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Investigating Student Interest in the Context of Problem-based Learning
A Design-based Research Study

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Abstract

This dissertation investigates motivation in the context of problem-based learning. It seeks to align the agenda of advancing motivational theories with using research to make a difference in classrooms. Specifically, its two major aims are (1) to investigate and improve the motivating potential of problem-based learning (PBL) environments in K-12 settings and (2) to empirically advance interest theory in the context of PBL. The dissertation includes five empirical studies which are guided by a design-based research approach. The approach blends a theory-driven design process of a particular intervention with empirical educational research. For this research, teachers and researchers cooperated in the iterative development of a PBL intervention around the topic of energy supply. Together the studies of the dissertation provide an in-depth analysis of how students' *interest* and their perception of *value* emerge and change in relation to the PBL intervention. Data are derived from student self-reports during three implementations of different version of the intervention in K-12 classrooms. The statistical analyses rely on multiple analyses of variance as well as on longitudinal structural equation modeling. Additional qualitative data are analyzed using content analysis. The dissertation comprises three individual manuscripts. In *manuscript I* a prototype version of the intervention is compared to an improved re-design version in a quasi-experimental study. Pre-post assessment results show that a clear alignment of the intervention design with a standardized PBL model is important for fostering students' appreciation of the value of science. Drawing on interest theory, *manuscript II* further investigated the individual activities of the redesign version. Results show that students' situational interest to a large extent contains the influence of individual activities. Drawing on an integrated framework of interest theory and self-determination theory, *manuscript III* further shows that the influence of individual activities on situational interest is mediated by students' satisfaction of the basic psychological needs. Together, the findings cumulated in this dissertation demonstrate the influence of individual PBL activities on student's interest and value. They also highlight the dynamics of motivation-in-context experiences for the motivational frameworks considered. Besides, the research identifies specific affordances of these activities which foster students' interest thereby extending the empirical basis for the motivational design of PBL environments.

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1. Introduction

1.1 Research rationale: A dual agenda

This dissertation pursues a dual agenda. Its two major aims are (1) to investigate and improve the motivating potential of problem-based learning (PBL) environments and (2) to empirically advance interest theory in the context of PBL. This dual agenda locates the present research in the realm of use-inspired basic research (Stokes, 1997) that seeks to combine the two goals of advancing scientific understanding and promoting practical utility of research in a *single* research program. The aims of this dissertation constitute a response to recent calls from motivational researchers in the field of teaching and learning to align the agenda of advancing motivational theories with using research to make a difference in classrooms (Kaplan, Katz, & Flum, 2012; Pintrich, 2003; Turner, 2010; Urda & Turner, 2005). To promote this aim, researchers suggested amplifying efforts of investigating motivation in ecological contexts. This so-called ‘person-in-context’ approach to motivation (Pintrich, 2003) emphasizes to conduct research on how individual and contextual factors *jointly combine* to shape students’ motivation and learning (Tsai, Kunter, Lütcke, Trautwein, & Ryan, 2008; Turner et al., 2014; Turner & Patrick, 2008). Ideally, this research yields both, a deeper scientific understanding of motivation in context, and useful applications to improve learning and education (Greeno, 1998; Pintrich, 2003; Wentzel & Wigfield, 2007).

Motivation as an energizer of task-related behavior is most relevant in every teaching and learning context (Schunk, Pintrich, & Meece, 2003; Wentzel & Wigfield, 2009). The choice of PBL as an appropriate context for this research generally owes to its increasing popularity and its pivotal role in developing 21st century skills such as problem-solving and self-directed learning (e.g. Hung, 2009, PISA 2012). PBL is an instructional design approach that provides learners with authentic problem solving experiences to promote their competence and flexibility in tackling non-routine, real-world problems (Hmelo-Silver, 2004; Schmidt, Van der Molen, Te Winkel, & Wijnen, 2009; Walker & Leary, 2009). As 21st century citizens, people are faced with these problems every day and their capacity to successfully approach and solve them is crucial for their development in various arenas throughout the lifespan (PISA 2012). Beyond the general and increasing importance of PBL in education, the present research focuses on PBL as a context for research on motivation for two major reasons directly related to the issue of motivation:

First, there is a strong assumption that instruction based on PBL, due to its context-based and student-centered character, fosters learners’ intrinsic motivation (Hmelo-Silver, 2004; Norman & Schmidt, 1992; Reinmann & Mandl, 2006; Wijnia, Loyens, & Derous, 2011). Thus, PBL may help to address crucial motivational challenges in education. One major challenge, for instance, is presently given by the ongoing quest to turn around

downward trends of K-12 students' interest development particularly in STEM subjects (e.g. Krapp & Prenzel, 2011). Previous research on PBL, however, has predominately focused on the field of medical education as well as on cognitive and skill-based outcomes. Consequently, recent meta-analyses on PBL do not include motivational variables (e.g. Gijbels, Dochy, Van den Bossche, & Segers, 2005; Walker & Leary, 2009). Moreover, recent empirical research on PBL has called its motivating potential into question as studies revealed lower levels of motivation for PBL than for conventional instruction (e.g. Schuman, 2010; Wijnia, Loyens, & Derous, 2011; Wouters, Nimwegen, Van Oostendorp, & Van Der Spek, 2013). As PBL might be particularly challenging for K-12 students, who are still rarely engaged in PBL (Ertmer & Simons, 2006, Seidel, 2011), there is a clear need for research on students' motivation in the context of PBL (Palmer, 2005, 2009; Stark & Mandl, 2000). The present research, therefore, seeks to investigate the potential of PBL in fostering K-12 students' value perceptions and interest in order to further inform the motivational design of PBL (Belland, Kim, & Hannafin, 2013) for this particular learner population.

Second, PBL represents an excellent paradigm for the study of motivation in context. According to Turner and Patrick (2008), research on motivation to learn may gain the most from investigating change and development of motivation in real-life learning environments. At the same time, however, this kind of research is particularly challenging with regard to research methodology and resources (Turner et al., 2014). These challenges arise from facing the full complexity of real-life classroom learning across time. PBL represents a real-life learning environment that typically consists of a problem and a set of problem-solving activities. Although the PBL context, that is the PBL environment learners interact and operate in, is still quite complex (including e.g. different tasks, leaning activities, social interaction processes etc.), it yet constitutes a rather controlled longitudinal sequence of activities. The systematic variations of the context provided by these activities seems to provide a more manageable and yet rewarding platform to investigate changes within and between individuals on various motivational variables across time (Tsai et al., 2008). Empirical information on the affordances and constraints of the different activities and their active psychological features can be used to explain *how* students' motivation develops and *why*, and thus help to advance the scientific understanding of motivation in context. Recently, researchers have suggested interest theory and current models of interest development (Hidi & Renninger, 2006; Renninger & Hidi, 2011) as a promising framework for research on motivation in PBL (e.g. Palmer, 2008, 2009; Rotgans & Schmidt, 2011a, 2014). In this respect, situational interest is a crucial motivational variable for learning and instruction as it provides an indication that learners start building connections to the educational content they are presently dealing with, both, on affective and cognitive terms (Renninger & Su, 2012).

Provided that SI is further supported, this connection may strengthen and develop into more enduring forms of interest as well as it may help to promote knowledge acquisition and skill development (Hidi & Renninger, 2006; Krapp, 2002). Recent studies on interest development during PBL (Rotgans & Schmidt, 2011a, 2011b, 2014), for example, have yielded important insights into how and why interest develops during PBL, which also refined the theoretical understanding of interest as an important psychological variable. The present study seeks to extend this research by providing an in-depth analysis of student interest development during PBL based on integrated motivational frameworks (Krapp, 2005), advanced statistical methods (Little, 2013; Steyer, Schmitt, & Eid, 1999) and a mixed method approach (Tashakkori & Teddlie, 1998).

To optimally support the two aims elaborated above, design-based research is selected as research strategy to guide the empirical investigations of this dissertation. The following section will present a short outline of the approach, as design-based research is still rarely used in educational research (Anderson & Shattuck, 2012).

1.2 Research strategy: Design-based research

A research approach which supports the dual agenda outlined above is the emerging method of design-based research (Anderson & Shattuck, 2012; Kelly, Baek, & Lesh, 2008). Design-based research blends empirical research on learning and the design of educational interventions (Design-based Research Collective, 2003). It is therefore theoretical as well as pragmatic in orientation (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003). The simultaneous pursuit of theoretical goals differentiates design-based research from formative evaluation (Barab & Squire, 2004) and makes it a prototypical research strategy for conducting use-inspired basic research (Fischer, Waibel, & Wecker, 2005). Design-based research processes are based on collaboration among researchers and practitioners and focus on the iterative development of a particular artifact or intervention design (Wang & Hannafin, 2005). This iterative process consists of “continuous cycles of design, enactment, analysis and redesign” (Design-based Research Collective, 2003, p.5.). In a spiral fashion, outcomes from previous cycles inform design and research in the next cycle (Collins, Joseph, & Bielaczyc, 2004). As a consequence, design researchers have to remain flexible and make changes and adjustments, revising both intervention and theory along the way (Joseph, 2004). In effect, this process leads to a co-evolution of the intervention design and the research design (Allert & Richter, 2011). Design-based research processes serve a *practical* as well as a *theoretical* purpose.

The *practical purpose* of design-based research is to develop and improve an intervention to address a relevant problem by providing an effective design solution (Razzouk

& Shute, 2012). In the present research, the problem space is defined as a well-documented lack of K-12 students' intrinsic motivation in terms of interest and value particularly for STEM subjects (e.g. Frenzel et al., 2011, Krapp & Prenzel, 2011). Interventions based on PBL design are assumed to be an effective way to address this issue as they provide opportunities for students to experience the value of what they are learning (Brophy, 1999, 2008; Hofer, 2010). An iteratively optimized intervention may thus help to address the problem and yield more information on effective design principles for PBL learning environments and motivational scaffolds. The *theoretical purpose* of design-based research is to utilize the intervention and the empirical information gained from its implementation to advance research and theory development (Shavelson, Phillips, Towne, & Feuer, 2003). In the present research, the theoretical purpose is to further test assumptions underlying models of interest development (Hidi & Renninger, 2006). As outlined above, the context of PBL provides an appropriate platform for this research. In the following two sections, the two aims of advancing interest theory and improving the motivational potential of PBL are presented in the context of related theory and recent research, which affords the development of specific research questions.

1.3 Aim 1: Improving the motivating potential of PBL

The first aim of this dissertation is to investigate and improve the motivating potential of PBL. The purpose of this section is, first, to define the instructional framework of PBL for the purpose of this research. Second, on the basis of previous research, this section identifies a specific and significant question that will initially guide the present research.

Problem-based learning has been defined “an instructional method that initiates students' learning by creating a need to solve an authentic problem” (Hung, Jonassen, & Liu, 2008; p.486). Moving the problem upfront is what mainly distinguishes PBL from traditional, direct instructional approaches. PBL, thus, flips the traditional didactic sequence of presenting learning content first and possible contexts for application and practice later (Gräsel, 2006). Hence, the PBL learning process starts with problems and not with content. By definition, these problems are ill-structured, real-world problems which lack a single correct solution (Hmelo-Silver, 2004). PBL connects the contextualization of content (through a problem) with a specific activity structure. In order to solve the problem, students go through a series of activities in small collaborative groups supported by a tutor. PBL comes in a variety of forms but models typically include the following activities: (i) Students define the problem; (ii) they ascertain what they already know, (iii) in order to determine what they need to find out to solve the problem. (iv) They engage in inquiry to find relevant information and (v) they synthesize the information to create a solution. (vi) Finally, they present and discuss their

solutions, and (vii) reflect on what they learned and the effectiveness of their strategies (Belland et al., 2013; Torp & Sage, 2002). According to Van Merriënboer and Kirschner (2012), a prototypical example for a PBL design model is the STAR.Legacy model (Cognition and Technology Group at Vanderbilt: Schwartz, Lin, Brophy & Bransford, 1999). STAR.Legacy provides a flexible framework for PBL design to scaffold student learning, which can be applied in a wide variety of ways across topics and courses. It organizes PBL activities in a clear sequence¹. The key issue that goes to the heart of STAR.Legacy is its cyclic character. Learners can deepen their understanding of a complex issue by repeatedly going through the activities facing ever more complex problems (challenges) related to this issue. Van Merriënboer, Kirschner, and Kester (2003) refer to this scaffolding strategy as simple-to-complex-sequencing, which is designed to reduce the high cognitive demands of PBL that would otherwise impede learning. This holistic design approach allows the design to support another distinctive feature of PBL, namely to retain the full, real-world complexity of the issue by scaffolding learners to acquire the intended complex knowledge and skills (van Merriënboer & Kirschner, 2012). Students' engagement in PBL activities is intended to yield a characteristic set of learning outcomes. According to Hmelo-Silver (2004) the intended outcomes of PBL for students are to support their acquisition (1) of flexible knowledge, (2) of effective problem-solving skills, (3) of self-directed learning skills, (4) of effective collaboration skills, and (5) their development of intrinsic motivation.

Related to this final goal, the question of whether PBL does indeed foster intrinsic motivation has recently spurred some research attention and debate, as research has repeatedly failed to support this conjecture (e.g. Schumann, 2010; Wijnia et al. 2011; Wouters et al., 2013). Further significance for this question arises in particular for the K-12 student population. This significance and the underlying reasoning are best illustrated by the following statement by Jere Brophy taken from his article "Developing Students' Appreciation for What is Taught in School" (Brophy, 2008):

"The learning of reading, writing, swimming, or other basic skills has obvious utility to almost everyone, including most primary grade students. However, as John Dewey and others have pointed out, most K-12 content has originated as practical knowledge derived through situational problem solving, but as it got systematized within what became the disciplines, it got formulated more abstractly and separated from its situated origins. Consequently, for much of what we teach at school,

¹ Star.Legacy activities widely match the seven consecutive activities described earlier in this section. For a detailed description of the model please consider reading: Schwartz, D. L., Lin, X., Brophy, S., & Bransford, J.D. (1999). Toward the development of flexibly adaptive instructional designs. In C.M. Reigeluth (Ed.), *Instructional design theories and models*. (Vol. 2; pp. 183-214). Hillsdale, NJ : Erlbaum.

especially the more abstract content and higher order processes, the reasons for learning it are not obvious to students, and sometimes not even to teachers.” (Brophy, 2008, p.134)

Contrary to recent findings, Brophy argues, that instructional methods such as PBL might be the most effective way to support student motivation on a K-12 level as these link content to relevant contexts and involve students in problem-solving. This combination might provide the strongest support for their motivation, as value is the motivational force that they currently lack most (Brophy, 1999, 2008; Hulleman & Harackiewicz, 2010).

A few lines of theory and related research have explicitly addressed the issue of value. Among these are *expectancy x value* theory (Eccles, 2009; Wigfield & Eccles, 2000), which construes motivation as a function of expectancy and value beliefs, and interest theory, which construes motivation as a result of a person’s affective-evaluative relation with some specific content (Hidi & Renninger, 2006; Krapp, 2002). Empirical research on interest and value generally supports parts of Brophy’s assertion and has yielded abundant evidence of declining academic interest and related variables during K-12 education, particularly in the context of STEM subjects (STEM: Science, Technology, Mathematics) (Daniels, 2008; Frenzel, Dicke, Pekrun, & Götz, 2012; Hoffmann, Häußler, & Lehrke, 1998; Köller, Baumert, & Schnabel, 2001; Spinath & Steinmayr, 2008). The prime reason for this downward trend, according to Brophy’s analysis, lies in the fact that the school environment falls short in providing support, as it has gradually separated K-12 content from the context in which this content might have appeared useful to students. Consequently, one way in which students could be supported in their perception of value and development of interest might thus be to change the design of learning environments (Renninger & Su, 2012). In order to be more motivating, the design would need to connect K-12 content in math, physics, biology and other subjects to its situated origins and engage students in related problem-solving activities.

Empirical support for this assumption might come from research on learning environments, such as PBL, which anchor or situate specific instructional content in relevant contexts (Aikenhead, 2006; Cognition and Technology Group at Vanderbilt, 1997; Hickey, 1997; Krapp & Prenzel, 2011; Parchmann, Gräsel, Baer, Nentwig, Demuth, & Ralle, 2006). The underlying assumption of these instructional designs is that through the simultaneous presentation of abstract instructional content *and* context related to students’ lives, the value of the content may become more discernible to students (Cordova & Lepper, 1996). It is assumed that when students are appropriately engaged with contextualized content, they will acquire so-called conditional knowledge (Brophy, 1999, 2008) referring to the fact that students know when, where and why they can use particular content and thus might be more likely to apprehend its value (Geary, 2009). Previous research on the motivational processes and effects of context-based designs, in general, and of PBL in specific, is scarce for K-12

settings and has yielded mixed results. Empirical research in science education, for example, described positive trajectories as well stability or decrease in students attitudes towards science in relation to context-based interventions (e.g. Bennett, Lubben, & Hogarth, 2007; Sadler, 2009). A major limitation of many of these studies, however, is that the evaluation design is not closely aligned with theoretical motivational frameworks, and that in many cases measurement instruments were developed specifically for a single study (Bennett et al., 2007; Krapp & Prenzel, 2011; Stark & Mandl, 2000). Further, research efforts in the realm of PBL have mainly concentrated on the field of medical education and most of these studies compared curriculum-level outcomes of PBL with conventional approaches, usually on a measure of knowledge (e.g. Schmidt et al., 2009). Consequently, the population of K-12 students and PBL's goal of fostering intrinsic motivation have received very limited attention. The scarce research on motivation in PBL has generally questioned the assumption that PBL presents a surefire method to support motivation (Belland et al., 2013; Schumann, 2010; Wijnia, et al., 2011; Wouters et al., 2012). Moreover, given the dominant culture of teacher-centered approaches to instruction in K-12 education (Seidel, 2011), researchers have argued, that this learner population in particular might be ill-equipped for the various challenges of PBL and therefore experience lower levels of motivation (Ertmer & Simons, 2006; Palmer, 2005, 2009; Sawyer, 2006). Thus, the present research investigates the significant question whether PBL environments support students' value perception in K-12 settings (research question 1).

Research Question 1: Do problem-based learning environments foster students' perceptions of value in K-12 settings?

1.4 Aim 2: Advancing interest theory in the context of PBL

The second aim of this dissertation is to empirically advance interest theory. The PBL context with its clear longitudinal structure of activities provides an excellent paradigm to investigate important assumptions of interest theory concerning the development of interest (Rotgans & Schmidt, 2011a, 2011b, 2014). This investigation seeks to contribute important insights concerning the underlying motivational processes of PBL and therefore to further support the understanding and improvement of PBL's motivating potential (aim 1). The purpose of this section is to provide a short outline of current theoretical conceptualizations of interest development and related research on situational interest in order to derive significant questions for the advancement of theory, but also for educational practice.

Theoretical conceptions of interest define the construct in terms of several important characteristics (Hidi & Renninger, 2006; Krapp 2002). First, interest is a distinct motivational variable, especially because it is content or object specific. Interested people are always interested in something. This 'something' may be a topic, an activity, or a school subject etc.

Interest thus constitutes a specific relationship of a person towards an object. By definition, people derive their motivation from the interaction with their interest object and not from some external consequence. Interest therefore represents an object-specific form of intrinsic motivation. Second, this relationship is characterized through affective as well as cognitive components; as such, people hold varying amounts of affect, knowledge or value for the objects of their interest. And third, interest is a dynamic variable, which develops through a person's interaction with the object it relates to. A recent framework (Hidi & Renninger, 2006: Four-Phase Model of Interest Development) describes this development in terms of four consecutive phases: 1. triggered situational interest, 2. maintained situational interest, 3. emerging individual interest, and 4. well-developed individual interest. The two initial phases are located on the level of a specific situation and together are referred to as 'situational interest' (SI). In a first phase, when a learner's SI is triggered (also called Catch-Phase), interest is experienced as focused attention accompanied by a positive emotional tone. During the subsequent second phase, when learner's SI is maintained (also called Hold-Phase), they perceive a sense of value (for the object) and a desire or intention to seek further knowledge (Lewalter & Knogler, 2014; Renninger & Su, 2012). The two following phases are located on a permanent level and together are referred to as 'individual interest'. Emerging individual interest represents the beginning of a relatively enduring predisposition to reengage with a particular class of objects over time. This reengagement is associated with increased levels of stored value, positive feelings, and usually results in increased knowledge or competence. Well-developed individual interest mainly differs from the previous phase in the sense that the strength of the relationship has grown stronger over time and people in this phase more actively pursue their interest.

A fundamental proposition of the Four-Phase model concerns the distinction between situational interest and individual interest (Schiefele, 2009). By definition, SI is considered a transient state variable which is predominantly influenced by the immediate environment or context. Individual interest, in contrast, is considered a trait variable expressing a high level of identification between a person and some content, and thus a strong relationship, which is less susceptible to contextual influences. Longitudinal studies recently investigated the stability of SI across time and its relation to individual interest. Their results indicated relatively high levels of longitudinal stability (e.g. Fulmer & Tulis, 2013; Rotgans & Schmidt, 2011a) as well as a substantial influence of individual interest in their measurements of SI (e.g. Linnenbrink-Garcia, Patall, & Messersmith, 2012; Tsai et al., 2008). These findings are not line with the theoretical definition of SI as a situation-specific, transient state that is mainly influenced by contextual factors (Hidi & Renninger, 2006). They rather signal that the investigated state (referred to as SI) is to a substantial extent an expression of a latent disposition (individual

interest) activated in the situation. Interest research, however, refers to this state as ‘actualized individual interest’ (Ainley, 2006; Krapp, 2002) or as ‘individual interest’ (Hidi & Renninger, 2006). Thus, depending on the source of influence (situation or person factor) the psychological state of interest is either conceived as SI or as individual interest. Research, so far, however has not investigated the relative influence of these two general factors across different situations (Tsai, et al., 2008). Thus, more research is needed to determine the relative influences of situation and person factors in order to validate the theoretical conception of SI as a situational construct (research question 2). At the same time, this research is relevant for educational practice because it helps to unravel the underlying processes of what influences SI during learning and to what extent this is a result of the design of the learning environment (situation) or related learner characteristics (person).

Research Question 2: What are the relative influences of person and situation factors on situational interest during PBL?

Moreover, a further (non-correlational) indication for the situational and malleable character of SI comes from longitudinal investigations of students’ group means. Here, student-centered learning environments (inquiry learning, project-based learning & PBL), which all provide sequences of different activities, are assumed yielding significant mean changes as students may perceive some activities as more interesting than others. This assumption has recently been supported by empirical studies in student-centered learning environments which applied a longitudinal repeated measurement approach (Holstermann, Ainley, Grube, Roick, & Bögeholz, 2012; Minnaert, Boekaerts, & DeBrabander, 2007; Minnaert, Boekarts, DeBrabander, & Opdenakker, 2011; Palmer, 2009; Rotgans & Schmidt, 2011a, 2014; Schmidt, Rotgans, & HJ Yew, 2011). Across all studies, student means varied as a function of the different activities. According to Towne and Shavelson (2002) scientific research in education is advanced when researchers seek to replicate and extend findings. Thus, it is important to further extend the empirical basis for the situational character of SI by investigating SI mean trajectories during PBL (research question 3). These findings also carry important implications for improving the motivational potential of PBL as they provide more nuanced feedback on the motivational appeal of *individual* activities.

Research Question 3: What are the developmental trajectories of students’ situational interest during PBL?

Moreover, it is crucial for interest theory as well as for educational practice to explain the emergence and change of SI during learning events (e.g. Rotgans & Schmidt, 2014). This

is important for the scientific understanding of underlying mechanisms as well as for identifying effective leverage points to improve PBL designs. Previous research has focused on knowledge-based explanations of SI development during PBL (Rotgans & Schmidt, 2011a, 2014). This research has yielded evidence that SI as a motivational concept reflects a motivational response to a problem-induced need-to-know. Students experience this problem-induced need when confronted with a problem they cannot solve on the basis of their prior knowledge. Complementary to this knowledge-based explanation, there is also the assumption that students SI is associated with the satisfaction of already existing innate psychological needs. These assumptions are based on a theoretical framework proposed by Krapp (2002, 2005) which connects cognitive-evaluation theory (a sub-theory within self-determination theory) (Ryan & Deci, 2000) and interest theory. Research on cognitive-evaluation theory has specified conditions that facilitate the development of intrinsic motivation in terms of the satisfaction of the three basic psychological needs for autonomy, competence and relatedness (Deci & Ryan, 2002). Within Krapp's (2005) integrative framework, learner's satisfaction of these basic psychological needs is assumed to have a positive effect on interest as content-specific form of intrinsic motivation. Previous research has investigated this assumption, and revealed both, a high level of need satisfaction during the learning event and a significant influence of this satisfaction on SI during collaborative project-based learning (Minnaert et al., 2007, 2011).

Based on these findings, further research is needed, first, to clarify to what extent the different PBL activities satisfy students basic needs (research question 4a) and, second, whether this has an influence on students' SI (research question 4b). On a practical level, this may yield important information on how to sustain high levels of SI during PBL by addressing students' needs. On a theoretical level, the integration of the two theories (interest theory and cognitive-evaluation theory) supports the advancement of the current agenda of motivational science. A major present goal in motivational research is to integrate across motivational theories and psychological models of motivation to reduce the overlap between theoretical concepts in order to arrive at more parsimonious models for explaining motivated behavior (e.g. Locke & Latham, 2002; Pintrich, 2002; Ryan, 2012).

Research Question 4 A: What are the developmental trajectories of the basic psychological needs for autonomy, competence and relatedness during PBL?

Research Question 4 B: How is the satisfaction of the basic psychological needs for autonomy, competence and relatedness associated with situational interest at different PBL activities?

1.5 The present research

The studies of this dissertation investigate students' interest and value perceptions in the context of problem-based learning. This is particularly important for K-12 education as there is abundant evidence that students' interest and sense of value gradually decrease as they progress through the grades. PBL might be an effective way to address this challenge, as it provides ill-structured, real-life problems and engaging activities, which may help students to find value and interest in what they are learning. Moreover, the context of PBL provides an excellent paradigm to investigate the development of interest and to address important questions in interest theory. By using the emerging design-based research approach, the present research addresses theoretical and practical aims in a single research program. In five empirical studies, both, intervention design and research design, are iteratively developed. The present research transcends previous efforts by providing an in-depth analysis of motivation in the context of PBL. The investigation uses a standardized model of PBL design and achieves a high ecological validity as data are derived from implementations in real-classrooms. The research draws on integrated motivational frameworks, theoretically and psychometrically sound measurement, advanced statistics and mixed-method approaches. The following five research questions are addressed to investigate student motivation during PBL.

1. Do PBL designs foster students' perceptions of value? (*Study 1 & Study 2*)
2. What are the relative influences of person and situation factors on longitudinal situational interest during PBL? (*Study 3*)
3. What are the developmental trajectories of students' situational interest during PBL? (*Study 4*)
4. A.) What are the developmental trajectories of the basic psychological needs for autonomy, competence and relatedness during PBL? (*Study 4*)

B.) How does the satisfaction of the basic psychological needs for autonomy, competence and relatedness influence situational interest during different PBL activities? (*Study 4 & Study 5*)

2. Methods

To address these research questions, the studies in this dissertation employed different methods. Table 1 presents an overview. Study 1-4 all relied on self-report questionnaire data and study 5 applied a qualitative approach based on retrospective student interviews. This dissertation realized two iterations of design. The first iteration (iteration 1) between study 1 and study 2 led to changes in the intervention design (Study1: Prototype → Study 2: Re-Design) and retained the research design (pre-post measurement). The second iteration (iteration 2) between study 2 and study 3-5 led to changes in the research design (Study 1/2: Pre-Post → Study 3/4: Process) and retained the intervention design (Re-design). This section describes in more detail which participants were investigated, which intervention designs were implemented, how motivation was measured, and how the data were statistically analyzed.

Table 1
Participants, Design, Intervention, and Statistical Methods by Study

Study	Participants	Intervention	Design	Statistical Method
Study 1	112	Prototype	Longitudinal:Pre-Post	Student's t-Test
↓ ITERATION 1				
Study 2	156	Re-design	Longitudinal:Pre-Post	Student's t-Test
↓ ITERATION 2				Multivariate Analysis of Variance
Study 3	327	Re-design	Longitudinal: Process	Confirmatory factor analysis
				Longitudinal structural equation modeling
Study 4	327	Re-design	Longitudinal: Process	Longitudinal structural equation modeling
Study 5	31	Re-design	Retrospective interviews	-

Note. Study 3 and Study 4 used the same sample. Study 5 used a subsample of this sample.

2.1 Participants

Student sample. Student participants in all studies were 9th and 10th grade students from German secondary schools ('Gymnasium'). Gymnasium is the highest track in the three-tier secondary school system in Germany; about one-third of students are enrolled in such schools based on their achievement in elementary school. The students were recruited from 25 classes from 11 different schools, whose teachers chose to participate in the study. Overall, 595

students participated in the interventions and questionnaire surveys during the years 2010, 2011 and 2012 (Table 1). Participation in the surveys was voluntary and uncompensated. 100% of target students participated. Additionally, a subsample of 31 students participated in individual retrospective interviews. Participation was voluntary and students were offered a compensation of €20. A more detailed description of student samples is provided in *manuscripts I-III*.

Teacher sample. Altogether, 16 teachers participated in the studies. This sample was based on self-selection as all teachers chose to take part in the study after attending a full-day workshop on the facilitation of PBL in general and the intervention in specific. Most teachers were science teachers ($n = 15$) and all teachers had at least five years of classroom experience.

2.2 Intervention

Design. Following a design-based research approach, teachers and researchers cooperatively developed an initial prototype version of a PBL intervention; and subsequently they developed a re-design version² in a first iteration. The individual structures of the two designs (Prototype & Re-design) are depicted in Appendix 1. The two designs confront students with the problem of energy supply and embed the curricular topic of energy and energy technology in the context of a realistic scenario. The overall task for the students in the two designs is to collectively develop an energy concept for a rural district striving to become self-reliant in meeting its energy needs. Besides, the two designs are based on the standardized PBL model STAR.Legacy (Schwartz et al., 1999) (see 1.3) and confront students with the overall task on two levels with rising complexity (Loop1: community level, Loop2: district level). As STAR.Legacy is a flexible design model, the designs added role-play components (Appendix 1). The major difference between Prototype and Re-design concerns the activity structure. The Prototype blends an initial direct instruction element with a condensed PBL element. The PBL element realizes most aspects of STAR.Legacy design, except for an extended inquiry phase during the first loop, as students had received relevant information for the following task through previous direct instruction. The Re-design is fully in line with the STAR.Legacy model. More detailed descriptions can be found in *manuscripts I & III*.

Implementation. In three consecutive years (2010, 2011, 2012), one implementation per year was realized. All interventions were run by course teachers. These teachers took part in a one-day facilitator training. They received an intervention manual that included detailed lesson plans and instructional material to support implementation fidelity. All interventions were implemented part-time in the course of three weeks. Trained observers checked

² This intervention received a nomination for the national German Teaching Award 2011 (Deutscher Lehrpreis) in the category “Innovative Instructional Design”

implementation fidelity with regard to adherence to critical intervention components and processes (O'Donnell, 2008). Observers were present in all classrooms throughout the interventions. Observations were based on protocol check-lists describing each activity to be conducted by teachers. Intervention fidelity was established based on a comparison between the intended intervention design and the protocol check-lists completed by observers. Achieved fidelity was excellent across interventions as protocols indicated a full adherence to the intervention as designed across different implementations.

2.3 Measurement of motivation

Quantitative trait measures. Multi-item questionnaire scales were applied to measure different dimensions of trait motivation. These measures were administered prior (T1) and after the intervention (T2) in study 1 and study 2 and prior to the intervention (T1) in study 3 and study 4. Study 1 and study 2 measured stable inter-individual differences in students' value perceptions of science for different contexts on four dimensions. These dimensions included "general value of science", "personal value of science", "topic-related value of science (for environmental issues)", "action-related value of science (for decision-making)" (Frey et al., 2006; Siegel & Ranney, 2003). Study 3 and study 4 measured stable pre-existing differences in individual interest in the topic of energy supply. All items provided four-point Likert-scales for self-rating. More detailed descriptions can be found in *manuscripts I-III*.

Quantitative state measures. Multi-item questionnaire scales were applied to measure different dimensions of state motivation at six critical occasions during the intervention. Previous research has referred to this approach as micro-analytical measurement (Pintrich, 2000; Rotgans & Schmidt, 2011, 2014). In study 3 and study 4 all state measures were administered after the following modules: *Briefing* (T2), *Inquiry I* (T3), *Role-Play I* (T4), *Debrief I* (T5), *Role-Play II* (T6), and *Debrief II* (T7). Students were asked to respond on the basis of their experiences of the preceding intervention module. The measurements included two dimensions of SI (SI-Catch & SI-Hold) (Lewalter & Knogler, 2014) and three measures indicating students' satisfaction of their basic psychological needs for autonomy, competence and relatedness (Lewalter & Willems, 2009). All items provided four-point Likert-scales for self-rating. More detailed descriptions can be found in *manuscripts II-III*.

Qualitative interviews. To investigate subjective reasons for students' interest levels during the intervention, individual retrospective interviews were conducted in a 1 to 3 week interval after the intervention. Interviews lasted between 25 and 45 min and were audio recorded. During the interview, students were given a matrix sheet with the module sequence of the intervention depicted on the horizontal axis and a four-point Likert-scale depicted on the vertical axis. Along with filling in the sheets, they were first asked to rate and then to explain

their levels of their interest-based motivation (as a proxy for SI) for each module. A more detailed description of the procedure can be found in *manuscript III*.

2.4 Strategies for data analysis

Study 1 and study 2: All quantitative data analyses were conducted using the software package SPSS 21. Missing data were due to missing responses on item-level. The missing rate was less than 3% and therefore considered as unproblematic (Graham, Cumsille, & Elek-Fisk, 2003). As students were not independently sampled but nested within classes, unconditional intra-class correlation coefficients were estimated. These were below cut-off criteria as recommended by Bickel (2007) indicating that less than five percent of explained variance was located on the group-level (ICCs < .05). The following model estimations, therefore, did not correct for non-independence of observations. Group mean differences for pre- and post-measures were investigated using Student's t-tests. Group mean differences across time and treatment condition were investigated using 2x2 mixed-model analysis of variance designs for a single dependent variable and using a 2x2 mixed-model multivariate analysis of variance design for multiple dependent variables.

Study 3 and study 4: All quantitative data analyses were conducted on a latent level using structural equation modeling based on the software package Mplus 6.11 (Muthén & Muthén, 2010). To account for missing completely at random (MCAR) data, a full information maximum likelihood procedure (FIML) was implemented. Due to the nested data structure, the “complex” option in Mplus with a robust maximum likelihood estimator (MLR) was used to obtain standard errors and fit statistics corrected for non-independence of observations in all subsequent model estimations. In study 4, longitudinal multi-state models were specified to investigate longitudinal measurement invariance (MI) of state variables and to estimate longitudinal structural correlations. Partial strict or strict factorial MI was established for all state variables following cut-off criteria by Chen (2007). To estimate stable and unstable variance components in repeated SI measurements, indicator-specific multi-state multi-trait models based on latent state-trait theory were specified following recommendations from Geiser and Lockhardt (2012). In study 5, latent neighbor change models were used to estimate difference scores between state variables from subsequent measurements. Besides, latent regression models were specified to estimate standardized regression weights for relations between exogenous variables (individual interest, basic needs) and endogenous variables (SI-Catch, SI-Hold) for all measurements. More detailed descriptions on statistical analysis can be found in *manuscripts I-III*.

Study 5: The qualitative data analysis was carried out on interview transcripts using MAXQDA 10 software. Content analysis procedures (Mayring, 2000) were implemented for

analyzing students' subjective reasons for their levels of interest-based motivation. The category system comprised seven categories including students' perception of autonomy (1a), competence (2a), relatedness (3a) and novelty (4). Following recommendations by Palmer (2009), the coding scheme also included statements that referred to a perceived lack of autonomy-support (1b), competence-support (2b) and relatedness (3b) as a reason for a lower level of interest-based motivation. Data were analyzed separately for each intervention module. A more detailed descriptions on the qualitative data analysis can be found in *manuscript III*.

3. Overview of studies

The purpose of this section is to provide an overview of the studies of this dissertation. The five studies are presented in three individual research manuscripts. After a general note on the authorship, the studies are presented with reference to the research questions and specific assumptions.

3.1 A general note on authorship

The author of this dissertation and first author of the three individual manuscripts played a leading role in the development, management and presentation of the research of this dissertation. This included the conceptualization, statistical data analysis, preparation, and publication-based presentation of the three manuscripts. A team of teachers supported the development and implementation of the interventions. The supervisor advised the origination, the preparation and the presentation of the three manuscripts. Co-authors served as partners for discussion and provided critical text reviews on the manuscripts. *Manuscript I* was published in the journal '*Psychologie in Erziehung und Unterricht*'. *Manuscript II* is currently under review in the journal '*Contemporary Educational Psychology*'. *Manuscript III* is currently under review in the journal '*Journal of Educational Psychology*'.

3.2 *Manuscript I*: Knogler, M. & Lewalter, D. (2014). Design-based Research im Naturwissenschaftlichen Unterricht: Das motivierende Potenzial situierter Lernumgebungen im Fokus. *Psychologie in Erziehung und Unterricht*, 61(1), 2-14.

In two consecutive studies, the purpose was to investigate the first research question whether context-based PBL designs foster students' value perceptions. As the core content of the intervention was the science-related issue of energy supply, the assumption was that the intervention would provide rich contexts for students to experience the value of science fostering their appreciation of the value of science (e.g. Aikenhead, 2006; Brophy, 2008; Sadler, 2009).

Study 1: To test this assumption empirically, a prototype version of an intervention was designed and implemented during 13 lessons in regular high-school classrooms (N=112 students; 38% female; mean age = 14.67 years, SD = .87). As an indication for the effectiveness of the intervention a pre-post self-report survey was employed. The questionnaire survey consisted of selected items from established instruments (Siegel & Ranney, 2003; Frey et al., 2006) and included four different value dimensions of science (general-, personal-, topic-related-, and action-related value of science). The prototype intervention consisted of two consecutive elements, blending a five-lesson direct instruction element with an eight-lesson PBL element. During the first direct instruction element, teachers offered important background information on the topic of energy supply. During the second PBL element, students were engaged in role-based tasks with the ultimate goal of having to decide on how to optimally organize the future energy supply of a fictitious rural district. Results based on pre-post mean comparisons revealed a significant and small difference only for the personal value dimension (Cohens's $d = .21$; $p < 0.05$). This finding did not confirm the above assumption.

Study 2: In line with the design-based research approach, a revised design (Re-design) was developed and implemented (N = 156; 34% female; mean age = 14.74 years, SD = 1.00). Improvement efforts were based on findings from study 1 by considering the empirical information derived from student self-reports, implementation observations and teacher suggestions as well as research literature. The resulting Re-design represented a full PBL design, as the direct instruction element of the prototype was replaced by an extended student-centered inquiry element (Appendix 1). With regard to the Re-design, significant differences on all value dimensions ($.29 < \text{Cohen's } d < .70$; $p < 0.01$) were ascertained with mean ratings being higher after than before the intervention. To further validate these findings, the two interventions were compared using a quasi-experimental 2x2 mixed factorial design (factor1: time; factor2: intervention design). A mixed-model MANOVA identified a significant overall interaction between time and intervention condition ($F(1,264) = 23.64$, $p < 0.01$, $\text{partial } \eta^2 = .08$) in favour of the Re-design. Following this overall test, four mixed-model ANOVAs on the different criteria identified significant interactions ($p < 0.01$) on three out of four criteria ($.04 < \text{partial } \eta^2 < .09$) with the exception of personal value of science. Thus, the re-design outperformed the prototype in its capacity to promote students' appreciation of the value of science on three out of four value dimensions.

Considered together, the two studies³ yielded preliminary findings in support of the assumption that PBL designs foster students' perceptions of the value of science for different

³An extended version of this study has received the 2014 Best Paper Award from the International Simulation and Gaming Association (ISAGA): Knogler, M. & Lewalter, D. (2014, July). *What makes simulation games motivating? A design-based research approach*. Paper presented at the 45th ISAGA conference, Dornbirn.

contexts. The findings indicate that the effectiveness of the design may depend on how rigorously PBL design principles are implemented. Only the full PBL design (Re-design) that included self-regulated inquiry activities was associated with positive changes.

3.3 *Manuscript II*: Knogler, M., Harackiewicz, J. M., Gegenfurtner, A., & Lewalter, D. (submitted). How situational is situational interest? Investigating the longitudinal structure of situational interest.

The purpose of this third study was to address the second research question and to investigate the longitudinal structure of SI to determine the relative influence of transient situation circumstances versus stable person influences on SI. In accordance with the Four-Phase Model of Interest Development and previous research, two assumptions were formulated (Hidi & Renninger, 2006; Tsai et al., 2008). The assumptions predicted that SI, as a transient and dynamic motivational state, (1) shows high levels of situation-specificity and (2) that substantial proportions of inter-individual variance in SI are unrelated to already existing individual interest and thus represent ‘pure’ situational influence.

To test these assumptions empirically, the longitudinal data from a third implementation of the intervention provided an excellent paradigm: Methodologically, the study provides an appropriate sample size ($N = 327$; 36% female; mean age = 14.79 years, $SD = 1.01$) and a larger number of six repeated measurements of SI following the individual modules of the intervention (T2: *Briefing*; T3: *Inquiry*; T4: *Role-play I*; T5: *Debrief I*; T6: *Role-play II*, T7: *Debrief II*). In that sense, the data were sampled following different and specified activities, the characteristics of which may provide an additional reference for the interpretation of findings. Finally, the study measured students’ initial individual interest in the overall topic of the intervention (energy supply) one week before the intervention (T1). This measure provided an indicator for individual differences in pre-existing individual interest. As recommended by previous research (Tsai et al., 2008), statistical analyses employed a latent structural equation modeling approach based on Latent State-Trait Theory (Steyer, Ferring, & Schmitt, 1992; Steyer, Schmitt, & Eid, 1999). Latent state-trait models offer a sound statistical method which allows for separating stable variance components (trait) from transient variance components (state) and measurement error variance in repeated measures. A set of preliminary confirmatory factor analyses of the repeated SI measures confirmed the two-dimensional structure of the construct for all measurement occasions. Therefore all subsequent analyses were carried out separately for each of the two construct components (SI-Catch & SI-Hold).

The results provided empirical support in favor of the two assumptions. Concerning the first assumption, the latent-state trait analyses revealed that across the six measurement

occasions between 9% and 47% (mean = 31%) of the total systematic variance in SI-Catch and between 11% and 39% (mean = 25%) in repeated SI-Hold measures were situation-specific. These proportions indicated that students' SI at the different occasions was substantially influenced by situation-specific factors. In comparison, between 27% and 53% (mean = 39%) of the total systematic variance in SI-Catch and between 29% and 42% (mean = 35%) in SI-Hold were consistent across all six measurements. These consistency proportions indicated that SI also reflected the influence of a cross-situational consistent factor exerting its influence across all PBL activities. Concerning the second assumption, the results showed that pre-existing differences in individual interest in the topic were not significantly related to any of the situation-specific variance components in SI-Catch or SI-Hold. This finding signaled that substantial proportions of SI variance were truly generated by situational factors and virtually unrelated to students' pre-existing individual interest. At the same time, moderate correlations emerged between students' initial interest in the topic and consistent variance components of both SI-Catch ($.32 < r < .43$; $p < 0.01$) and SI-Hold ($.47 < r < .57$; $p < 0.01$). Thus, the consistent components contained the influence of initial individual interest.

To summarize, this study confirmed SI as a state construct along two relevant criteria: (1) A high level of situation-specific variance, which (2) is unrelated to pre-existing individual interest. As such, it provided an estimation of the general sphere of influence of person and situation factors on SI. The following research efforts further specified these situational influences in terms of the satisfaction of the basic psychological needs and investigated their influence on SI during individual PBL activities.

3.4 Manuscript III: Knogler, M., Gröschner, A. & Lewalter, D. (submitted). Situational Interest and Basic Need Satisfaction during Problem-based Learning. A Mixed Methods Study.

The purpose of this mixed-method study was to address research questions 3 and 4. To investigate the third and the first part of the fourth research question (4a), the study analyzed the developmental trajectories of students' SI and of their basic need satisfaction across PBL activities. The assumption derived from previous studies was that students demonstrate varying mean levels of SI and basic need satisfaction as a function of different activities (e.g. Holstermann et al., 2012; Minnaert et al., 2007; Rotgans & Schmidt, 2011). To address the second part of the fourth research question (4b), the study examined the relations between students' basic need satisfaction and their SI for individual PBL activities. Drawing on the integrated framework of cognitive-evaluation theory and interest theory (Deci, 1992; Krapp, 2005), the assumption was that the basic needs differentially and uniquely influence SI during different PBL activities (Minnaert et al., 2007; 2011). To test these assumptions empirically, a

quantitative study (study 4), and a qualitative study (study 5) were combined in a mixed methods approach.

Study 4 used the same dataset as study 3 and additionally included data from repeated measurements of the basic needs for autonomy, competence and relatedness. These combined survey data were analyzed using structural equation modeling. First, latent mean levels and true change scores were derived from longitudinal latent neighbor change models that compared the latent mean levels of subsequent measurements for all variables. Second, a set of latent regression models for each of the six measurement occasions estimated the predictive effect of the basic psychological needs on the two components of SI (SI-Catch & SI-Hold). These models controlled for students' initial individual interest.

Study 5 investigated a subsample of 31 retrospective student interviews ($n = 31$; 45% female; age = 14.67 years; $SD = .98$). These students showed to be representative of the full sample in the sense that they were distributed across all courses and did not significantly differ from the full sample on any of the variables included in the data collection. The purpose of this study was to add to the quantitative investigation of magnitude relations of study 4 and to qualitatively examine ways in which the different PBL activities satisfy students' needs and how this is related to their interest-based motivation (as a proxy for SI). During the interviews, students were asked to explain and give reasons for their level of interest-based motivation for each of the different PBL activities. Transcripts of audio-recorded interviews were coded in seven categories. Six categories related to the basic psychological needs; of these, three categories indicated how students' explained a high level of interest-based motivation with a satisfaction of the individual needs. Following Palmer (2009), another three categories indicated how they explained a low level of interest-based motivation based on a lack of support of the basic needs. Moreover, with one category the study also explored students' perceptions of novelty as a source for their interest-based motivation.

The results of study 4 revealed a dynamic change pattern for the two SI components (SI-Catch & SI-Hold) (Figure 1). All change scores between subsequent SI measurements were significantly different from zero and showed varying effect sizes. The largest effect sizes (Cohen's d) were ascertained between role-plays and debriefings. These ranged between $d = -.99$ ($p < .01$) and $d = .91$ ($p < .01$) for SI-Catch and between $d = -.70$ ($p < .01$) and $d = .50$ ($p < .01$) for SI-Hold. Students' trajectories of their basic needs were less dynamic. Significant changes for autonomy occurred between *Briefing* and *Inquiry* ($d = .27$; $p < .01$) and between role-play sessions and subsequent debriefings (*Role-play I – Debrief I*: $d = -.30$; $p < .01$; *Role-play II – Debrief II*: $d = -.23$; n.s.). Further, competence ($d = .43$; $p < .01$) and relatedness ($d = .25$; $p < .01$) significantly increased between *Inquiry I* and *Role-play I*. Moreover, the analyses of latent regression estimates confirmed an incremental predictive effect of the

satisfaction of the basic need system on SI for all six measurements. The effect sizes in terms of explained true-score variance ranged between 23% and 42% in SI-Catch and between 17% and 26 % in SI-Hold after controlling for initial individual interest. The predictive patterns varied across the individual measurements. During the two initial modules (*Briefing* and *Inquiry*) students' feelings of autonomy and competence predicted both components of SI. During the two role-play sessions, especially students' sense of autonomy and relatedness were associated with students' SI. Finally, during the debriefing sessions, SI-Catch was both a function of autonomy and relatedness and SI-Hold was predicted by autonomy.

The results from study 5 underlined and extended the findings from study 4. Transcripts from 31 student interviews included 206 statements referring to the basic needs and 63 referring to the perception of novelty as subjective explanations for their interest-based motivation levels during different PBL activities. The frequency in which students referred to need-based explanations supported the association of the basic needs with interest-based motivation and thus the quantitative results of study 4. Moreover, the statements provided further insights into the correlational findings of study 4. During *Briefing*, for example, students identified both, a sense of feeling competent and a lack of competence support as having a positive or a negative influence, respectively, on their interest-based motivation. Furthermore, student explanations highlighted different ways in which one and the same underlying factor might foster interest-based motivation during different activities. During *Briefing*, for instance, students frequently referred to the novel character of the learning environment whereas during *Inquiry* and *Role-play II* they referred to the novelty aspect of new information as positively influencing their interest.

Considered together, the findings of the two studies supported the two main assumptions. Concerning the first assumption, the two SI components showed frequent and substantial mean changes across the PBL activities. This finding highlighted the transient character of SI underscoring findings from study 3. The parallel trajectories of the two SI components across time signaled that PBL activities may stimulate both, SI-Catch and SI-Hold, in a similar fashion. In line with interest theory (Hidi & Renninger, 2006), SI-Hold was more difficult to stimulate than SI-Catch. Students' satisfaction of the basic needs remained more stable across time, and students demonstrated high levels of competence and relatedness signaling that the learning environment was particularly supportive of these needs. Concerning the second assumption, the basic needs differentially and uniquely predicted SI during the individual PBL activities. The interview data showed how these correlations reflect both satisfied and non-satisfied needs (in terms of a lack of support). Finally, students frequently referred to their perceptions of novelty, providing further support for the important role of novel stimuli for the generation of interest-based motivation.

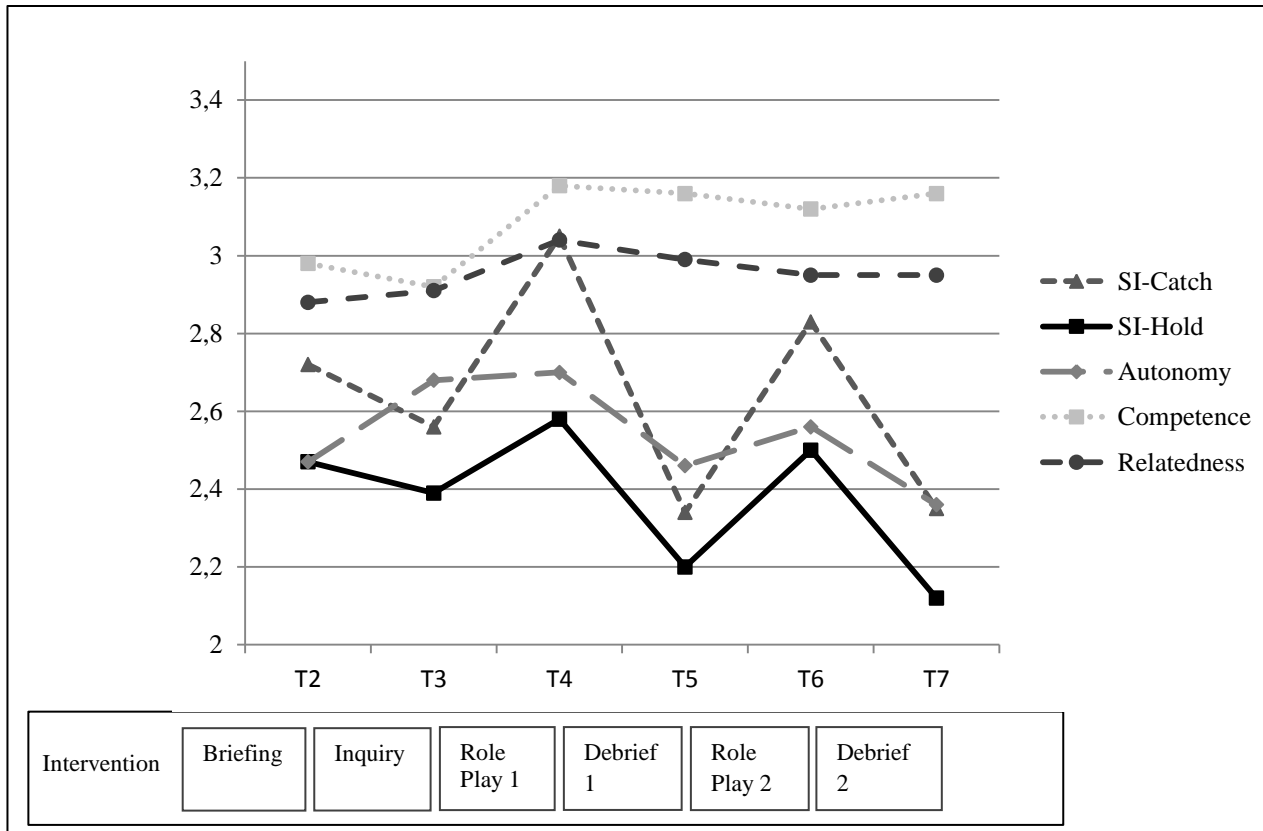


Figure 1. Latent mean levels of motivational state variables at all measurements.

4. Summary and Discussion

The aims of this dissertation were, first, to investigate and improve the motivating potential of PBL environments and second, to empirically advance interest theory in the context of PBL. The first aim carries particular importance for K-12 education as there is abundant evidence that students’ interest and sense of value for what they are learning gradually decrease during school (Eccles et al., 2003). PBL environments are assumed to be an effective tool for addressing this challenge as they feature ill-structured, real-life problems and engaging activities. Moreover, the context of PBL provides a suitable paradigm for investigating the development of interest and to address significant questions in interest theory.

To support the two aims simultaneously, the present research closely examined the relations between instructional affordances provided by PBL design and students’ internal psychological processes with regard to their development of interest and perception of value. This research construed context on the micro-level of the learning environment (Lewalter & Krapp, 2004) and used a short-term longitudinal approach for investigating motivational processes and influences of the changing conditions of the immediate surroundings. In applying a design-based approach, two different versions of a PBL intervention were iteratively devel-

oped, implemented in K-12 classrooms, and investigated in five empirical studies. The research focus changed across studies; it gradually zoomed in from a coarse analysis of the whole intervention (study 1, study 2) to a more fine-grained analysis that focused PBL as a chain of activities (study 3), and, finally, to the analysis of individual activities (study 4, study 5).

Study 1 and study 2 iteratively compared two different versions of a PBL intervention. This design-experiment yielded the finding, that the configuration of activities plays an important role for fostering students' value perceptions in a PBL context. The two interventions under investigation both contextualized curricular content; however, they provided different structures for activating students to engage with this content. The second design (study 2), which was more in line with PBL models, initially introduced students to an overall challenge as well as individual problem tasks, and engaged them in self-regulated inquiry activities for problem-solving. This structure was associated with higher gains in students' value perceptions than the first design, in which students relied on teacher-centered input for problem-solving. The quasi-experimental character of the studies, however, warrants great caution for interpreting the findings and does not support a causal relation between the design manipulation and the different change patterns. Thus, it supports the preliminary conclusion, that PBL designs are supportive of student's perception of the value of curriculum related disciplines and curricular content. Drawing on interest theory, study 3 revealed that the students adopted consistent levels of situational interest (SI) in relation to the whole PBL intervention. At the same time, they showed situation-specific fluctuations due to different PBL activities. Hence, this study highlighted the influence of individual PBL activities on student SI from a process perspective. For interest theory, it confirmed the situation-specific and susceptible character of the SI construct. Drawing on the integrated framework of cognitive evaluation theory and interest theory (Krapp, 2005), study 4 and study 5 further investigated individual PBL activities. The findings signaled, that the PBL environment continuously provides need-satisfying (basic needs, need for novelty) experiences and confirmed their predictive effect on student SI for all PBL activities.

Overall, this dissertation systematically investigated student interest in a PBL context. Based on a sequence of clearly defined PBL activities, the explanatory power of information on instructional tasks could leverage insight into motivational dynamics and help to overcome limitations of previous studies (Tsai et al., 2008). Constrained by the specifics of a certain context, these results, however, are tentative in nature, and thus require replications, modifications, and extensions to further deepen insights into motivation in a PBL context and revise preliminary conclusions. Thus, in the final sections, implications for theory development, for educational practice as well as limitations and directions for future research are discussed.

4.1 Implications for theory development

This investigation of student interest in a PBL context has several implications for the development of interest theory, the integration across theories of motivation and for an emerging motivational instructional design theory.

First, in line with the second aim, the present research provided an in-depth analysis of student interest (study 3, study 4, study 5) and yielded implications for interest theory with regard to two different perspectives on a student's state of interest (Hidi & Renninger, 2006). Within interest theory, a *situational interest perspective* emphasizes the influence of context on a learner's state of interest. It is therefore particularly relevant for education and instruction as the learning context is open to direct intervention from educators (Hidi & Harackiewicz, 2000). The present PBL design offered a varied set of intentionally designed activities. These contextual variations were associated with change in SI, both within students across time and between students across time. Analysis of within-student change, aggregated on the level of group-mean values, yielded substantial changes in SI across activities. Thus, on average, students found some activities significantly less or more interesting than other activities. Moreover, the two SI components (SI-Catch, SI-Hold) displayed a more dynamic change pattern than other state variables (basic needs). Longitudinal analysis of between-student variance (latent state-trait analysis) yielded substantial variance components influenced by situational circumstances and unrelated to individual interest. Thus, not always the same students found the activities most interesting or least interesting, but students changed their rank order positions (with regard to SI) from one activity to the next (medium rank order stability). Moreover, variance in students' SI at each of the six measurements was more associated with state measures (basic needs) than with a trait measure (individual interest). Together, these findings support a situational interest perspective and extend the empirical basis for interest research that focuses the identification of contextual sources for SI (e.g. Bergin, 1999; Schraw & Lehmann, 2001). At the same time, the findings empirically support an *individual interest perspective*. This perspective highlights the influence of learners' stable individual preferences for specific content on their state of interest across situations. Latent state-trait analysis revealed that there are substantial proportions of variance in state-interest which remain consistent under the condition of contextual variation provided by PBL. Moreover, these consistencies were associated with pre-existing differences in individual interest. This finding offers empirical support for an actualization mechanism assuming that stable individual preferences for certain content (topic of energy) exert a positive influence on student interest across situations (topic-related PBL activities) (Ainley, 2006; Krapp, 2002). As these associations were small to medium in magnitude, it follows, that it is legitimate to use trait concepts (e.g. individual interest) for explaining observed consistencies in states (e.g.

in state interest), yet that it is unwarranted to equate them with the consistencies themselves (Mischel, 2009). As such, this set of findings supports an individual interest perspective. It extends the empirical basis for interest research that focuses on identifying learner characteristics which may act as resources and facilitate learners' experiences of interest across situations and contexts (Durik & Harackiewicz, 2007). This dissertation contributes to the theoretical framework in particular by showing that longitudinal data can be used to decompose (e.g. by means of latent state-trait decomposition) situation-specific from consistent components as well as from measurement error. Based on these findings, study 3 underscored a particular quality of interest theory that lies in its well-articulated conceptual framework and sound theoretical grounding for empirically observed situation-specificity and consistency. A further contribution of this dissertation for interest theory concerns the analysis of two different components of SI (SI-Catch, SI-Hold) across time. For the present research the two components were defined as prototypical experiences occurring during the two different phases of SI development. Thus, this operationalization supports the alignment of interest measurement with interest theory, which is arguably the major current obstacle for the further advancement of interest theory (Renninger & Hidi, 2011). Extending from previous cross-sectional analyses (e.g. Lewalter & Willems, 2009), the longitudinal analysis of study 3 confirmed the two-dimensional structure of SI across different situations. SI-Hold was more difficult to stimulate and more associated with stable individual preferences (individual interest) than SI-Catch. This suggests a different functioning of the two components in line with their different developmental status (Hidi & Renninger, 2006). For this particular PBL context, the two components showed high latent correlations and similar mean trajectories on different absolute levels; this suggests that the PBL activities stimulate both experiences in a similar fashion, yet to a different degree. To provide references for further interpretation of these findings, more research is needed, as this was the first study to use this multidimensional and repeated measurement approach.

Second, the present research used an integrated framework (Krapp, 2005) of cognitive evaluation theory (Ryan & Deci, 2003) and interest theory to investigate situative antecedents of SI for different PBL activities (study 4, study 5). Based on this framework, the present research further refined the understanding of the nexus between students' basic psychological needs for autonomy, competence and relatedness and the intrinsic motivational state of SI. The present mixed methods investigation (study 4, study 5) of individual activities generally confirmed previous research and provided further evidence of quantitative magnitude relations between basic needs satisfaction and SI across different activities (Lewalter & Willems, 2009; Minnaert et al., 2007, 2011; Tsai et al., 2008). The large spectrum of affordances of different PBL activities combined with the open response format of interviews (unconstrained by

quantitative scale content), this research identified nuanced ways of how a satisfaction of the basic needs is associated with SI. The specific affordances of ill-structured problems, for instance, granted students the possibility of framing the problem and finding their own solution, instead of pursuing a single or a preconceived answer. For students, this satisfied a cognitive sense of autonomy (Tsai et al, 2008) and in turn SI. Students also identified various ways of insufficient basic needs support across different activities and needs as detrimental for SI. Additionally, the important role of other students across the different activities and the ways in which this is conducive for students' SI may lead to a refined definition of relatedness in the instructional context of PBL and its relation to SI (Wentzel & Wigfield, 2007). Finally, this research pointed at the important role of a need for novelty in students, which is satisfied through PBL in different ways at different activities. This balanced portrayal of quantitative and qualitative accounts in the present research has led to a more nuanced understanding of these need constructs with regard to their relations to SI. This has implications for the definition of the constructs and their operationalization in complex learning environments; as the definitions gain in breadth, broader or more specified sets of indicators are necessary. These will better represent an underlying need satisfaction, for instance and, thereby, enhance the development of integrated theories of motivation such as Krapp's (2005) framework. In general, this may support the motivation research agenda in its strive for convergence of theoretical perspectives in order to arrive at a richer and fuller understanding of motivation in various contexts (Ryan, 2012).

Third, the present research further carries implications for the development of a motivational instructional design theory for PBL and other complex learning environments (Van Meeriënboer & Kirschner, 2012). In a recent review, Belland et al. (2013) noted, that scaffolding frameworks have previously ignored the issue of motivation by assuming that student-centered learning environments are automatically engaging and therefore motivating. Recent research however has failed to support this conjecture (e.g. Belland et al., 2013; Wijnia et al., 2011). Whereas cognitive instructional theories, such as cognitive load theory, have received a lot of research attention and are far advanced (Sweller, 2011; Van Meerienboer & Kirschner, 2012), an established and conclusive instructional design theory based on motivational frameworks does not yet exist. Consequently, current PBL designs are not built around an explicit model of motivation and may not support motivation in optimal ways (Belland et al., 2013; Palmer, 2005; Schumann, 2010; Stark & Mandl, 2000). Thus, there is clear need for research to match PBL models with appropriate models of motivation to guide investigations in order to identify the most effective leverage points for supporting motivation in PBL (Walker & Leary, 2009). Current matching efforts are still in an early stage (Belland et al., 2013). In line with earlier recommendations (Palmer, 2005, 2009), the present research

therefore proposes interest theory as a suitable framework for investigating and improving PBL. Previous research has attested to the high educational relevance of interest (Schunk, Pintrich & Meece, 2003; Renninger & Hidi, 2011) and the significant role of SI in explaining task-related behavior and knowledge development in PBL (Rotgans & Schmidt, 2011a; 2014). The present research further contributes by showing that current models of interest development (Hidi & Renninger, 2006) offer a well-articulated theoretical framework that is able to face the major challenges of assessing and modeling motivational processes in PBL environments. According to Wentzel and Wigfield (2007) these challenges currently are threefold and concern a measurement that affords (1) different levels of content specificity, (2) an assessment of process and change and (3) multiple methods for investigation. Drawing on interest theory, the present research demonstrated the ability to appropriately address these challenges. First, it measured student interest with high object-specificity (interest in a topic), which could be supplemented with measures of lower object-specificity (interest in a school subject). Second, interest theory's clearly defined trait and situation-specific state variables support both summative and process assessment as well as the investigation of quantitative and qualitative change as state and trait are linked through a developmental model (Hidi & Renninger, 2006). Third, the interview study showed, that these models are amenable to mixed-method investigations. The dissertation, thus, adds to the empirical basis for establishing interest theory as a suitable framework for motivational instructional design of PBL. Based on these investigations, several significant implications for educational practice can be drawn.

4.2 Implications for educational practice

Research on motivation-in-context inherently has a high ecological validity and provides scientific descriptions and explanations of students' motivational processes. This knowledge can be used to guide the design and facilitation of PBL. Moreover, the design-based character of this research provides for the development of tangible outcomes, which support the implementation of PBL for making a difference in classrooms. These two aspects are discussed in the following.

First, this research provides educators with evidence-based guidelines for the design and facilitation of PBL, to best support students' interest and their value perceptions. In this context, Mayer (2004) has warned of a 'constructivist teaching fallacy'. According to Mayer, designers and facilitators often think of PBL as a set of activities such as hands-on inquiry or discussion and make related effectiveness claims (Zahorik, 1996). These activities, however, are overt activities, the active hands-on character of which should not be equated with corresponding cognitive or affective processes that drive learning (Schmidt et al., 2009). Thus,

Mayer (2004) holds, that it is the task of research “to discover instructional methods that promote appropriate processing in learners rather than methods that promote hands-on activity or group discussion as ends in themselves” (Mayer, 2004, p. 15). This dissertation used two approaches for the discovery of effective methods. A first approach was a design experiment (study 1, study 2), in which the activity structure of the design was manipulated before re-implementing and testing it again. The findings showed that an activity structure, which is closely aligned with PBL design, can be effective in supporting students’ value perceptions of science (study 2). This is in line with meta-analytic findings showing a combination of student-centered inquiry and discussion to be the most effective option for supporting learning in science education (Furtak, Seidel, Iverson, & Briggs, 2012). A combination of an initial direct instruction element and the use of PBL as a context for transfer cannot be advised on the basis of the current findings. This design (study 1) did not show to support transfer from the context of acquisition (direct instruction element) to the context of implementation (PBL element), which is an important prerequisite for recognizing the value of some content (Mandl & Gerstenmaier, 2000). Both contexts might have been too different to support transfer and motivation (Habgood & Ainsworth, 2011). Thus, designers of PBL environments are generally advised to operate *within* PBL design frameworks such as STAR.Legacy, and design the structure of their learning environment accordingly. These design frameworks still provide a high level of flexibility for their implementation in various contexts as well as for integrating other effective design features and scaffolding strategies (Schwartz et al., 1999). In the present research such features and strategies were discovered by means of a second approach, which employed a close micro-analytic examination of student SI and need-related experiences during PBL (study 3, study 4, and study 5) (Hung, 2009; Schmidt et al., 2011). The findings suggested several measures for implementation in PBL design and facilitation to support student needs and in turn SI: a distributive task structure, role-play sessions, competence scaffolding, and autonomy scaffolding. A *distributive task structure* seems particularly beneficial for maintaining student needs satisfaction. The students received specific role-based tasks to tackle different aspects of an overall challenge, which reduced task-complexity for individual students, and formed collaborative groups. Student interviews revealed that this increased their feelings of competence and relatedness. Collaborative groups consequently worked on different aspects of the problem and shared information later, satisfying their needs for novelty and relatedness. The implementation of a distributive task structure has previously been recommended by collaborative script theorists for supporting knowledge and skill acquisition (Fischer et al., 2013). The present research suggests that it is also beneficial for supporting student needs as well as SI, and thus, further recommends their implementation. *Role-play sessions*, as an innovative design for presentations, were associated

with high levels of needs satisfaction and SI. Previous research on self-determination theory in game settings has particularly emphasized the immersive character of role-play as conducive to motivation (Rigby & Ryan, 2011). The present findings seem to further support this and recommend the implementation of immersive design elements such as role-plays. As students frequently mentioned a lack of competence support during briefing, the findings emphasize that students require *competence scaffolding* especially at the beginning of a PBL sequence. This underlines findings from classroom research on the beneficial effects of goal clarity (Seidel, 2011) and highlights the role of these scaffolds especially for complex learning environments such as PBL. Finally, debriefing sessions seem to be critical events as they yielded the lowest SI mean values in the PBL activity sequence. Findings also indicated low levels of autonomy during the two debriefings and a strong association of autonomy with SI. It is therefore advised to implement *autonomy scaffolds* in the facilitation of debriefing. Debriefing sessions, which support autonomous reflection, do not break with the general student-centered character of PBL. Although debriefings and reflections are seen as a major catalyst for learning, they are still widely neglected in practice as well as in research (Kriz, 2010). In debriefings students reflect on previous learning events in explicit ways to leverage insight and learning. Reflection activities in principle have a great potential to foster student interest and value perceptions (Hulleman, Godes, Hendricks, & Harackiewicz, 2010) and complements implicit learning that occurs during inquiry or role-play (Kolb, 1984). For that reason, more research is needed to identify effective ways to design and facilitate debriefings. Together the findings of this research suggest design features and facilitation strategies which help to sustainably support students' needs and SI beyond the initial support provided by an intriguing problem (Rotgans & Schmidt, 2014).

Second, this research has produced tangible outcomes for educational practice. In line with the design-based research approach, an intervention was developed based on a theory-driven PBL model and iteratively refined on the basis of empirical information provided by almost six hundred students. The current version of this intervention is a ready-to-use design for the K-12 setting which 'has passed the classroom test' (Turner, 2008). The findings of the present research suggest that it supports students' SI and their perceptions of the value of science. It may, thus, be a useful tool for educational practice in science education, for example. Here, research has highlighted the benefits of students' active engagement in socio-scientific issues such as energy supply for fostering students' scientific literacy (Fensham, 2004; Sadler, 2009). Along with the intervention, training materials and a trainer workshop have been developed. These enable educators to run the intervention with a high level of fidelity which is fundamental for its effectiveness and scalability (O'Donnell, 2008). Both, intervention material and facilitator training are import for teachers to "jump the

implementation hurdle” (Ermter & Simons, 2006) and help to establish PBL as an alternative to direct instruction on the K-12 level. Besides they provide the foundation for effective dissemination strategies of innovative designs and practice (Gräsel, 2010).

4.3 Limitations and directions for future research

At the end of this chapter, a close look at the limitations of the present studies can inform directions to take in future research. A first limitation concerns the scope of this research. By viewing a certain intervention through the lens of a particular motivational framework, the present research narrowed its focus on a particular concept of individual interest, of motivation and of PBL. Thus, future research should aim for a higher empirical saturation of these phenomena. To better represent the individual interest construct, measures with varying object specificity (e.g. interest in a subject) or with a different object focus (e.g. interest in PBL activities) should be considered. Besides, knowledge has been construed as an integral part of interest (Renninger & Hidi, 2011). Therefore, the inclusion of a measure of knowledge (e.g. structural knowledge) is advised as it could help to further explain the development of SI during PBL activities (Rotgans & Schmidt, 2014), and thus further support the investigation of much needed integrated models of motivational and cognitive processes (Pintrich, 2003). To better represent the meta-concept of motivation, future research should include indicators of students’ self-concept as a stable estimate of their competence beliefs. These are seen as important influencing factors on motivation complementing value oriented concepts such as interest (Wigfield & Eccles, 2000). The inclusion of self-concept measures, for example supports an investigation of the extent to which the high levels of students’ feelings of competence found in the present studies are related to an underlying trait structure. To better represent PBL, it is advisable to investigate implementations of a more conventional realization of the STAR.Legacy design or other PBL models (Hung, 2011) without integrated role-play design features. These features may confound with standard PBL elements in their impact on the motivational experiences of the participants. Besides, a systematic variation of different problem types is an interesting field for further research (Jonassen, 2010). The present research has shown that larger and more complex problem structures may interact differently with SI development than simple intriguing problems used in previous research (Rotgans & Schmidt, 2014). Finally, an extension of the scope should also pertain to the horizontal dimension of time and include follow-up measures to assess the long-term effects of PBL interventions on student motivation.

A second limitation pertains to the fact that the research design of the present studies does not allow for establishing causal relationships. The correlational or quasi-experimental research designs cannot rule out alternative explanations for the observed effects, which can

likely occur in complex learning environments. To test theoretical causality claims and to enhance internal validity, the design-based research process should include investigations of specific effects under more controlled conditions including random assignment of participants (Stark, 2004). As an example, the effect of different kinds of problems or different activity configurations on student SI could be tested in randomized PBL classroom studies (e.g. Rotgans & Schmidt, 2014).

A third limitation is given by the fact that all data in the studies were obtained from students. These were collected either in the closed format of Likert-scales or in the more open-ended format of interviews. The validity of self-report measures relies on the capability and willingness of participants to accurately report about internal psychological states. Researchers have warned that especially at earlier stages of interest development, people may lack metacognitive awareness of their interest and, thus, produce measurement inaccuracy (Renninger & Su, 2012). The focus of the present research, however, was on students' subjective motivational perceptions. Self-report measures are currently the most widely applied measurement approach in research on motivation (Renninger & Hidi, 2011). Future research is therefore advised to extend efforts to further investigate the validity of measurement by using contexts such as PBL which allow testing important aspects such as the situation-specificity of the measurement approach (study 3). Moreover, future research is encouraged to employ multiple sources of information such as systematic observations of student behavior which showed to mediate the relationship of SI and performance. (Rotgans & Schmidt, 2011).

A final limitation pertains to the generalization of findings for the high school student population. In the present research, all participants were sampled from the same two grades and the same academic track of the three-tier German secondary educational system. Therefore, replications of the present results in samples especially in less selective student populations than in a sample of academic track students are desirable. Another interesting population for investigating motivation in PBL are students from alternative school models, which stronger promote student-centered methods. This research may reveal the motivational dynamics and consequences of a more frequent use of PBL in K-12 education.

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Appendix 1. *Intervention Designs*

Prototype				Re-Design			
Duration (lessons)	Modules	Star Legacy Components	Learning Activities	Duration (lessons)	Modules	Star Legacy Components	Learning Activities
<i>T1: Pre-test</i>				<i>T1: Pre-test</i>			
Loop 1 (community level)				Loop 1 (community level)			
4-5	Direct instruction		Teachers provide students with relevant information on the topic of energy supply.	1 (+1)*	Briefing	Look ahead, Multiple Perspectives, Generate Ideas	Students are introduced to the scenario and the inherent challenge as well as their individual roles and tasks. They brainstorm task solutions.
1-2	Briefing	Look ahead, Multiple Perspectives, Generate Ideas	Students are introduced to the scenario and the inherent challenge as well as their individual roles and tasks. They work on task solutions and prepare for presentation.	4	Inquiry I	Research & Revise, Test your mettle	Teams of 2/3 students gather and discuss task-related information to work out the best strategy in terms of their stakeholder roles. For self-assessment, they write position papers.
1	Role-Play I	Go Public	Students discuss their ideas and negotiate their different solutions in a simulated town-hall conference.	1 (+1)*	Role-Play I	Go Public	Students discuss their ideas and negotiate their different solutions in a simulated town-hall conference.
1	Debrief I	Reflect back & Look Ahead	During an intermediate whole-class debriefing session, students systematically reflect on the learning process in retrospect and preview the following cycle.	1	Debrief I	Reflect back & Look Ahead	During an intermediate whole-class debriefing session, students systematically reflect on the learning process in retrospect and preview the following cycle.
Loop 2 (district level)				Loop 2 (district level)			
2	Inquiry	Research & revise, Multiple perspectives, Test your mettle	Students extend their inquiry to the district level integrating different problem solutions.	2	Inquiry II	Research & revise, Multiple perspectives, Test your mettle	Students extend their inquiry to the district level integrating different problem solutions.
½ day	Role-Play II	Go Public	In a multiple-course role-playing session, students discuss their ideas and negotiate different solutions in a simulated district conference. A collective vote on the best solution concludes the simulation.	½ day	Role-Play II	Go Public	In a multiple-course role-playing session, students discuss their ideas and negotiate different solutions in a simulated district conference. A collective vote on the best solution concludes the simulation.
1	Debrief II	Reflect back	In a final debriefing session in class, students systematically reflect on the learning processes and outcomes of the whole project.	1	Debrief II	Reflect back	In a final debriefing session in class, students systematically reflect on the learning processes and outcomes of the whole project.
<i>T2: Post-test</i>				<i>T2: Post-test</i>			

*For the implementation of the Re-Design in study 3-5, the time of two modules was extended by 1 lesson.