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# Design principles as bridge between scientific knowledge production and practice design

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Abstract

This paper uses design-based research (DBR) to describe an approach that combines scientific knowledge production with the development of innovative practice concepts. The DBR research process begins with the following question: How can an aspired, initially vaguely formulated goal be reached by a yet to be developed design? As the research process progresses, interventions are developed, tested in the field, and evaluated. This process generates increasingly stable practice concepts for reaching the aspired goals through several iterative cycles and statements about the effectiveness of the intervention's supporting pillars based on theoretical and empirical research. These statements are developed in the form of design principles. In this paper, we describe the characteristics that constitute design principles and how they emerge within a DBR research process.

Keywords
DBR process
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# Design principles as bridge between scientific knowledge production and practice design

Dieter Euler

## 1.0 Starting points: The role of science in designing educational practice

While the role of science and research is widely accepted as describing, explaining, and understanding historical or current situations, its role in the design of innovative educational practice remains controversial (Sloane, 1992; Reinmann, 2005; Euler, 2011). The German Education Council ("Deutscher Bildungsrat") defines the "tasks of educational research" only broadly in its recommendations: „They range from pure data surveys on the development of products utilized in schools to experimental programs" (quoted in: Tenorth, 2014, 155; own translation). In the past, as well as currently, educational practice needs "useful knowledge to design a better - and later-on an equal, fair, fostering, inclusive - educational system..., and the teaching profession demands orientation with everyday life issues and assists with difficult questions" (Tenorth, 2014, 141; own translation). Educational research should fulfill these requirements of the action focal points, thereby addressing criticism of, the innovation of, and implementation assistance for educational practice. This leads to research that, in this perspective, is conducted with a theory, development and practice orientation, depending on the problem statement.

Various approaches propose a closer interlinking of knowledge production and practice design, as well as a conceptual differentiation. Gibbons et al. (1994) thus differentiate between a conventional, scientifically organized "Mode 1" - as well as a design and application oriented „Mode 2" - research. The latter can, amongst others, be characterized by the following features (see Gibbons et al., 1994):

- The definition of research questions follows the search for problem solutions for educational practice.
- Research and application are interlinked; the development, testing, and evaluation of practical problem solutions are interconnected.
- The research processes are designed in the context of cooperative organizational forms. Practice representatives take on an active subject role in an inter-institutional research and development group context. Research is not conducted into or for educational practice, but rather with it.
- The fixation and dissemination of the results do not only occur by means of the discipline's publications and institutional channels, but also through the practitioners who participated in the research.

These research types can be assessed from two reference points - the science system and educational practice. Within the science system, the assessment of the respective type ultimately depends on the underlying science concept. Opinions differ primarily regarding the question of the extent to which theory application, in addition to theory formation and theory review, should become part of scientific activities (Euler, 1996). Science politics regulates this assessment, for example, via access to prestigious publications or the allocation of research resources. In economic and social sciences, the incentive structures are increasingly criticized for being too one-sided, thus resulting in methodological monocultures. In particular, young scientists "do not pursue research questions that they consider important for the progress of science, but rather collect points for ranking lists. They no longer choose the path of scientific discovery, but follow the beaten track flagged with rankings. Extrinsic motivation displaces intrinsic motivation" (Kieser, 2010, 12; own translation). In this context, it is rational to empirically explore as many narrowly defined research questions as possible, and to publish the results separately. The result is a huge number of articles whose authors refer to each other only very seldom. An integration of the atomized knowledge base in the form of meta-analyses or textbooks is lacking, since this is usually not rewarded as a scientific performance. Field studies and practical projects are also not incentive compatible, as such projects are relatively time-consuming. As a result, there is a danger that plural research cultures will disappear and be replaced by scientific monocultures.

These incentive structures in the academia are in contrast to the second reference point, educational practice. If scientific findings, although conducted technically clean and accurate according to the rules of quantitative empirical social research, remain irrelevant, inaccessible, and incomprehensible for educational practice, this can threaten the legitimacy of educational research. This background leads to a new interpretation of the question whether science only undertakes research into educational practice or also for it (see Euler, 1996; 2000; 2007).

Against this background, this paper explores the connection between scientific knowledge production and innovative practice design. Design-based research (DBR) presents an approach that interlinks both action focal points. The "design principles" act as a hinge between these focal points. On the one hand, these principles arise as a result of theoretically and empirically guided forms of knowledge production. On the other hand, they form, as prescriptive statements, the basis for designing practical action concepts to achieve the defined practice goals. The reasoning is structured as follows:

- The following Section 2 outlines the claim and core features of a DBR.
- Section 3 describes the key characteristics of design principles.

- Section 4 explains how design principles are developed.
- The concluding Section 5 summarizes the key points of this paper.

## 2.0 Design-based research: Interlinking of knowledge production and innovative practice design

DBR follows the direction of development-oriented research and proposes guidelines for a concrete research practice. The claim of integrating the development of innovative solutions for practical teaching problems with the production of scientific knowledge is characteristic of DBR. Similar claims can be found with terms such as „dual-impact research," „dual-purpose research" or „useful research," for example, in organizational sciences (Mohrman & Lawler III, 2011, 1). „The challenge for design-based research is in flexibly developing research trajectories that meet our dual goals of refining locally valuable innovations and developing more globally usable knowledge for the field" (Design-Based Research Collective, 2003, 7). Accordingly, DBR is defined as "the systematic study of designing, developing and evaluating educational interventions (such as programs, teaching-learning strategies and materials, products and systems) as solutions for complex problems in educational practice, which also aims at advancing our knowledge about the characteristics of these interventions and the processes of designing and developing them" (Plomp, 2007, 13).

DBR aims to contribute to the development of "innovative educational environments" (Brown, 1992, 141) and at the same time to develop practice-relevant theories. DBR therefore begins with the search and identification of significant problems in concrete practical contexts, which can be accomplished with innovative solution approaches. In the sense of interventions, these solution approaches are not usually included, but still need to be developed. Thereby, innovative practical solutions are sought for unresolved problems, i.e. it is not only about investigating existing realities, but also about ensuring the exploration of possibilities. "Design experiments differ from most educational research, because they do not study what exists; they study what could be." (Schwartz et al., 2005, 2)

Consequently, DBR pursues concepts or theories that are, on the one hand, useful for the respective practice. On the other hand, these theories should go beyond the scope of an individual case. DBR does not only aim at explaining the effect of interventions in a unique learning environment, but also aims at formulating "proto theories" of learning, or area specific theories that fit a broader context (see also Cobb et al., 2003, 10f.) The theories are primarily generated in the form of design principles, which are tested for a dedicated application context (see van den Akker, 1999; Reeves, 2006; Bereiter, 2014).

## 3.0 Design principles: Formulation - generalization range - degree of concretization

### 3.1 Formulation

The DBR research process begins with the following question: How can an aspired, initially vaguely formulated goal be reached by a yet to be developed design? The following example is based on a DBR project that is repeatedly used in this paper as an illustration: How can appropriate forms or versions of problem-based learning foster the moral reflection competencies of secondary school students? The central research question already structures the research steps roughly: (1) Concretization of the goal construct "moral reflection competency"; (2) description of the contextual conditions ("secondary school"); (3) development and evaluation of a goal oriented design in a problem-based learning context.

Against this backdrop, the design principles represent the supporting pillars of the interventions to be designed that substantiate (empirically, theoretically or plausibly) the fostering of the goals. With reference to the outlined central research question, interventions could be supported, amongst others, by the following problem-based learning principles:

1. The problem statement should challenge the students by presenting a moral dilemma situation so that they grapple profoundly with a situation's moral dimension.
2. In terms of its complexity and structuring level, the problem statement should be structured in such a way that it triggers original thought processes in students and cannot be dealt with by retrieving existing knowledge.
3. The problem statement should allow references to students' prior knowledge, in order to combine new and existing learning experiences.
4. The problem statement should be linked to authentic practical challenges to facilitate their transfer from theory to practice via a situated cognition.
5. The students should, as far as possible, work in a self-directed way on the problem statement in order to engage them and support the sustainability of the learning outcomes.
6. The students should use teacher support where necessary to avoid learning blockages and to receive new impulses for the development and consolidation of the learning outcomes.
7. The processing of the problem statement should take place in groups to enrich, through different ideas and perspectives, the triggering of reflections on the moral dimensions of action.

The examples show the structure and formulation of the design principles. They are prescriptively formulated ("should"). In each case, specific teaching and/or training activities are described and linked to an assumed consequence or effect. These consequences or effects refer directly or indirectly to the aspired goal. It would also be possible to relate the latter principle to other goals (e.g. "...should be in a groups, also foster team collaboration in addition to the moral reflection goal"). Such a reference is only substantiated and plausible if a corresponding learning objective was previously introduced and identified (e.g. fostering of team competencies).

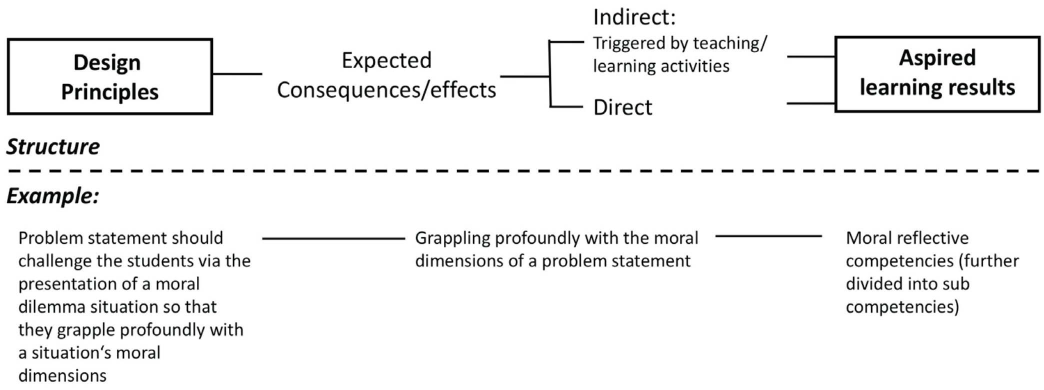


*Figure 1: Structure and formulation of design principle*

In the formulation of the structure, the consequences of each learning process intervention should be expressed as explicitly as possible. In this sense, teaching activities are always a medium (e.g. the design of the problem statements in principles 1-5, the teacher support in principle 6, and the social form in principle 7) to trigger learning activities.

The outlined structure can, amongst others, be found in Sandoval, who describes design principles as "embodied conjectures" (2004, 215). By this, he understands theory-based design assumptions or hypotheses embedded in a systematic process within which the theories are tested and developed further, and the learning environment can be improved.

## 3.2 Generalization range

The production of general theories is an ideal in research. "All science is sure, evident knowledge. We reject all knowledge that is only likely, and think that only fully known things without any doubts should be believed." (Descartes, cited in Capra, 1984, 56; own translation). This scientific knowledge ideal is also claimed by part of the social sciences, for example, sociology: "An empirical sociologist would rarely formulate a statement limited to the examined group, because such a specific statement would be worthless for science. Conversely, the researcher wants to uncover general laws that allow predictions for other objects in other situations." (Roghmann, cited in Seiffert, 1980, 224; own translation). Popper (1965, 58, 213f.) also believes that, in methodological terms, there is no difference between theories in social and natural sciences. In this view, science strives towards theories with a larger generalization range, ideally in the form of space-time-invariant laws.

Such an ideal would, in principle, be feasible under the assumption that human beings' actions are only oriented according to a biologically determined aptitude, or the fulfillment of social rules. Research's investigation of social rules could then explain human actions. This is in contrast with an image of a human being with individual and autonomous, as well as socially and foreign controlled, parts, whose actions thus only partially follow social rules and standards. Within this context, Goffman (1967, 9f.) differentiates between personal and social identity, Mead (1978, 216ff.) between a personal and social self. From a socialization theoretical perspective, Berger and Luckmann raise the point that the socialization of individuals is never fully completed: “Certain humans ‘inhabit’ their traditional sensual world more decisively than others” (1984, 114; own translation). If a human is understood as a person with autonomous parts in his actions, who can make decisions and carry responsibility, then his actions cannot be comprehended in the form of invariant law statements.

The learning capacity of humans also implies the possibility of ongoing changes in action over time. It follows that scientific theories published on human actions relate to historical data and are subject to recent changes. The more dynamic the changes, the more problematic the transfer of statements about future situations. Research aimed at comprehending human action regularities is only possible under the assumption that the regular part of human activity remains constant over a certain period of time, is therefore determined retrospectively, and accepted as effective in the future.

Even if one were to assume the possibility of comprehending the regular part of human actions, the question remains how accurate this could be. Human actions take place in concrete situations in which countless factors interact and are unique. In the course of a school year, a teacher may, for example, teach the same subject and the same class, but a closer look shows that the situation between two points in time differs. The cognitive and motivational prerequisites of the student change, as well as numerous spatial and temporal contextual conditions. Human actions (e.g. a teacher's in a school class) are embedded in a complex variety of possible influencing factors, and can only be comprehended to a limited extent. “The characteristic of complexity is fundamental in the sense that the constant change in system behavior creates the biggest problems regarding the mental comprehension and the factual influence of such a wholeness. It is this characteristic, resulting from the system's structure and dynamic, that makes us aware of the principle limits of exact knowledge, the prognosis of future conditions, and ‘the making'”. (Ulrich & Probst, 1991, 97f.; own translation) Weinert (1989, 211) concludes in relation to teaching research that “there are no isolated, simple, stable, and invariant, valid dependency relationships between teaching success criteria and teaching characteristics” (own translation).

For research, this means that the claim of invariant law statements in social contexts, for example, action in learning or educational organizations, cannot be maintained. If the action-determining factors are not sufficiently understood, then any reduction in complexity inevitably results in blurred statements. According to Merton (1957, 5ff.), this leads to a social science goal that does not strive towards general laws, but rather towards "medium range theories" that should explain social situations that are temporally and spatially strictly limited.

Against this background, design principles strive towards statements about social relationships (e.g. problem-based learning and moral reflection competency) that are not linked to a general theory claim, but are generally unique statements about specific cases. Design principles „recommend how to address a specific class of issues in a range of settings" (McKenney & Reeves, 2012, 19). They identify "regularity in messy, complex settings" (DiSessa & Cobb, 2004, 84), but are, in their scope and generalizability, inevitably limited to the research context in which they were created (e.g. classroom, school level, subject, age group). The principles provide orientation for actions within the relevant context; "they provide guidance and direction, but do not give 'certainties'" (Plomp, 2007, 22). In this context, Ulrich and Probst (1991, 66ff.) talk about "order patterns" that, although unable to exactly predict the conditions of a system, can determine them within limits and uncertainties. By using a tree as an example, they illustrate that, although the condition of the tree with its leaves, blossoms, buds, and fruit cannot be determined for a specific hour, it can, however, be determined within a certain time frame: when the tree blooms, when the fruit ripen, or when the leaves fall.

A practical application of design principles requires a concretization, as well as a transfer to the relevant practice situation. This results in design principles not having an effect in the form of fully prepared statements, but only indirectly through the practitioner's transfer performance.

## 3.3 Degree of concretization

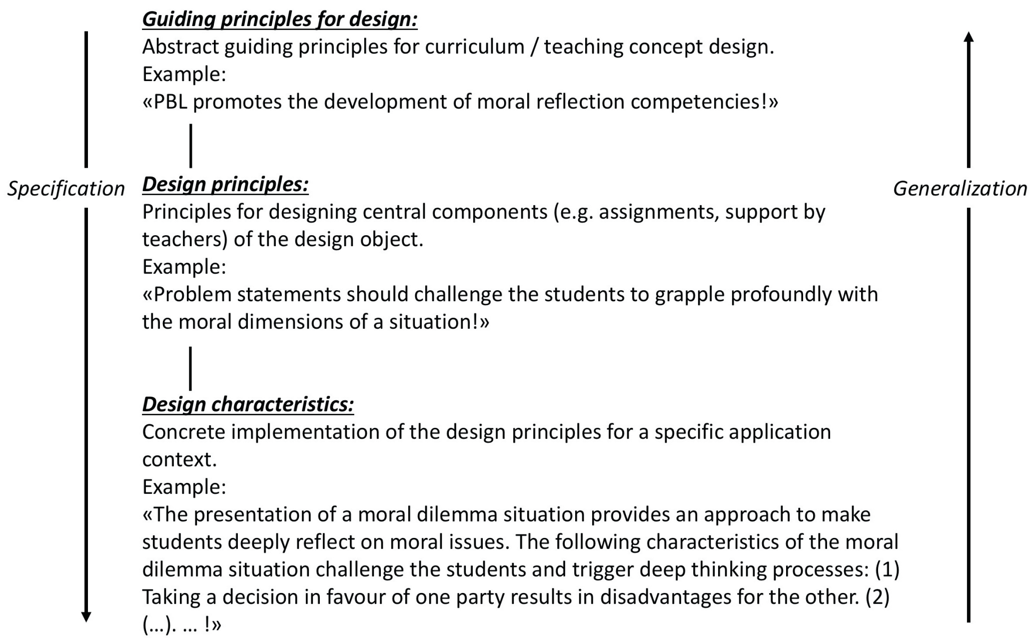


*Figure 2: Degree of concretization of design principles*

The target range and degree of concretization of a design principle formulation are in a tense relationship. While research strives towards general knowledge, the practitioner searches for concrete instructions for a yet to be designed practical situation. The more abstract the formulation of the principle, the higher the range, but also the more indeterminate the practical action instructions. Conversely: The more specific the principle formulation, the lower the range, and the more definite the practical action instructions. This relationship can be illustrated by means of the example introduced in Section 3.1.

While the first level of abstract guiding principles moves towards the claim of general theories, the third level of implementation approaches the unique individual case. Concrete design principles are found between these poles in the sense of a medium degree of abstraction.

There is also some latitude for the presentation of design principles within the second level, because concretization or abstraction presents relative terms that are not absolutely defined, but can only be illustrated with examples. Positive examples for formulating concrete design principles are already described in Section 3.1. They are thus described as specific teaching and learning activities that should substantiate the fostering of identified goals (e.g. moral reflection competencies) in a certain context ("secondary school"). These determine the three basic components of a design principle: In which context will which teaching/learning activities contribute to the fostering of which goals?

Conversely, in order to establish design principles, the following three examples illustrate that statements, often referred to as „principle," are not sufficiently precise:

- Piaget determined the principles of assimilation and accommodation as supporting principles of cognitive learning (Euler & Hahn, 2014, 115f.). This is about guiding principles that need to be clarified and established in concrete didactic contexts, in the sense of the outlined figure above.
- In the "cognitive apprenticeship" approach (Collins, Brown & Newman, 1989), a teaching-learning process is structured through a series of principles that introduce novices to a specialist area by means of the guidance of experts. In order to trigger corresponding learning activities in students, the principles (e.g. modeling, articulation, coaching, scaffolding, reflection, fading) describe teaching activities on a more concrete level compared to the preceding example.
- Based on his evaluation of meta-analyses, Hattie (2009) identified a total of 150 influencing factors on different abstraction levels, which influence learning with varying effect size. Hattie partially summarizes the substrate of knowledge in the form of principles where he uses "strategies," "big ideas," or "signposts" beside the term "principles" (see e.g. Hattie, 2012, 113ff.) He, for example, identifies "feedback" as a principle to foster learning (2012, 129ff.), but it remains unclear which of the numerous characteristic variations is meant for

which objectives. In this sense, the presentation of empirical "findings" remains open, because no links are drawn to the assumed consequences or effects.

## 4.0 Development of design principles

The development of design principles is embedded in the overall DBR process. The following overview outlines the principal flow of this process and describes each of the aspired results for the individual process phases (Euler, 2014):

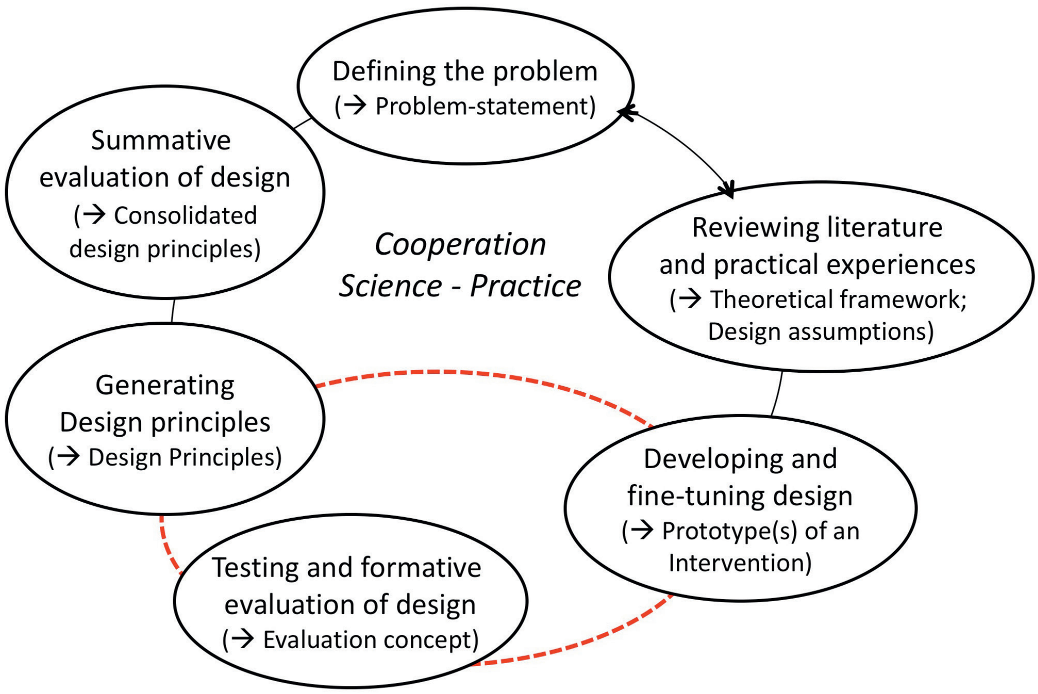


*Figure 3: Phases of a DBR process*

The research and development process takes place in repeated cycles of design development, testing, evaluation, and re-design. The design is progressively optimized within these cycles and the design principles are simultaneously evaluated and, if necessary, revised. „One of the distinctive characteristics of the design experiment methodology is that the research team deepens its understanding of the phenomenon under investigation while the experiment is in progress." (Cobb et al., 2003, 12)

Within the process, design principles initially constitute the result of the theoretical foundation. Interventions are refined and broadened in the development, testing, and evaluation context, in order to present a state of knowledge, after completion of the development cycles, which may be subjected to a summative evaluation. The phases of the DBR process are illustrated by the example introduced in Section 3.1 to further explore the development of design principles in this context.

In addition to the designated central research question ("How can appropriate forms or versions of problem-based learning develop the moral reflection competencies of students in a secondary school?"), the following aspects need to be clarified in the context of precise problem statements:

- The practical and scientific relevance of the key research questions.
- The organizational and social contextual conditions in the selected practice field („economics course lessons in secondary schools“).
- The (provisional) assumptions about the students and teachers’ prerequisites.
- Forms of cooperation between science and practice.

Initially, the evaluation of the available scientific literature and practice experience serves to improve the understanding of the key research question and, as a result, to develop a research-structuring frame of reference. Explorative interviews with relevant stakeholders from practice can, in addition to the literature analysis, support this step. An appropriate frame of reference might look like this:

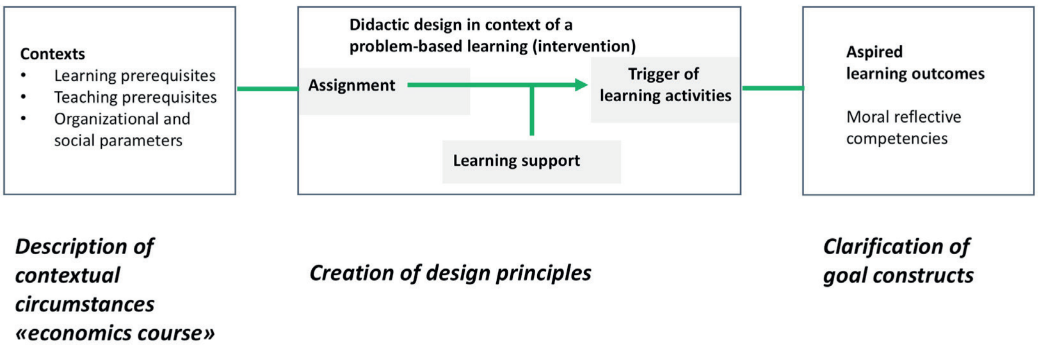


*Figure 4: Didactic frame of reference for the development of design principles*

The frame of reference models the relationships of a teaching situation in the practice field. In the context of problem-based learning, students deal with appropriate tasks. These should trigger learning activities that lead directly or indirectly to the achievement of the aspired learning outcome („moral reflection competencies“). Indirectly triggered learning activities are, for example, those that awaken an interest in a deeper task processing, guide the search for relevant information, or encourage planning of the task processing steps. Forms of learning support can also supplement the triggering of goal-orientated learning activities. In the process, personal and material forms are distinguished, i.e. a teacher’s activities, but also support in the form of media and materials (e.g. textbooks, Internet resources). In turn, the assignments are designed by taking the identified context into account.

Within the frame of reference, design principles relate to the didactic design’s components. Initially, before the development of a first intervention, the design principles rely on the literature analysis and exploration of available practice experience. In this phase, they will not have the characteristics of proven principles, but rather those of untested hypotheses, and can therefore be described as design assumptions (Raatz, 2015, 25). Accordingly, they are often not very concrete. They have two functions in the subsequent research and development processes: (1) They describe the central components that need to be implemented in the development of the first intervention. (2) They define the objects that need to be evaluated in the context of the upcoming testing.

The path from design assumptions to design principles follows specific testing and evaluation steps. This area in DBR research could be described "as a patient and simultaneously economic experimenting..., where the researcher understands the importance of being surprised." (Oelkers, 2014, 91; own translation). The evaluation methods for the respective design aspects are determined for each testing cycle.

A didactic design is evaluated in various phases with different focal points (McKenney & Reeves, 2012, 136ff.). In the alpha phase, the evaluation of internal coherence and design consistency, as well as the practical implementation, are primarily in the foreground. Within the context of a "developer screening," it is possible to test whether the design assumptions are adequately realized, the design decisions are sufficiently motivated, and the design can be implemented within the assumed contextual conditions. These questions can, amongst others, be explored by means of expert interviews, focus group interviews, or checklist analyses. The evaluation's focus of identifying possible design optimizations lies in the beta phase. Here, for example, are the expected and unexpected activities that the students and teachers show with respect to specific design features of interest. Alternatively, contextual conditions that affect the learning processes become apparent, and should thus be given greater consideration. The methodological considerations during this phase are, amongst others, (video-based, participating) classroom observations, oral and written interviews of the persons involved, analysis of the students' work resulting from the lessons, and reflective reports by the students. In the following gamma phase, the focus is on the investigation of the effectiveness and impact of design in terms of the aspired goals. Owing to the usually small sample and the lack of a control group, the validity of the results remains limited. Nevertheless, further evidence to improve and stabilize the design could be obtained.

Based on the above outlined frame of reference, the evaluation in the beta phase can, for example, focus on the question of which learning activities the assignments trigger. The result could show that students only evaluate individual tasks as moderately challenging. It further shows that teachers use moral dilemma situations in assignments not as a starting point of the learning process, but as an example to practice or consolidate theories that they deductively conveyed beforehand. As a result, the students' cognitive activities of comprehending the conveyed theories remain limited, the problem situation is (too) well structured, and rather too simplistically introduced. Accordingly, the students' interest, as well as their cognitive processing depth, remains limited.

Two significant consequences can be drawn for the next testing cycle from such evaluation findings: From a practical point of view, the design needs to include appropriate instructions for the teachers to ensure that assignments are used as a trigger for a problem-solving process and does not function as an illustration or exercise. The formulations introduced in Section 3.1 can be modified in two aspects to develop design principles:

- Principle 5 could be refined, for example, as: "In the context of an inductive teaching strategy, students should independently analyze and deal with problem statements to trigger cognitive activity and a high processing depth."
- A further principle could be added to principles 5 and 6: "Problem statements should be used as a trigger for a problem-solving process where the necessary knowledge is not introduced beforehand, but inductively generated during problem solving. Thereby, the interest in the topic grows and this leads to a more profound grappling with the problem's moral dimensions."

## 5.0 Summary

The educational science literature has, for many years, controversially discussed the relationship between scientific knowledge production and practice design. Even if, in principle, there is consensus that educational research is relevant for educational practice, there is no consensus on how this relevance postulate should be realized.

DBR offers an approach for interlinking the two action focal points. In a development, testing and evaluation process of innovative practice concepts, area-specific theories should emerge in the form of design principles. Starting with a key research question, design principles initially constitute the result of an evaluation of the relevant literature, and a first exploration of the corresponding practice field in the sense of the first design assumptions. In the course of the research process, the principles are refined and extended, if necessary, via specific testing and evaluation steps.

Although design principles go beyond the scope of a unique individual case, they remain limited in their generalization range, as well as in the degree of the abstraction of the statements, in the context of the respective testing fields.

In DBR research practice, the question is still open regarding how design principles should be formulated more concretely. Within the formulation of the design principles, it is proposed that the description of the respective action should be linked to suggestions about the expected consequences or effects, as well as the aspired (sub)goals (see the examples in Section 3.1). In this way, design principles can also contribute to the structuring of a stringent means-end reasoning.

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