidation and adaptation of different elements of theories and their genesis in the DBR research process are examined in analysis 2 (section 3.2). These theory elements are theoretically-conceptually or empirically confirmed within their specific scientific fields but have not yet been integrated in this specific form. Analysis 2 is based on the DBR project "ExpeditioN Stadt"[6] (Hiller et al., 2019; Hiller & Conrad, 2023; Hiller et al., 2023). On the one hand, the project focusses on the development of digital rallies for sustainable urban development using the smartphone app Actionbound. On the other hand, the project focusses on the professionalisation of teachers and actors in the field of Education for Sustainable Development (ESD).

Analysis 3 centres around a theory element which is not yet empirically underpinned (section 3.3). The theory element "switching languages" (switching the language in the context of bilingual learning) draws on instructional experiences and initial didactic approaches. It is the object of study in the DBR dissertation project "Understanding Geography through Bilingualism – a Design-Based-Research-Study on Bilingual Geography Education Using the Geographical Concept of Change"[7] by Serwene (2023). This project examines how switching languages can support subject learning in bilingual geography education.

To ensure comprehensibility of the analyses, all case studies are structured by using the same analytical framework. The first step involves explaining the selection of the theory or theory elements and

[5] Original title: "SpielRäume – Eine DBR-Studie zum mobilen ortsbezogenen Lernen mit Geogames" (Feulner, 2021).
[6] Original title: "ExpeditioN Stadt: Didaktisches Handbuch zur Gestaltung von digitalen Rallyes und Lehrpfaden zur nachhaltigen Stadtentwicklung" (Hiller et al., 2019).
[7] Original title: "Geographie verstehen durch Zweisprachigkeit – eine Design-Based-Research-Studie im Rahmen des bilingualen Geographieunterrichts am Beispiel des Fachkonzepts Wandel" (Serwene, 2023).

placing them within the paths of theory adoption as outlined by Prediger (2015, see section 2.2). The next two steps of the analyses focus on theory development within the DBR cycle. Step 2 addresses the translation of theories into design principles during the design phase, while step 3 examines the verification of theories during the application and analysis phase. Each analysis includes an excerpt of the operationalisation of one DP, illustrated in a figure (see Fig. 1, 2 and 3). The presented operationalisation process shows the final version of the DP after going through several design cycles. The analysis concludes with an examination of the insights gained from the selected theory or theory elements in relation to the dual outcome of DBR projects. The process of theory application, verification and development proposed by Euler (2014a) is also addressed.

The operationalisation of the design principles follows a consistent approach across all three analyses, applying the following stages (Feulner et al., 2021):

- stage 1: design guidelines (in German: Handlungsleitlinien)

  theory-guided differentiation or adaptation of general didactic principles, subject-didactic/subject-specific theories, models and theory elements

- stage 2: application principles (in German: Umsetzungsprinzipien)

  instruction-related implementation of the design guidelines (deductive-inductive interplay within the design cycles)

- stage 3: adaptation to the concrete learning environment (in German: zielgruppenspezifische Konkretisierung der Umsetzungsprinzipien)

  recipient-oriented design of the learning environment, taking into account didactic and methodological considerations.

3.1 Analysis 1: Self-Determination Theory

Explanation for the selection of the theory

Literature provides numerous indications that game-based teaching methods, as well as field trips or the use of mobile devices, can have positive effects on the intrinsic motivation of learners (Baer, 2008; Ohl & Neeb, 2012; Lude et al., 2013). The use of certain methods or media are often “justified” by their potential positive impact on the learning process, but the actual effects are less frequently empirically examined. In the dissertation project by Feulner (2021), the motivation of the participating students during the implementation of a digital exploration game was examined. The aim of the study was to design the instructional environment in a way that would generate intrinsic motivation (with reference to the SDT) and sustain it throughout the gameplay for as long as possible. The intention was to generate knowledge about the factors that facilitate or hinder this kind of motivation.

Based on an extensive literature review, the "Self-Determination Theory" by Deci and Ryan (e.g., 1985, 2002) was chosen as a theoretical basis. This theory represents a broad framework as a macro-theory of motivation, encompassing various mini-theories. It has been researched, refined and extended over many years and has been applied by numerous researchers in various domains (e.g., in the context of games by Ryan et al., 2006; Rigby & Przybylski, 2009). A core assumption of the theory is that the degree of perceived self-determination influences our actions and, consequently, affects the quality of learning. Three basic psychological needs (autonomy, competence, relatedness) that each person has, attribute to the sense of self-determination. The theory can therefore contribute to a better understanding of the relationship between learning and motivation in instructional designs.

Transfer of the theory into design principles (design phase)

With regard to the different paths of adopting initial theories according to Prediger (2015, see section 2.2), this corresponds to a "complete adoption from the literature" (path 0). Several authors have already identified measures that contribute to enhancing this type of motivation (Prenzel & Drechsel, 1996, p. 220). This corresponds to an "abstraction or generalisation of practical knowledge about both the phenomena to be researched as well as solution approaches" (path 1) according to Prediger (2015).

A selection of these measures was identified (Feulner, 2021, pp. 168 f.) and incorporated into the derivation and operationalisation of the DP. These measures are also included in the teaching design as they were considered during the development of the design and in the redesign of the teaching-learning environment (design phase). Therefore, they were also part of the empirical analysis throughout the research process.

An example of the transfer of the theory into DP and their operationalisation can be seen below:

Figure 1: Extract from the operationalisation of the design principle "game-based learning with Geogames" (Feulner 2021)

design principle: game-based learning with Geogames		
design guideline	application principle	adaptation to concrete learning environment
Through game-based learning, increased motivation can be generated among students, thereby stimulating a more engaging learning process.	With reference to the "Self-Determination Theory" (focus on the mini-theories OIT, BPNT, CET), the aim is to foster intrinsic motivation in practice.[8]	To meet the need for autonomy, the game provides various choices, initiating and promoting independent exploration, planning, action and learning. Negotiation processes within the group can also contribute to this basic need. Enhancing the basic psychological need for relatedness, teams compete against other groups. In addition to that, certain tasks explicitly require collaboration within the group.[9]

Verification of the theory (application phase and analysis phase)

Two design cycles were completed in the main study. Prior to this, there was an extensive exploration phase which was necessary due to the highly innovative character of the design (Feulner, 2021, p. 212). During the implementation phase, where the instructional design was tested in real settings, the verification of the theory took place, forming the basis for the further development of design principles. To generate insights into the emergence and the maintenance of motivation, guided interviews with the participating students were conducted. In addition to that a questionnaire was used in a post-test. In this instrument scales from the standardised measurement

[8] In addition to the mini-theories of SDT, the "Person-object theory of interest" (in German: „Person-Gegenstands-Theorie des Interesses“), (Krapp, 1992) was also considered. This theory is also well-researched and can be seen as a complementary approach to the SDT (Krapp & Ryan, 2002).

[9] These operationalisations are based, for example, on measures identified by Prenzel and Drechsel (1996) to promote the need for autonomy, perceived freedom of choice and relatedness. Measures identified by them include, among others, cooperative work, providing choices, creating spaces for exploration, enabling independent investigations, planning, actions and learning processes.

instrument "Intrinsic Motivation Inventory" (IMI) were chosen and scales from the "Game Play Questionnaire" (GPQ) were added. These research instruments are sufficiently validated through numerous studies (Brandstätter et al., 2013, p. 100; Liu, 2012; Kim & Shute 2015). The questionnaire was descriptively evaluated due to the small sample and the results were then triangulated with additional data from the accompanying research (e.g. the interviews) to generate insights into the effects of the developed design. Through the data analysis, specific influencing factors and variables were identified. According to Euler (2014a, section 2.2), up to this point, one can speak of theory application and theory verification.

Research results were for example that at times the aspect of group composition had a significant impact on the motivational process, which manifested itself in the area of “relatedness". This had implications for the practical implementation in the form of specific rules and organisational measures. On the third stage of the DP, an additional guideline was formulated: The need for relatedness is met by having at least two participants voluntarily play together in a group. Up to that point, the grouping was often done by the teachers, who deliberately separated certain students from each other. Further adjustments included for example changes in the game design (e. g. the scoring or the layout of the game field). These modifications ensured that the game flow remained more balanced, which was also beneficial for aspects of "perceived competence." Additional insights were mainly generated regarding the developed tasks within the game, which led to their revision, as well as adjustments in the guidelines for creating tasks.

Insights regarding the theory (dual outcome)

In the context of the intended goal of gaining insights into generating and maintaining intrinsic motivation, both practical and theoretical outcomes were generated. The practical product includes game prototypes for location-based games to promote a "differentiated spatial perception" and guidelines for teachers on how to create this type of game for their own school location or field trip destination. These guidelines include design templates and teacher training, among other things. In addition, theoretical insights were gained on motivational influencing factors, task design in mobile location-based learning and insights on how to ensure that game mechanics and game content are meaningfully interconnected. As the results of the theory development are formulated prescriptively and provide guidance for the design process in the form of guidelines to support the independent design processes of practitioners, they can be characterised as design methodology (following Edelson, 2002).

However, since this study explored an innovative application of a newly developed instructional design in the field of geography education, some insights have an exploratory nature and need to be (re)examined in terms of their validity and transferability. It must also be pointed out that these findings have certain limitations regarding generalisability, as the game flow and thus motivation depend on a complex interaction of various aspects, not all of which can be controlled or anticipated, but which can significantly influence motivation. This also implies that further research is necessary to deepen the knowledge acquired and to address remaining gaps in knowledge.

3.2 Analysis 2: Theory elements for mobile location-based learning

Explanation for the selection of the elements of theories

The complex topic of sustainable urban development can be experienced not only in the classroom but also in the students' living environment. Planning a city field trip with this objective can involve the use of digital media, such as the smartphone app Actionbound, to facilitate self-directed and task-oriented learning on site. However, designing mobile location-based learning environments requires various competencies, including subject-specific content knowledge (CK), pedagogical-didactic knowledge (PK) and technical knowledge (TK). This combination of competencies is referred to as TPACK framework (Mishra, 2019).

The "ExpeditioN Stadt"[10] project aims to professionalise teachers and ESD actors and has therefore a dual objective target: On the one hand, prototypical city rallies (bounds) are developed for exemplary cities in south-west Germany. On the other hand, assistance and support guidelines for the development of one's own mobile, location-based learning environments are formulated as so-called didactic tools.

To achieve these objectives, various elements of theories from different subject areas needed to be integrated. These elements vary significantly in their theoretical precision, analytical depth and empirical saturation. These elements of theories were:

- sustainable urban development from an urban geographic perspective (WBGU report, 2016; Heineberg, 2022; BMI, 2020)
- ESD: competency model recognize/assess/act (KMK & BMZ, 2016), four "classic" sustainability dimensions, SDGs
- situated learning (Gerstenmaier & Mandl, 2001)
- "new task culture” (Reinfried, 2016; Hofmann, 2021)
- mobile learning (Lude et al., 2013)
- excursion didactics: methodological diversity between cognitivism and constructivism (Ohl & Neeb, 2012)

The specific content-related theoretical element "sustainable urban development from an urban geographic perspective" will be discussed in more detail. Since there is no empirical evidence for this specific

[10] More information about the ExpeditioN Stadt project: www.expedition-stadt.de

approach within the field of mobile location-based learning, the associated theoretical element has been fully adopted from the literature ("path 0" according to Prediger, 2015).

Transfer of the elements of theories into design principles (design phase)

In the design phase, all six elements of theories were transformed into design principles through a multi-stage operationalisation process (as described above, Feulner et al., 2021). One feature of the ExpeditioN Stadt project is the formulation of the DP on the third stage as "practical tips for teachers and ESD actors" to support the creation of their own learning environments (bounds). The theme-specific design principles for the theoretical element "sustainable urban development from an urban geographic perspective" were initially divided into three design guidelines to consider (1) historical urban development paradigms (Heineberg, 2022), (2) the paradigm of sustainable urban development (BMI, 2020: New Leipzig Charter) and (3) the specific characteristics of each city (WBGU, 2016). An example of the operationalisation process for one of these guidelines is the adaptation of the "specific characteristics" dimension from the “normative compass” of the WBGU (2016). After the formulation of the design principles concrete learning environments (“Bounds”) were designed as a creative act.

Figure 2: Excerpt from the operationalisation of the design principle "sustainable urban development from an urban geographic perspective" (Hiller et al., 2023)

design principle: sustainable urban development from an urban geographic perspective		
design guideline	application principle	adaptation to concrete learning environment
Emphasise the specific characteristics of your city.	Take the local agenda (2030) into consideration.	Refer to measures that are already taken or planned by your city (e.g. bound "sustainable mobility in the city of Heilbronn", location "Bike Street").

Verification of the elements of theories (application phase and analysis phase)

In total, the project passed through four design cycles, based on which the DP were further developed: Cycles 1 and 2 involved piloting the developed prototypical city rallies in Ludwigsburg and Heilbronn with several school classes and teacher trainees in project seminars. Cycle 3 focused on the further development of the bounds based on learning process analyses and participant observations. Cycle 4 aimed to evaluate the didactic task quality of selected types of tasks.

The present description focusses on the most recent cycle. So called “in-bound evaluations” were conducted to address the uniqueness of mobile location-based learning in the context of sustainable urban development. The research design consisted of an evaluation study in which student trainees acted as subject matter evaluators and assessed the didactic task quality through on-site expert interviews. As part of their studies, student teachers at the PH Ludwigsburg completed several field trips, including individually conducted, digitally supported self-learning excursions. The prototypical bounds from the ExpeditioN Stadt project were used as subject-specific field trips that teacher trainees simulated on site for teaching purposes and that were then reflected upon. The bounds were slightly modified by adding questions for reflection. At multiple locations, the teacher trainees reflected on and evaluated selected types of tasks. During gameplay, the students switched their roles from being "students" to "subject matter experts" and provided their evaluations on short items directly in the app Actionbound.

Insights regarding the elements of theories (dual outcome)

In addition to publishing the prototypical bounds and implementing various marketing measures (e.g., media coverage, public sustainability events, presence on digital ESD platforms), six didactic tools were formulated. These tools were developed in co-creative theory-practice tandems, consisting of project staff and practitioners (teachers and ESD actors) and they serve as guidance for independently developing mobile location-based learning environments.

This theory development (Euler, 2014a) can be considered a contribution to the didactic discourse in the field of mobile location-based learning (see Figure 3). When classified according to the schemes from section 2.2, the development of the tools can be understood as "networking existing theories" since they emerged through the recombination of existing theoretical elements (path 4 according to Prediger, 2015). As they are formulated prescriptively and aim to initiate independent design processes by practitioners, they can be characterised as design methodologies (according to Edelson, 2002).

Figure 3: The didactic tools of the ExpeditioN Stadt project (Hiller et al. 2023)

No.	Description
1	**Didactic scripts** for target planning help to precisely define framework conditions, goals, target groups and implementation structures at the beginning of the design of the theme rallies.
2	A **didactic task typology** includes 18 different task formats for creative task design along the three ESD competence areas: recognize/assess/act.
3	A grid designed as a **spider chart** contains quality criteria for task design (e.g., location reference, level of difficulty) and helps designing and compiling tasks as well as the structured analysis of existing bounds.
4	Practical tips support specific implementation questions, such as the use of the Actionbound function "Switches," which allows breaking the linear logic of theme rallies and making the sequence of tasks or locations more flexible.
5	**Teaching vignettes** are compact documentations of evidence-based developed task examples, showing their integration into didactic concepts. They are structured according to the following sections: design in Actionbound, exemplary solutions, empirical evaluation results and didactic commentary.
6	**Bound modules** which can be replicated for free simplify creative design of ESD theme rallies using tasks from the task typology. They can be easily adapted to individual needs in the “Actionbound Bound Creator”.

The theoretical element "sustainable urban development from an urban geographic perspective", which was mentioned above, influenced the formulation of the tools at various points. Through the development of prototype tasks and processed locations in the context of sustainable urban development, application examples of the tools (scripts 1, task typology 2, analysis spider 3, bound modules 6) were formulated based on the DP. The practical tips (4) correspond to the last stage of the operationalized DP and provide valuable design guidance for creating individual theme rallies. The teaching vignettes (5) show how DP form the intersection between practice (development of tasks and locations) and theory (empirical evidence of the design cycles and theoretical elements for interpretation).

3.3 Analysis 3: Theory element "language switches” (in German: “Sprachwechsel”)

Explanation for the selection of the theory element

In current bilingual lessons in Germany, many students find it challenging to grasp a subject matter solely in the target language, often requiring support (foreign language scaffolds) and reverting to the language spoken in classroom to comprehend a complex subject matter (Falk & Müller, 2013, p. 4; Diehr & Frisch, 2018; Thürmann, 2013, p. 231). One strategy to promote subject-specific learning in bilingual teaching is the use of language switches (English/German). However, integrating the school language effectively and balancing it with the target language poses a significant challenge for teachers engaged in bilingual instruction. Therefore, the DBR dissertation project by Serwene (2023) aimed to explore the potential benefits of using language switches to support subject-specific learning in bilingual geography education.

Language switches can be understood as a didactic principle of bilingual education, involving switching between the school and target languages with an intended function (e.g. understanding geographical concepts in both languages) for the teaching and learning process (Frisch, 2016). Based on existing publications on language switches, Frisch (2016) identifies five functions of language switches in bilingual education: cognitive, communicative, pedagogical, time-economic and affective functions. In the context of subject learning, the cognitive function of language switches plays a crucial role. This form of language switch serves to overcome subject-related challenges and to acquire subject concepts (Frisch, 2016). However, didactic approaches on the planful use of both languages are still scarce. Theoretically, different strategies have been proposed, such as the various functions of language switches according to Frisch (2016), the idea of combining the change of representations (graphic to text) with language switches according to Bohrmann-Linde (2016), or the teaching-learning concept of translinguaging (Garcia & Lin, 2017). All these strategies share a lack of empirical evidence and practical examples for bilingual subject-specific instructions practised in Germany. Consequently, language switches represent a theory element with limited empirical saturation and limited theoretical-analytical depth.

Transfer of the theory element into design principles (design phase)

In the design phase of the learning environment, the theory element "language switches'' was incorporated through the integration of practical knowledge from the collaborating teacher and suggested solutions from literature (Frisch, 2016). In addition, language switches with a cognitive function were adopted to subject-specific learning in bilingual geography education. The transfer of the theory element occurred through the three-tiered operationalisation process of the design principle "bilingualism" (in German: “Zweisprachigkeit”).

Content-cognitive language switches were one of four design guidelines (translanguaging, presentation of the instructional materials in two languages and bilingual learning tasks) of that design principle (Serwene, 2023, p. 172).

Figure 4: Excerpt from the operationalisation process of the design principle "Bilingualism" (Serwene, 2023, p. 305)

design principle: bilingualism		
design guideline	application principle	adaptation to concrete learning environment
guided content-cognitive language switches	Language switches serve as a supporting function for subject-specific comprehension.	The learners initially acquire the information monolingually, according to their proficiency in the foreign language. Learners with weaker foreign language skills work with the learning materials in German. The learning outcomes are presented by the learners in English. There are phases during the elaboration process in class in which only the German or English set of information cards is used.

Due to the low empirical and theoretical-conceptual saturation of the theory element "content-cognitive language switches”, a high level of creativity and innovation was required in operationalising this design guideline. The outcome of the design phase was a bilingual learning environment with intended language switches to support subject learning in bilingual geography lessons in year 10.

Verification of the theory element (application phase and analysis phase)

Because of the limited existing knowledge about content-cognitive language switches, an exploratory research design was required, which allowed for a holistic examination of the instruction. The aim was to understand when language switches are helpful for subject-specific learning during the teaching and learning process and to observe students' learning strategies when using bilingual learning materials.

The testing of the prototypical learning environment was videotaped to gather information about the students' interactions with bilingual learning materials and their behaviour in such an environment. In each design cycle, four student duos were videotaped throughout the entire teaching sequence (3 x 90 minutes) (Serwene, 2023).

The video data was analysed using verbal transcripts and observation protocols through "Qualitative Content Analysis" with an inductive coding procedure. In the first design cycle, the learning process analyses revealed that the students lacked strategies to work independently with bilingual teaching materials. Consequently, changes were made on all three operationalisation stages in the first redesign of the learning environment. The most significant change was the transformation of the design guideline into "guided content-cognitive language switches", which meant that teachers explicitly instructed language switches during the learning and teaching process. In the second cycle, the guided language switches led to altered communication behaviour among both teachers and students. This resulted in a new design guideline for the third design cycle: "The instructional languages are German and English." (for a detailed explanation of the redesign, see Serwene, 2023, p. 305).

Referring to Euler's (2014a) chosen terminology, the theoretical results can be considered as theory development. On the one hand, language switches that specifically support subject-specific learning in bilingual geography education have been identified at the micro-level of learning processes. On the other hand, relevant insights regarding the impact of teachers' communication behaviour on the successful implementation of bilingual learning environments have been obtained at the macro-level of the teaching process (Serwene, 2023). Through multiple design cycles, the theory element was further differentiated and empirically confirmed, resulting in new explanatory approaches and didactic concepts. The changes affected all three operationalisation stages. Aspects originally located on the third stage of operationalisation gained increased relevance through repeated testing and analysing. Finally, they were listed as design guidelines and were further differentiated on the stages 2 and 3. An example of such a design guideline is: "The instructional languages are English and German".

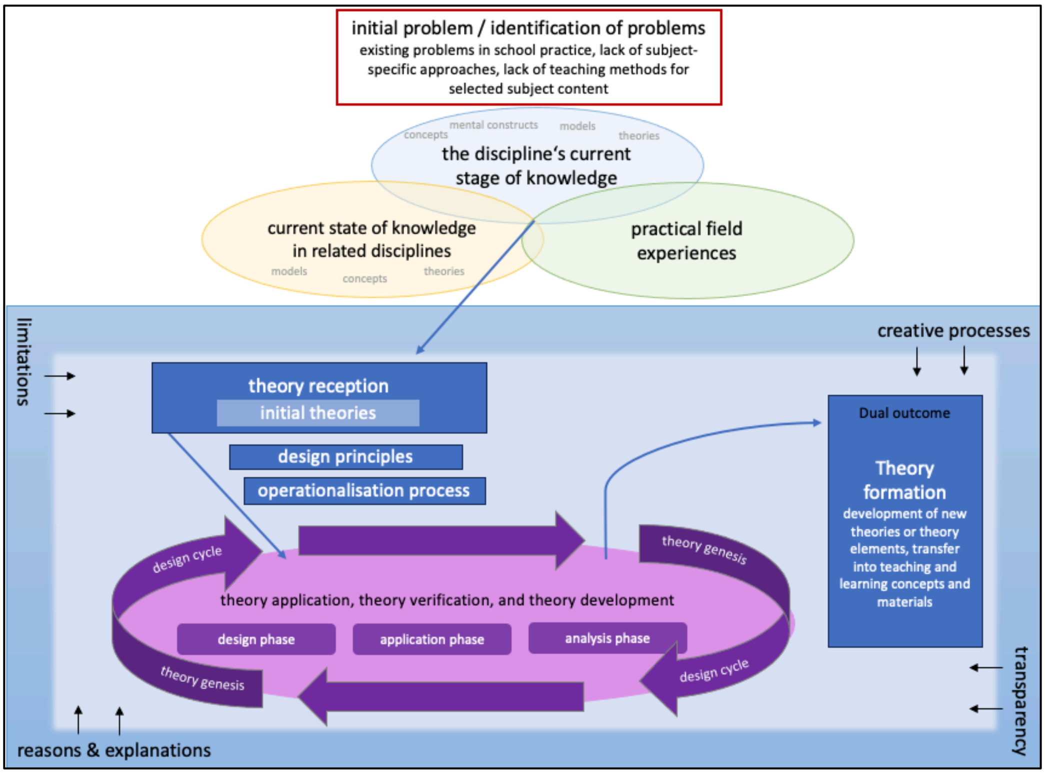
Insights regarding the theory element (dual outcome)

Both practical and theoretical outcomes were generated regarding the theory element "guided content-cognitive language switches". The product is a finalised bilingual learning environment that integrates language switches to support subject learning. This outcome is designed as a design-framework according to Edelson (2002). On a theoretical level, guidelines for language switches to promote subject-specific learning in bilingual geography education were formulated as domain theories (Edelson, 2002). Moreover, theoretical insights were gained into the impact of teachers' communication behaviour on the acceptance of both languages in bilingual learning environments. Due to the context-specific implementation, the completion of the study presents not only initially differentiated theoretical findings concerning the chosen theory element, but also many new questions that need to be addressed in further research.

4.0 Model of theory genesis in DBR projects

This section aims to address the question of how generalisable the different paths of theory genesis can be in DBR projects. Based on the analyses of the three projects by the authors (see section 3), a model of theory genesis in DBR projects is presented here:

Figure 5: Model of theory genesis in DBR projects using design principles (own design)



The variety of theories that have been analysed by the authors form the foundation on which the model was developed. Moreover, the model's development was influenced by the authors' previous work on DBR processes (Feulner et al., 2021) and by Eisend & Kuß's "Model of Theory Development" (in German: "Modell des Theorie-Entwurfs") (2021, p. 140).

This model visualises how theories are applied, examined and developed in the DBR process. At the beginning of each DBR project, the identification of an initial problem is the starting point, derived from the current state of knowledge in the field of study or related disciplines, as well as from practical knowledge. To find solutions for this initial problem, the process of theory reception follows. Based on so-called initial theories (Prediger, 2015, see section 2), design principles are derived and operationalised in a multi-staged process. During the transition into DP, the degree of adaptation, integration and conceptual development of the chosen theories or theory elements already diverges, requiring various creative processes from the designers.

The transit into the design cycle forms the final stage of operationalised design principles. A design cycle consists of three phases: the design phase (theory-guided development of suitable solutions based on DP), the application phase (testing in practice and data collection) and the analysis phase (interpretation of data using appropriate evaluation methods) (Feulner et al., 2021). During the design cycles theory genesis unfolds which includes the application, verification or further development of existing theories or theory elements. In each iteration, not only the designed artefacts but also the design principles are continuously refined at all stages of operationalisation if necessary.

Although the visualisation suggests a sequential order in generating theories, it should be emphasised that predominantly the iterations of the design cycles enable theory genesis.

The process of theory formation arises from the final analysis phase of the design cycles. Based on the interpretation of data, new theories or theory elements are formulated. In addition to the practical outcome, the developed theories or theory elements constitute the dual outcome of a DBR project.

Since all theory-generating processes are creative and highly complex and therefore difficult to be conceived as a whole it is essential to ensure a high level of transparency in all steps of theory genesis. Ways to do so is by reasoning decisions and explaining motives (e.g., for the choice of an initial theory or for the formulation of a specific DP). It is also important to be aware of limiting conditions. The contextuality of the data collection in educational contexts often entails externally determined constraints (e.g., student groups with individual prerequisites or time restrictions) that need to be considered and reflected upon. Likewise, the individual characteristics of the researchers (preconceptions, education, theoretical and methodological knowledge) must be considered. Furthermore, the theories developed in DBR projects are highly context-specific, which is why they are attributed with limited validity or generalisability (e.g., Renkl, 2023).

However, when theory formation takes place in a rule-guided, justified, and transparent manner, the developed theories possess sharpness and contour, allowing them to be taken up and reused in subsequent projects. Thus, DBR-specific theory formation has the potential not only to develop isolated "mini-theories" with intermediate scope but also to produce more comprehensive "macro-theories" through the combination of several of these theories.

5.0 Conclusion

The aim of this article was to examine the role of theories in DBR processes, specifically focusing on theory genesis.

It became evident that the role of theories in research processes cannot be regarded as static or unchanging, but rather as a dynamic process that requires constant reflection and development. The integration of different theoretical perspectives, the critical reflection on assumptions and the continuous examination and adaptation of theories are crucial to ensuring the quality and relevance of research results. The role of theories in DBR processes is also of great importance because it seeks to develop innovative solutions to complex problems in the field of education. Although the theories developed may be temporary and in parts incomplete, the combination of practical application and empirical validation provides a solid foundation for the continuous progression of theoretical knowledge and the improvement of practice.

Given the differences in the empirical saturation of initial theories, it is important for researchers to be aware that theories not only serve as a means to explain and test phenomena but may also contain assumptions and perspectives. Furthermore, during the operationalisation process of the DP, creative and practice-oriented adaptations of theories and theory elements are increasingly incorporated into the research project. Another important aspect to consider is that the developed theories may have limited empirical saturation and are closely tied to the context of the research project itself. Therefore, it is important to emphasise that the validity and applicability of these theories need to be re-evaluated, possibly in other contexts and situations. This process of empirical validation then allows for determining the generalisability of theories with limited scope or "mini-theories" (Renkl, 2023) and investigating their possible transferability to other educational domains, making necessary adjustments as needed. Moreover, the combination of multiple mini-theories also presents the opportunity for the emergence of theories with broader scope. Thus, DBR has the potential to contribute macro-theories to research on teaching and learning.

The aspect of transparency is crucial to critically reflect on these and other limitations in theory development in DBR projects. By transparently addressing the role of theories in research processes and critically reflecting on both design decisions and acquired research data, we can contribute to theories serving as tools for developing innovative solutions in education, based on theoretically and empirically grounded insights.

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