EXAMINING CONTEXT-BASED TASK CHARACTERISTICS

THE EFFECTS OF TASK CHARACTERISTICS ON STUDENTS’ MOTIVATION AND METACOGNITIVE EXPERIENCES

from

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Abstract

Science education has been facing important challenges in the recent years: the decline in student's interest in scientific topics, and moreover, the decrease of students pursuing science beyond their compulsory studies (Bennett, Hogarth, Lubben, 2003). As a result, research has focus on examining different approaches that could attempt to improve the situation. One of these approaches has been the use of context-based problem-solving tasks (Kölbach & Sumfleth, 2011; Bennett, Hogarth, Lubben, 2003). While research into context-based problem-solving tasks suggest *that* they are very motivating for students, it is still unclear *how* they influence motivation. Following an experimental *pretest-postest* design, two studies examined the effects of context-based task characteristics of contextualization, complexity, and transparency, on students' motivational variables, performance, and metacognitive experiences. Results from both studies suggest that the task characteristic of contextualization directly influences how students' interest is triggered and maintained throughout the task. On the other hand, the task characteristics of complexity and transparency had different effects for the other dependent variables of effort, difficulty, and solution correctness. Moreover, data shows that other motivational variables such as anxiety and success expectancies are strongly influenced by the interaction of the parameters under study. The dissertation concludes that appropriate design and use of context-based task characteristics can benefit students' learning processes and outcomes.

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Chapter 1: Introduction

> *"…science is not engaging the attention of students; (school) it is not presenting science in a manner that excites them to enjoy scientific developments as an interest that can be continued into adult life or that suggests it is a fascinating field within which they could find a career."*
>
> *(Fensham, 2009, p. 189)*

Problem Statement

It is a fact that Fensham has not been the first or last author to openly state science education lifelong challenge. In 2003, Bennett, Hogarth, and Lubben developed an in-depth systematic review of the effects of context-based approaches and were able to obtain articles dating back to the 1920s in which the very same concerns were expressed: *students do not find science interesting, and even worst, they don't see the point of what they are doing*. Despite science being often overlooked or taken for granted, modern society depends on it.

In 1997, the Organization for Economic Cooperation and Development (OECD), launched the Program for International Student Assessment (PISA) as a collaborative effort by member countries and other non-member countries. PISA represents a mean by which governments of OECD member countries can monitor the outcomes of their educational systems in terms of student achievement, within a common international framework (Bybee, McCrae & Laurie, 2009). The PISA study combines the assessment of school topics such as science, mathematics and reading; in addition, it collects information regarding students' background and views of learning. Administered every three years, the PISA surveys focus (every time) on a "major" domain, and two "minor" domains. The year of 2006 was the year for *science literacy* as a major research domain, and concentrated not only on assessing students' scientific competencies and knowledge, but also, students' attitudes towards science. This last aspect was measured through three areas: support for scientific inquiry, responsibility toward resources and environments, and interest in science. For the 2006 PISA assessment, Finland scored the highest out of all other countries, and Lavonen and Laaksonen (2009) decided to explore *why*. In their research, the authors found that besides classroom communication, interest in science was clearly a possible explanation for Finnish students' performance.

If the lack of student interest in science is one of the biggest challenges for science education, and more importantly, interest is a key factor needed for improving student performance (as explored within the PISA framework), then science education's goal should be how can it promote and improve students' interest. Fensham (2009) proposes two features as starting points: first, science to be learned must be perceived as interesting and of relevance to students' lives, personally and socially; second, learning of science should empower students to engage with the real world, involving of course science and technology.

Extensive research on the matter has come to agree on an approach able to apply scientific competencies in "real-life": ***context-based approaches*** (Kölbach & Sumfleth, 2011; Bulte, Westbroek, van Rens, Pilot, 2004; Bennett, Hogarth, Lubben, 2003). Context-based approaches are used as a mean to help students develop a deep understanding of scientific ideas, concepts, and skills, as well as to relate them to current scientific matters that can affect their lives and their surroundings.

According to Bennett et al. (2003), research on context-based approaches has focused on three main areas: the development of students' understanding of scientific ideas, teachers' responses and use of context-based materials, and students' motivational and affective responses. Research developed in science education has brought increasing attention to such area, and has claimed that context-based tasks are very motivating for students. Moreover, Campbell, Hogarth and Lubben (2000) state that such tasks provide relevance to the learning of science and improve students' enjoyment of science.

In Bennett et al. 2003's systematic review, not only important key findings were presented: (*1) context-based approaches motivate students; 2) such approaches promote positive attitudes towards science, and 3) context-based approaches do not adversely affect students' scientific literacy*), but it also discusses the areas where there is still a knowledge gag. Research has failed to make a distinction as to what precisely makes students more motivated or interested: is this the result of the type of materials used, approach, or task? The authors state that context-based approaches cover a wide range of teaching strategies and activities, a main example would be using context-based problem-solving tasks. They suggest that research should focus on examining, through an experimental way, how this type of problem-solving tasks affect students' motivation.

In order to provide an answer to the main research goal, it is important define a context model and its characteristics. Furthermore, an analysis on the effects of task characteristics on student motivation and metacognition will be provided. This will provide a base of new knowledge to the field of science education and psychology.

Theoretical Background

The starting point: determining a model of *context*. Since the beginning of the 1980s, science education welcomed context-based approaches into worldwide high schools' and university courses' curriculum. Examples include, in the Netherlands, *PLON* (Dutch Physics Curriculum Development Project, 1988); *ChemCom* (American Chemical Society, 1988) in the United States; *SLIP* (Supported Learning in Physics Project, 1996) in the UK; and *STEMS* (Science, Technology Environment in Modern Society) in Israel (Bennett, Hogarth, Lubben, 2003). Such types of projects have one or both of the following objectives: to provide students the opportunity to understand how science relates to their lives, and to promote interest in science, the latter being one of the most significant concerns of science education research.

It is important to highlight that all of such projects view the term "context" from a different perspective. Consequently, different approaches to context can be identified as a result of different views on the definition of context. However, in order to ground the research studies, a notion of the concept of context, and a model that helps operationalize our variables. Our theoretical background follows the context model[1] developed by Löffler and Kauertz (2016) (Fig. 1). The model considers two levels, the surface structure and deep structure, which are distinguished by three task characteristics: *contextualization, complexity, and transparency*.

At the level of the surface structure, the model identifies the task characteristic of *contextualization*. Such task characteristic can be adjusted (i.e. high or low) accordingly to the given amount of information adjunct to the relevant real object (and its characteristics) and events described in the problem situation (Löffler & Kauertz, 2016). At the level of the deep structure, the

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[1] For a profound analysis and examination of the development of the model, please refer to Patrick Löffler's (*loeffler@uni-landau.de*) dissertation which is as well part of the *UpGrade* Graduate School from the University of Koblenz-Landau.

task characteristic of *complexity* is allocated and characterize by two levels (i.e. high or low), which depend on the structure of the solution (Kauertz, 2008). Finally, the model considers a third task characteristic which connects the surface and deep structure levels. Such task characteristic is identified as *transparency*, and is as well characterized by two levels (i.e. high or low) according to the linking features of the surface structure with the deep structure (Löffler & Kauertz, 2016).

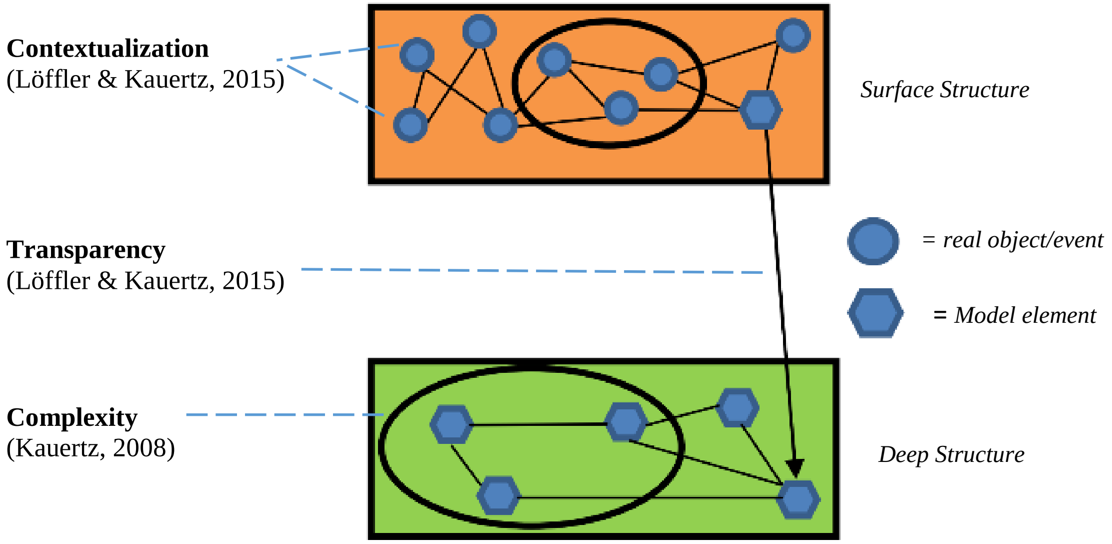


Fig. 1: Context model Löffler & Kauertz (2016) – example of high contextualization, high complexity, low transparency

Such model of context has been selected for grounding our research studies after careful examination of other “context” models and frameworks, which unfortunately, have not provided sufficient evidence to describe and categorize context and its elements. Previous frameworks have described the links between surface and structural features based on the content of the task, which uses either professional technical terms or everyday jargon (language) as fillers. Results of such study revealed no significant impact of such elements on task difficulty (Dorschu, Krabbe, Kauertz, & Fischer, 2013). Therefore, the context model based on the task characteristics of contextualization, complexity, and transparency may serve as a basis to examine the effects of tasks on students' motivation in a more differentiated way.

The next section will provide a theoretical examination of student motivation and metacognition, and the possible influence task characteristics can have on such mechanisms.

Interest: *connecting* students and the learning material. Research into context-based approaches has argued that there is evidence to indicate that students respond positively in lessons where such approaches are used (Bennett et al., 2003). Most of this evidence claims that context-based tasks are very motivating for learners, mainly because they make students interested in the science topic discussed at hand.

According to Durik & Harackiewicz (2007), the main goal of teachers is to not only teach so that students can learn, but also, to motivate students so that they care about what they are learning. If students are motivated enough, then they may enjoy and value the learning experience (Heller & Hollabaugh, 1991), and even perhaps seek out more learning experiences.

The importance of interest has been stated as early as the beginning of the 19th century (Krapp & Prenzel, 2011). Friedrich Herbart (1776-1841) developed the first general theory of education, were interest played a crucial role. Herbart stated that interest must not only be seen as a "desirable" motivational condition of learning, but as well, an important outcome of education. By the twentieth century, the concept of interest was used in different fields of educational psychological research which aimed at examining the relation between interest and learning (Krapp, Hidi, & Renninger, 1992). The use of "interest" in different contexts brought as a result, the development of new and divergent theoretical approaches and psychological constructs. Thus, research on "interest" was focused on attention, curiosity, intrinsic motivation, value orientation, and attitudes (Krapp, Hidi, & Renninger, 1992; Krapp & Prenzel, 2011). As empirical research into the relation between interest and learning continued, it became quite clear that new and modern theories do not consider all the important aspects of the traditional concept of interest (Krapp & Schiefele, 1986, Krapp, Hidi, & Renninger, 1992).

As a result, research into the concept of “interest” has renewed itself and focused on examining not only the influence of interest on learning, but as well on the origin and transformation of interests (Schiefele, Winteler, & Krapp, 1988; Krapp, Hidi, & Renninger, 1992). Despite new research into the topic, it still exhibits different concepts and approaches that might not be comparable, however, they do complement each other. Research up to now has two main foci: a) the influence of individual interest as preferences for a particular object domain, and b) the effect of interestingness (i.e. the environmental factors found in learning materials or settings) which trigger a situation-specific interest in the learner (Krapp, Hidi, & Renninger, 1992). The following section will provide background information on the conceptualization of interest as a motivational variable.

The concept of interest: theoretical background. Interest as a motivational variable refers to the psychological predisposition to reengage with particular types of objects, events, ideas, or in other words, “contents”, throughout time. Moreover, interest is consider as the specific relation developing between person and some topic or content (i.e. task, topic, or domain). This idea is commonly referred to as “person-object relationship” theory (Krapp, 1999), which has an important aspect: interest is *object-specificity*. Furthermore, interest is characterized by affective as well as cognitive components, it implies a notion of personal relevance, value, and readiness to engage with high levels of effort of persistence (Ryan & Deci, 2000). Interest has the quality of personal significance, and it is associated with positive experience (Krapp & Prenzel, 2011). Thus, interest-based interactions with content provide optimal experiential nodes that combine positive cognitive qualities (i.e. meaningful goals) and positive affective qualities. If optimal conditions occur, a flow state could be experienced during interest-based activities (Csikzentmihalyi, 1975; 1990) (Flow will be discussed in the next section). The fact that interest includes both affective and cognitive components, and is the outcome of an interaction between person and particular “content”, is what distinguishes it from other motivational variables. More importantly, it is what it distinguishes from enjoyment (Krapp, 1999).

Regardless of the general assumptions concerning interest, researchers use different conceptualizations, which describe different theoretical orientations and paradigms of empirical research (Krapp, 1999). Krapp, Hidi, and Renninger (1992) have identified three main conceptualizations of interest which are related to each other (Fig. 2): 1) interest as a dispositional characteristic of a person, 2) interest as a characteristic of the learning environment (interestingness), and 3) interest as a psychological state.

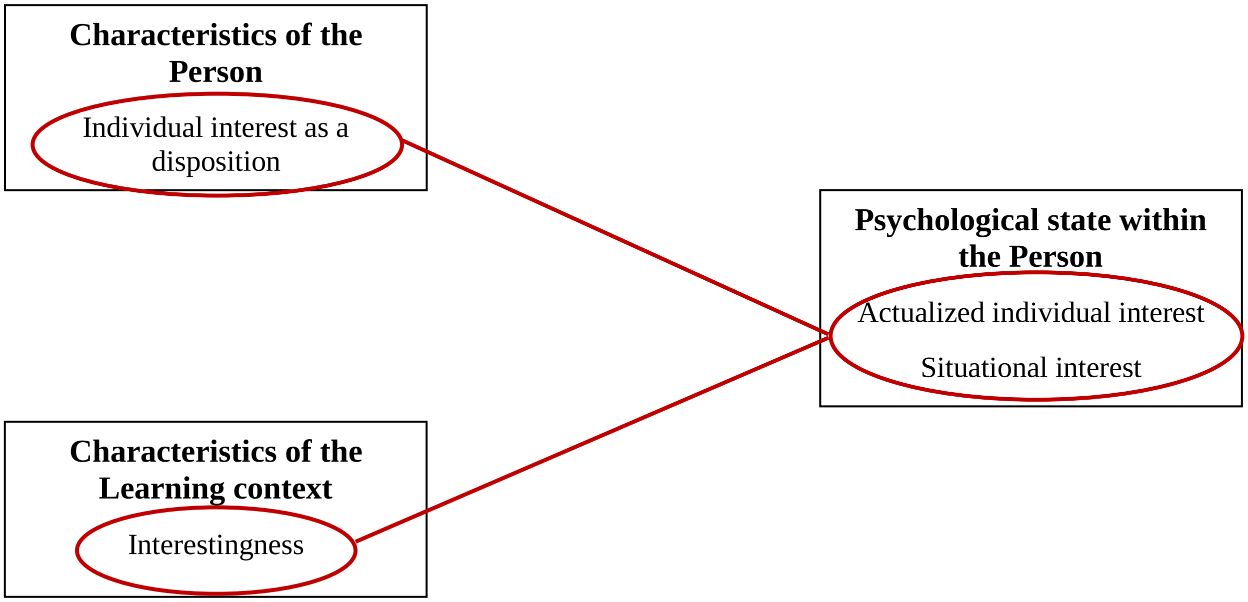


Fig. 2: Three perspectives on research in interest (Krapp, Hidi, & Renninger, 1992).

One line of research conceptualizes interest as a motivational disposition, referring to a long-lasting preference for a specific topic. Research following this line attempts to describe and explain individual differences in regards to learning and development. On the other hand, another line of research views interest as a specific psychological state, rather than a disposition. Researchers focus on the cognitive and affective states (and processes as well) that are triggered while experiencing an "actualized interest". As it has been stated before, the main conceptualizations of interest are related to each other: interest can be traced back either to the "interesting" factors of the context or situation, or to an already existing interest. This assumes that interest arises from an interaction between individual and situational factors.

To address the goals of our studies, we will ground our research approach on ***interest as an outcome of an interaction between person and a specific content***. According to this line of research (Hidi & Renninger, 2006), interest is within the person, but the content and the environment define its direction, and moreover, contribute to its development. Thus, other individuals, the person's own efforts, and other motivational variables, can support the development of interest (Renninger & Hidi, 2002).More importantly to discuss is the fact that because interest is content specific, it will not be equally triggered or developed throughout all academic activities. According to research, even highly motivated students have generally interests for a specific set of subject areas.

Two types of interest have been the main focus of study: situational and individual interest (Krapp, Hidi, & Renninger, 1992, Krapp 1999, Renninger & Hidi, 2002, Hidi & Renninger, 2006). Situational interest refers to the focused attention and affective reaction which is triggered by an environmental stimuli, content, or situation; whereas individual interest refers to a person's predisposition to reengage with a particular topic/content over time (Krapp 1999; Hidi &

Renninger, 2006). Situational interest can be initiated by some stimuli in the environment, like a text about soccer that a teacher uses in class, a new chemistry software that students with little interest want to explore (Hidi & Renninger, 2006), or simply, picking up a magazine and focusing on a particular article (Kuhn & Müller, 2014). However, individuals also may respond to stimuli of the environment due to prior experience. For example, a person with previous background knowledge in science can become interested in technology because it allows him or her to pursue deeper topics in science. Situational interest has been shown to positively influence an individual’s cognitive performance, focused attention, facilitate the integration of new knowledge, as well as to enhance the levels of learning (Hidi & Renninger, 2006; Durik & Harackiewicz, 2007).

Hidi and Renninger (2006) established their model of development of interest, in which they describe how interest is influenced by the experience of positive affect in relation to an activity by perceived value. Furthermore, they theorized that interest develops in four phases:

- Phase 1 – *triggered situation interest*: momentary interest is triggered/activated by some external cue such as surprising information, task features, or personal relevance. Most commonly, situational interest is externally supported, meaning that certain aspects of the environment are needed to catch students’ attention.
- Phase 2 – *maintained situational interest:* situational interest is maintained when the individual finds a task meaningful and relevant, as well as has the desire to continue pursuing the activity. As triggered situational interest, maintained situational interest can be typically externally supported.
- Phase 3 – *emerging individual interest*: if situation interest is sustained over time, and an individual continues to engage in such activity, then individual interest may begin to develop. Individual interest is typically self-generated.

- Phase 4 – *developed individual interest*: continuous reengagement with the task over a period of time, along with increased knowledge and positive affect. Such variables can create an enduring interest in the activity. Just as emerging individual interest, a developed individual interest is commonly self-generated.

The model describes situational interest in terms of affective and cognitive processes, as well as the basis for the development of individual interest (Renninger, 2000; Renninger & Hidi, 2002; Schraw & Lehman, 2001). In addition, according to research (Renninger & Hidi, 2002; Hulleman, Godes, Hendricks & Harackiewicz, 2010) interest is reciprocally related to other variables such as effort, self-efficacy, goal setting, and self-regulated behavior. More importantly, such variables can change as interest develops or decreases.

In contrast to individual interest, situational interest is normally externally supported. Such external support refers to specific task characteristics that have a high level of *interestigness* (Krapp, 1999), as well as meaningful, relevant, and with a strong value to the individual. Therefore, exploring the types of external support (i.e. task characteristics) that might promote situational interest in a learning condition (i.e. context-based problem-solving tasks) is of great interest of the purpose of our study.

Different factors and approaches have been found to promote situation interest (Schraw & Lehman, 2001). A first approach is to manipulate features of the general environment, such as the feedback a teacher provides or how that teacher introduces the task at hand. A second approach is using perceptual features that can increase attention and arousal. A last example would be to explore the features of task themselves (Durik & Harackiewicz, 2007). Researchers have identified some task characteristics that trigger interest by allowing students to participate at a personal level (Parker & Lepper, 1992).

The specific features of task characteristics and situations that can actually empower students and spark their interest are quite varied. However, researchers agree that one feature is of high importance: meaningfulness. Students are more likely to engage in materials and tasks they find meaning in, independent of whether they enjoy overall content or not. Appropriate design and use of task characteristics should be novel, surprising, and stimulating, but as well, that emphasize the utility of the material being taught in order to catch and maintain students' situational interest.

Flow: the *optimal* experiential state. As mentioned briefly in the previous section, given optimal conditions, flow may be experienced during activities or tasks that are based on people's own interests. If individuals are reengaging constantly with a particular content, this has been stated as an interest. Therefore, it would be expected that individuals experience a state of complete concentration with the content at hand. Such state is commonly referred to being "in the zone", a concept often heard in sports. In the field of psychology, and following a motivational approach, flow has been described as (Csikzentmihalyi, 1975; Rheinberg, 2008; Engeser & Rheinberg, 2008)

- A sense of balance between one's skills and the perceived difficulty of the task. One feels to be engaging challenges at a level that is appropriate to one's capacities.
- The task is coherent, without contradicting demands.
- Clear goals and immediate feedback.
- The individual experiences high levels of concentration due to an undivided attention.

Being in the "flow" is a functional aspect, in which individuals experiencing flow are highly concentrated and optimally challenged by tackling goals, processing feedback, and feeling that they have control of actions. Such functional state contains positive valence and explains why people do not require external rewards to be committed to the task. Under these conditions, the experience unfolds from moment to moment, and one enters a subjective state with the next characteristics (Nakamura & Csikzentmihalyi, 2005):

- Intense and focused concentration
- Merging of action and awareness
- Loss of self-consciousness
- A sense that one has control over one's actions: one can deal with the activity or task because one knows how to respond to what could happen next
- Distortion of time (i.e. time passes much faster than it seems to)
- Experience of the activity as intrinsically rewarding

Flow has been operationally defined and researched based on the reformulated model by Csikzentmihalyi and Csikzentmihalyi (1988). The model proposes that flow is a state of dynamic equilibrium, where one has a sense of balance between perceived action abilities and perceived action opportunities (see Figure 3). However, such balance is fragile.

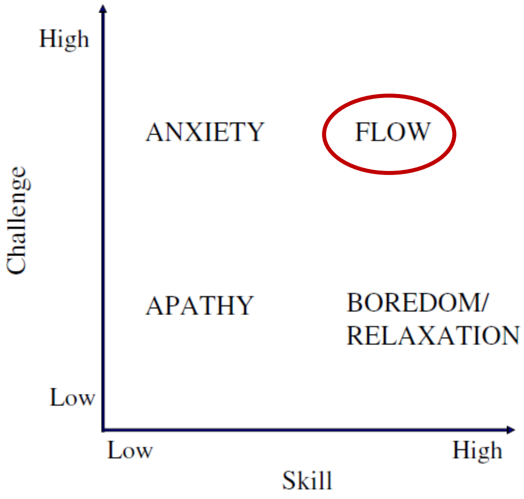


Fig. 3: Flow model by Csikzentmihalyi and Csikzentmihalyi (1988).

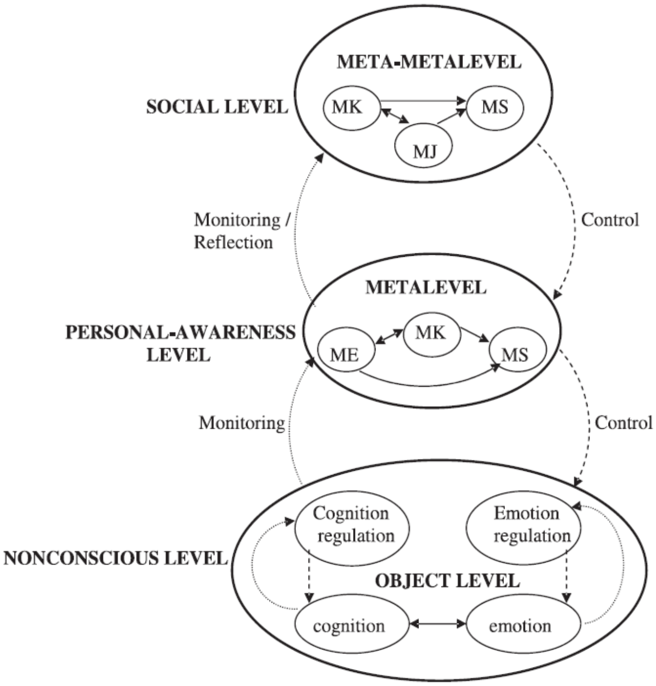
If challenges were to exceed one’s skills, one first becomes aware of what is happening, and then anxious. On the other hand, if skills begin to exceed challenges, one must first relax and then become bored. Shifts in such subjective state provide feedback about the changing relationship to the “content”. Experiencing anxiety or boredom makes a person adjust his or her level of skill and/or challenge in order to reenter again the state of flow (Nakamura & Csikzentmihalyi, 2005).

Research on flow has been integrated into the empirical literature on intrinsic motivation and interest (Nakamura & Csikzentmihalyi, 2005; Krapp, Hidi, & Renninger, 1992). A key characteristic that flow shares specifically with theories of interest is interactionism. Rather than focusing on the individual’s traits or personality types that provide a disposition, flow research has highlighted the interrelationship between person and “content”. There is an emergent motivation in such relation, as it is shaped by both the person and the content: what happens at any given moment is a result from what has happened immediately before within the interaction, rather than being established by a previous disposition from the person itself or the content. Possessing interest in an activity is one precondition for finding flow on it, however, by the emergent motivation phenomenon (Nakamura & Csikzentmihalyi, 2005), one can come to experience a new or previously unengaging activity as interesting if flow is found in it. The motivation to persist in or return to the activity is a result of the experience itself. Thus, a flow state can expand an individual’s interest structure by developing new interests. Furthermore, according to research (Vollmeyer & Rheinberg, 2006), other motivational variables such as students’ success expectancies and anxiety are key factors to induce learners into a flow state.

Because flow has an important relation to interest, meaning, interest-based activities can induce an optimal flow experience, it would be important to examine whether context-based problem-solving tasks can in fact develop such experiential state. Moreover, it can be highly valuable to examine how an individual might stay in flow as a result of functions such as anxiety resulting from the levels of challenge relative to skill. It is needless to say, that the balance between challenge and skill, is mainly monitored, processed, and controlled by an individual's metacognition.

Metacognition and its facets: the monitoring and control of cognition. The concept of metacognition is used to refer to *cognition of cognition* (Flavell, 1979), and its relationship with learning has been long researched. Metacognition is considered a representation of cognition which is built based on information from the monitoring function that informs the control function when cognition fails. Nevertheless, exerting control requires high levels of effort, and in order to develop high levels of effort, there must be motivation (Efklides, 2006). Moreover, there are facets of metacognition that have an affective character by nature (i.e. metacognitive experiences). Therefore, a connection between motivation and metacognition is theoretically assumed. The focus of the following section is to address metacognition and its effect on the learning process, while linking such processes to motivation. Special focus will be placed on metacognitive experiences, as it can provide important information about students' metacognitive and cognitive processing, and it's link to motivation and affect when coming across context-based problem-solving tasks.

Metacognition serves two functions at the meta-level (see figure 4): monitoring and control of cognition (Efklides, 2008; Efklides, 2001; Flavel, 1979). It is needless to say that the individual is aware of the outcome of the monitoring process, which is mainly done through the metacognitive experiences and metacognitive knowledge. The above assumptions imply that metacognition is multifaceted, involving different facets for both: the monitoring of cognition and the control processes (Efklides, 2001).



Note: ME = metacognitive experiences; MK = metacognitive knowledge;
MS = metacognitive skills; MJ = metacognitive judgments
←········ = Monitoring; ←- - - - - - - - = Control

Fig. 4: The multifaceted and multi-level model of metacognition (Efklides, 2008).

Two of three of the facets of metacognition have already been mention, namely metacognitive knowledge and metacognitive experiences. The third facet in the model is metacognitive skills. An attempt to provide a description of the facets (Flavel, 1979, Efklides, 2001, Efklides, 2008) will be presented in what follows.

- Metacognitive knowledge is declarative knowledge that is stored in memory and comprises “models” of cognitive processes such as language, memory, etc. It also involves information concerning persons (the self and others as cognitive beings, that is how an individual or other people processes different tasks), as well, as information about tasks, strategies, and goals. Metacognitive knowledge gets continuously “updated” by integrating information that proceeds from the monitoring of cognition at a conscious level or through observations, and awareness of an individual’s own metacognitive experiences.

- Metacognitive skills denotes the deliberate use of strategies (i.e. procedural knowledge) in order to control cognition. Moreover, metacognitive skills involves orientation strategies, planning strategies, strategies for regulation of cognitive processing, strategies for monitoring the execution of planned action, and strategies for the evaluation of the outcome of task processing (Veenman & Elshout, 1999). In order for metacognitive skills to be activated, it is necessary that the individual is aware of the fluency of cognitive processing, as well as that there is a possible conflict. This information is provided by the metacognitive experiences, which triggers control decisions.
- Metacognitive experiences refer to what the person is aware of and what the individual itself feels with the task at hand and the processing of information related to it. Metacognitive experiences are the interface between the individual and the task, the awareness the person has of the task characteristics, of the fluency of processing, of the progress towards goals and objectives, the effort exerted on cognitive processing, and of course, of the outcome of processing (Efklides, 2001, Efklides, 2008). Researchers have continuously suggested that metacognitive experiences have a direct effect on cognition. This influence is done, as mentioned within each of the two first facets, through metacognitive knowledge and control decisions regarding strategy use. Thus, they are an essential component of the regulation process, and having an important impact on learning.

Metacognitive experiences: becoming aware of the learning process. As it has been previously described, metacognitive experiences are the manifestations of the monitoring of cognition as an individual comes across a task and processes the information related to it (Efklides, 2009). They comprise metacognitive feelings, metacognitive judgements, and online task-specific knowledge (Efklides, 2001; Efklides, 2006; Efklides, 2008). Metacognitive feelings are: feeling of knowing, feeling of familiarity, feeling of difficulty, feeling of confidence, and feeling of satisfaction. Metacognitive feelings, such as feeling of difficulty, are widely studied in the context of problem-solving, because they are crucial for the self-regulation of effort. Furthermore, the monitoring of fluency processing is a critical cue for the feeling of difficulty (i.e. lack of processing fluency, or no problems while processing). All information provided by the metacognitive feelings provide a database for metacognitive judgements or control decisions.

On the other hand, examples of metacognitive judgement involve judgements of learning, estimate of effort, estimate of time needed, and estimate of solution correctness. In addition, episodic memory judgements, source memory, and estimates of frequency. Online task-specific knowledge covers task information that are use, like words used and thoughts a person is aware of while he or she is performing a task, as well as the metacognitive knowledge the person retrieves from memory in order to process the task (Efklides, 2001; Efklides, 2009).

As to the implications of metacognitive experiences for the learning processes, there are two main issues: the accuracy of metacognitive experiences and the effects of the particular metacognitive experience on learning.

According to Efklides (2001), the accuracy of metacognitive experiences is quite important because it has an effect on the efficiency of the control decisions in learning situations in regards to effort, time investment, and strategy use. How accurate metacognitive experiences are will be defined based on their correlation with performance. Examples of why a metacognitive judgement might not be accurate are: judgements are nonconscious, heuristic, or based on an erroneous inferential process that uses different cues affecting the fluency of processing (Efklides, 2001).

Furthermore, the metacognitive experience of feeling of difficulty commonly correlates with performance, which suggests that such feeling is highly accurate (Efklides, 2001). Nevertheless, this correlation is higher when the task has a moderate difficulty, whereas, with low or high difficulty task, the correlation decreases and becomes weaker. If the task is perceived as easy, then the required response is immediately available, and as such, there is no experienced difficulty. Given the case that any difficulty is experienced at all, could be attributed to extrinsic cues, which have nothing to do with the procedural knowledge that controls performance. However, if the task is perceived as very difficult, three possibilities can happen: 1) feeling of difficulty is high, making the person have a negative affect and quit the task, 2) the person experiences a negative affect but there are some mnemonic cues regarding the source of difficulty, which helps the individual overcome the difficulty. This could lead to successful or unsuccessful performance, which of course reduces the correlation between perceived difficulty and performance. Finally, 3) feeling of difficulty is low, despite the objective difficulty of the task, because there is an illusion of feeling of difficulty. This difficulty could manifest because the task seems familiar to the student, or because the student does not understand the task demands. As a result, the student fails to invest the necessary effort in order to succeed, and the performance is low.

Nevertheless, there is a calibration of the reported feeling of difficulty, when a person is repeatedly exposed to the task or develops expertise (Efklides, 2001). This calibration is associated with higher feelings of familiarity, better analysis and comprehension of task demands, and a regulation of behavior and actions.

As described previously, one can understand that metacognitive experiences have an impact on the regulation of learning, behavior, and actions. Important to highlight is the fact that this impact, though highly significant, might not always be positive. Therefore, it is necessary for research to focus on examining the conditions that develop accurate metacognitive experiences and which are beneficial for learning. Considering that metacognition (and its facets) and motivation are interconnected and affect how a learner decides to deal with a task, it would be important to examine how context-based problem solving-tasks can influence first of all how a student approaches the tasks, and how the student executes it as well.

The Underlying Models of Study: Linking Task Characteristics with Student Motivation. Based on our theoretical background, a model was develop in order to ground the research objectives, operationalize variables, and select appropriate instruments of measurement. Building on the revised existing research and theoretical literature, a model of *task-learner interactions* is established. In line with the context model from Löffler and Kauertz (2016) (see Figure 2) described in the first section of the theoretical background, three task characteristics have been distinguished: contextualization, complexity, and transparency.

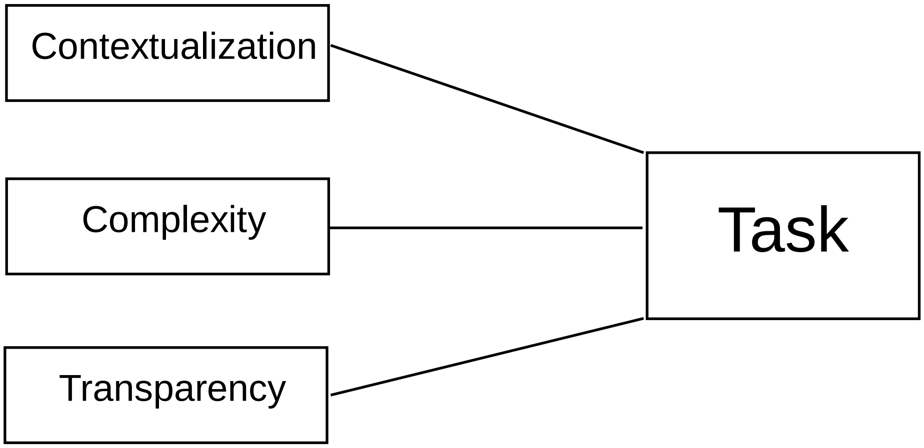


Fig. 5: Task Characteristics.

Corresponding to the learner characteristics, motivational variables, flow state, and metacognitive experiences are considered:

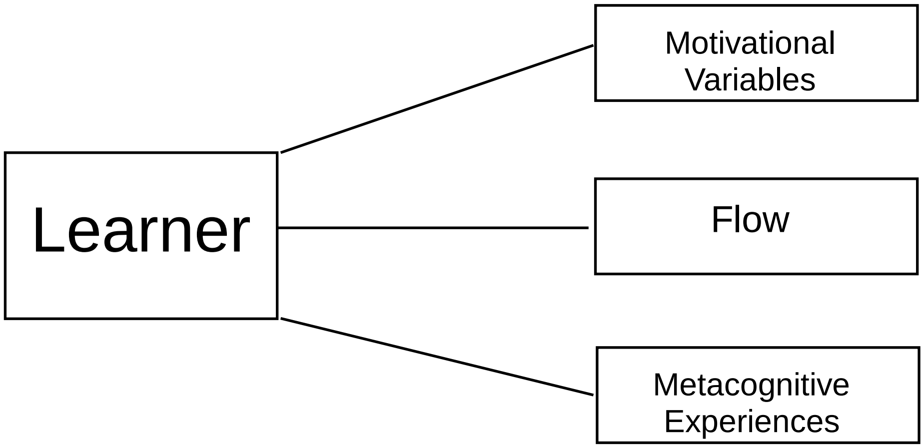


Fig. 6: Learner Characteristics.

The motivational variables taken under study are: interest, anxiety, and success expectancies (Hidi & Renninger, 2006; Vollmeyer & Rheinberg, 2006; Wigfield & Eccles, 2000; Ronen & Eliahu, 2000). In line with Efklides (2001), the metacognitive experiences examined in the model are: feeling of difficulty, estimate of effort, estimate of solution correctness, feeling of confidence, and feeling of satisfaction.

The model, task-learner interactions, considers the interrelationships that occur between the task characteristics and the learners. Following the person-object relationship theory (Krapp, 1999), the model focus on the "interactionism" between task-learner, and how the relationship is shaped by both. Prior knowledge and cognitive abilities are also considered and controlled for in the model (Hidi & Renninger, 2006; Krapp & Prenzel, 2011). Students' cognitive abilities, and specially, prior knowledge are considered as important factors in the four phase model of interest and as part of a variable that can influence the state of flow.

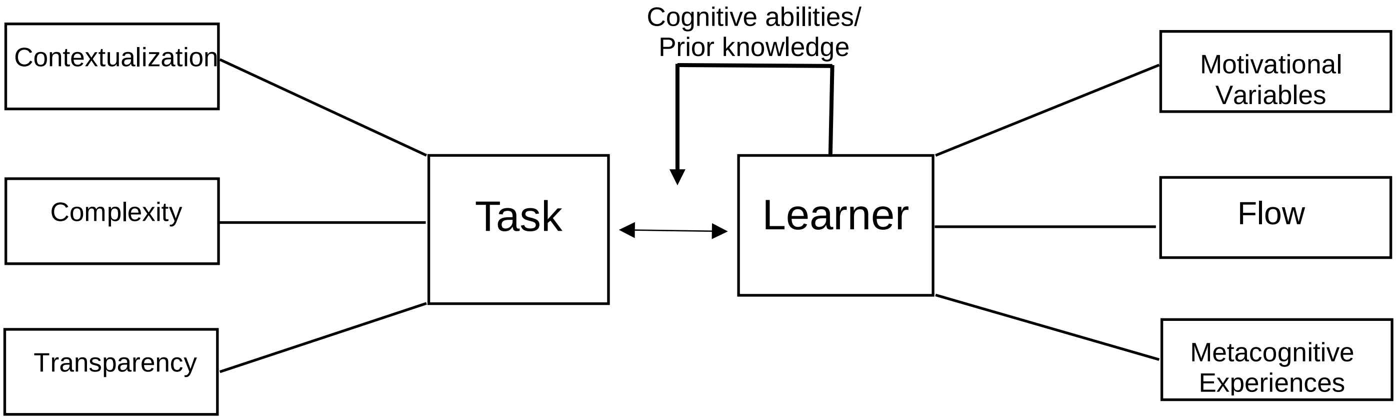


Fig. 7: Task-learner interactions model

It is important to mention that interest, and other motivational variables such as success expectancies, has been theoretically consider as motivational factors that may influence learning and performance (Hidi, 1990; Hidi & Renninger, 2006, Harackiewicz, Durik, Barron, Linnenbrink, & Tauer, 2008). A large body of research has attempted to examine the correlation between motivational variables and performance (Krapp & Prenzel, 2011), but normally considers for example, interest, alongside other affective and motivational factors. Inconsistent results have been obtained, while some studies find correlations, there are other studies where weak to nonsignificant correlations has been found (OECD, 2007; Köller, Baumert, & Schnabel, 2001). Therefore, our model does not consider performance as another learner variable, but still *acknowledges* the theoretical assumptions behind.

The task-learner interactions model will serve as the main object of study in the next following chapters. For the purpose of this dissertation two main studies were developed in which the interrelationships between task characteristics and learner characteristics were examined. Despite a large body of research into context-based problems, there are still important knowledge gaps. As analyzed in the previous sections, findings have suggested that context-based problems influence students' motivation. Research still lacks to explain specifically which elements of context-based task are the ones to influence student motivation. It is necessary as well to specify which concepts of motivation are those being influenced. To fulfill this knowledge gap, a context model has been established which defines specific task characteristics. Moreover, an analysis of the motivational variables of interest, anxiety, and success that are expected to have an influence from such task characteristics was developed. In addition, there has been no research up to date that examines the effects of context-based task characteristics on flow state as well as metacognitive experiences.

General Description of the Dissertation

The next chapters will focus on describing the two studies developed for our main research goal: what are the motivational effects of context-based problem solving tasks. The first study initially was conceptualized as a pilot study, focused on piloting the problem-solving tasks of thermodynamics as well as examining any possible systematic and unsystematic errors that could be prevented in the main study. Nevertheless, the study provided strong effects that gave an insight onto the motivational and cognitive processing behind the development of tasks, and as well, raised several questions that needed to be further investigated. Therefore, the main study developed into a second study which focused on addressing the questions from the first study and providing a deeper understanding of students' metacognitive experiences when dealing with different task characteristics.

Chapter two will focus on describing the first study which had as a main goal to examine the effects of task characteristics on students' motivational variables of situational interest, anxiety, and success expectancies. It also addresses how task characteristics and its effects on motivation could influence students' performance. The chapter will close posing questions and issues that will be addressed in the second study.

Chapter three will describe the second study which has as a starting point the limitations of the first study. The main objective of the study was to examine how task characteristics and task topics influence students' motivational variable of interest and metacognitive experiences. The chapter will close by addressing main results that unify both studies.

Chapter four will develop a discussion on the results of both studies, focusing on providing explanations to the main research objectives of the dissertation. The chapter will also focus on describing as well implications and limitations of the two studies. Finally, the chapter will close by describing what further research on the matter should focus.

It is important to mention that the studies were developed in conjunction with another doctoral student, whose focus was on examining how context-based task characteristics influence students' mental modelling abilities and overall performance. Each doctoral student has its own research focus under the same project: Physics in Context from the *UpGrade* Graduate School from the University of Koblenz-Landau. The project was funded by the German Research Association (*Deutsche ForschungsGemeinschaft/DFG*) during the period of 2013-2015.

Chapter 2

Study 1. An insight into the effects of task characteristics on students' motivation and performance

As indicated previously by research, real life context-based problems have specific task characteristics that can positively influence students' problem-solving strategies, motivation, and performance (Heller & Hollabaugh, 1991). Nevertheless, it is still unclear how the design of these task characteristics can influence students' motivational variables in a physics problem-solving task. Therefore, the goal of the first study was to explore how the students' interest, anxiety, and success expectancies change as a results from the different task characteristics in each problem-solving task. Students' cognitive abilities and prior knowledge were assessed as a way to control for moderating effects. In addition, the relation between the motivational variables and performance was examined. Though the model of task-learner interactions does not include performance, it still acknowledges the *theoretical assumption* (Hidi, 1990; Hidi & Renninger, 2006, Harackiewicz, Durik, Barron, Linnenbrink, & Tauer, 2008; Krapp & Prenzel, 2011) that there is a correlation between the motivation and students' performance. Therefore, it was included as part as this first study.

The research questions to be answered are the following:

1. *What are the effects of students' motivational variables when working on a context-based physics problem-solving task?*
2. *What are the moderating effects of students' prior knowledge and cognitive abilities on their motivational variables as a result of different task characteristics?*
3. *What is the influence of students' motivational variables on their performance?*

Based on the theoretical framework and model of task-learner interactions described in the section before, the hypotheses for the research questions are the following:

A) Interest after working with a highly contextualized task is higher than after working with a low contextualized task. As describe by theory, the interestingness present in a highly contextualized task, students' interest level will be increased by the end of the task.

B) Anxiety after working with a highly complex and transparent task is higher than after working with a low complex and transparent task. The task characteristics of complexity and transparency might increase the level of difficulty of the task, and as a result, the students' fear and stress.

C) Expected success after working with a highly complex and transparent task is higher than after working with a low complex and transparent task. According to theory (Wigfield & Eccles, 2000), learners' overall effort and persistence can be explained by their subjective beliefs on how well they will do on the task at hand. Highly complex and transparent tasks are considered to have high levels of "difficulty", therefore, it is expected that this tasks will negatively affect students' subjective beliefs of success.

D) Flow will be experience with a highly contextualized task than with a low contextualized task. Because interest is a precondition for individuals to experience flow (Nakamura & Csikzentmihalyi, 2005), it is expected that highly contextualized tasks might induce a flow state.

E) Covariates of prior knowledge and cognitive abilities will have a positive moderating effect when working with the task characteristics of complexity and transparency. As students' prior knowledge and cognitive abilities are necessary to induce proper cognitive activation in problem-solving processes, it is expected that this covariates could influence students' motivational variables.

F) Motivational variables have been theoretically considered as factors that may influence learning and performance (Hidi, 1990; Hidi & Renninger, 2006, Harackiewicz, Durik, Barron, Linnenbrink, & Tauer, 2008), it is expected that the motivational variable of interest will positively predict students' performance. Anxiety will negatively influence students' performance, and success expectancies will predict students' performance.

Method

Study design and procedure. The study follows a quantitative pre-post approach, where different experimental conditions are tested. The independent variable of task characteristics are tested to examine the effects on the dependent variables of the motivational variables (i.e. interest, anxiety, and success expectancies) and performance. Furthermore, the design takes into consideration and controls for the covariates of prior knowledge and cognitive abilities, as literature has constantly suggested that the level of general knowledge influences how learners approach a task (Chi & VanLehn, 2012).

The study was developed in a 90 minutes time frame in normal school hours. The experimenters informed the participants that they would be taking part of a physics study in which they would have to answer some questionnaires and a physics' task. The experimenters randomly distributed one of the eight different booklets (differences will be described in the next paragraphs, important is to highlight that each which a perceptually different superficial information) contain 1) cognitive abilities assessment, 2) prior knowledge assessment, 3) one version of a thermodynamics task, and 4) a questionnaire on current motivation (pre and posttest). Participants were informed that they would have to follow a time limit (for each section of the booklet), which would be managed by the experimenters. Explanations and instructions were also given at the beginning of every section. Participants were not familiar with any of the tests, thus preventing prior learning effects.

At the beginning, students' cognitive abilities and their prior knowledge in thermodynamics were evaluated. Afterwards, students received instructions concerning the tasks and immediately after, students completed a motivational questionnaire (first measurement point/pre-test). Students then started solving the task; during the task, students had to answer a flow state questionnaire. After solving the task, students had to complete again the motivational questionnaire given at the beginning (second measurement point/posttest).

The tasks[2] (Kauertz, Löffler, Fischer, 2014) used in the study described a convection (thermodynamics) problem situation to be solved. Though the task topic (thermodynamics) was kept the same for all versions, each version of the task was perceptually different to one another as a result of the level of contextualization and transparency (high or low). The highly contextualized versions described a real-life situation, which is the discovery of a glacier mummy named "Ötzi" (*Frozen Fritz*). The tasks contained the explanation concerning the mummy, artifacts, temperatures, and other images. The low contextualized versions presented the same convection problem, but using a traditional textbook approach, were abstract and detailed information of temperatures, symbols, and numbers are provided, and only one picture is included. The highly transparent versions include in the problem's description physics concepts, terms, and measurements of heat, whereas in the low transparent versions, less scientific and more common concepts are being used. The main difference between all tasks is how physics concepts are explicitly varied throughout each of the tasks.

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[2] The tasks used in this study were developed by *Patrick Löffler* (loeffler@uni-landau.de) as part of his doctoral dissertation, and therefore, will not be included in the appendixes. Please refer to his dissertation for further information on the matter.

Sample and data collection. In order to obtain an appropriate sample size, the software *G*-power (Faul, Erdfelder, Buchner, & Lang, 2009) was used. This software is used as a mean to plan a research study because it helps perform a statistical power analysis. By developing a power analysis one is able to simulate different scenarios (small to large effect sizes in an experimental manipulation) in order to select a realistic but yet statistically powerful sample.

The sample was collected through three schools from the state of *Rhineland-Palatine* which were contacted by email. After they agreed to participate, an informational meeting was schedule were the main goals of the study were presented. Furthermore, important information concerning time, dates, and distribution of classes were also discussed. Consent forms were handed to the physics' teachers, who distributed them to their students. The signed forms were picked up before the study began, in order to check which students were allowed by their parents to participate.

The sample consisted of 211 tenth grade students from six high-track classes (106 males, 105 female; mean age 15.44, *SD* = .59). Participants were randomly assigned to one of the eight versions of the thermodynamics task (Table 1).

Table 1

Eight versions of the thermodynamics task.

Group	**Description**	**Participants**
1	low complexity + high transparency + high contextualization	n = 27
2	low complexity + low transparency + high contextualization	n = 26
3	high complexity + high transparency + high contextualization	n = 27
4	high complexity + low transparency + high contextualization	n = 28
5	low complexity + high transparency + low contextualization	n = 28
6	high complexity + high transparency + low contextualization	n = 25
7	low complexity + low transparency + low contextualization	n = 24
8	high complexity + low transparency + low contextualization	n = 26

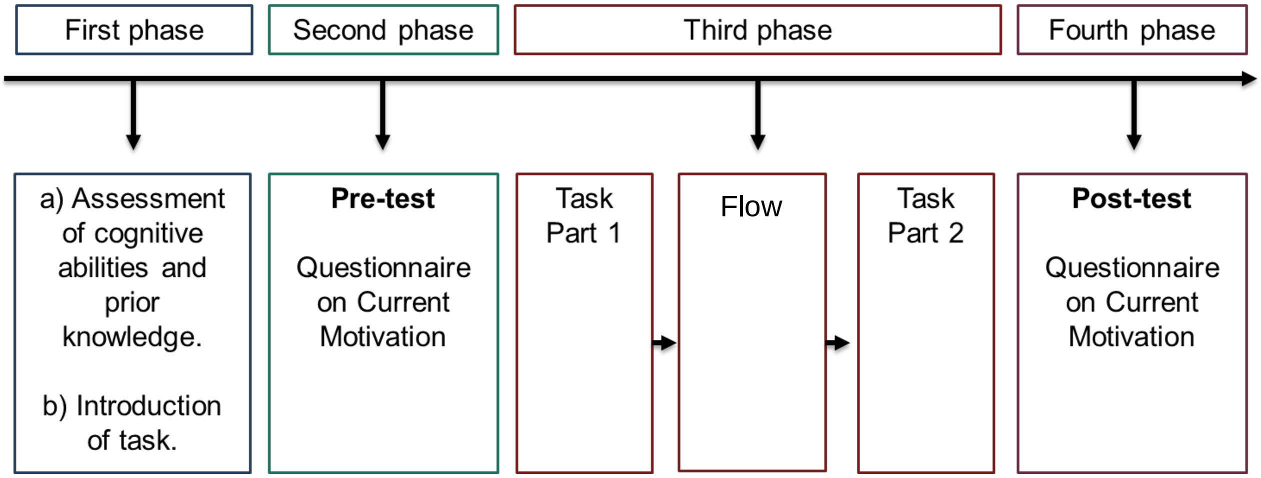

Fig. 8: Study 1 design

Measures[3]**.**

Cognitive abilities. Students' cognitive abilities were assessed using the subscales of verbal intelligence and spatial intelligence from the Intelligenz-Struktur-Test 200R (Amtheur, Brocke, Liepman & Beauducel, 2001). The IST 2000R (*Intelligenz-Struktur-Test 2000R*) is a multidimensional intelligence test developed by Liepmann, Beauducel, Brocke, and Amthaeur. The IST 2000R is used not only for aptitude diagnostic but as well in the clinical field to identify deficits of patients. The test is focused on examining the discrete factors of general intelligence stated by Cattel (1971), the fluid and crystallized intelligence. Fluid intelligence includes abilities such as pattern recognition, abstract reasoning, and problem solving. On the other hand, crystalized intelligence relies on specific acquired knowledge, meaning that when a person learns new facts, the individual's knowledge is expanded. Vocabulary tests or verbal subscales are measures of such type of intelligence.

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[3] Please refer to the Appendixes section for an overview of all the measures used in this doctoral dissertation.

The test consists of a basic module which includes nine tasks in total, but can also be expanded by applying the general knowledge test. The authors state that when used for diagnostic purposes, the complete test should be administered. For the case of research purposes, the test can be separated into subscales or individual components according to the demands of the study. The basic module of the test consists of:

- Subscale *Verbal Intelligence*:
    - Reasoning
    - Analogies
    - Similarities
- Subscale *Numerical Intelligence*:
    - Arithmetic Problems
    - Series of Numbers
    - Computing Characters
- Subscale *Spatial Intelligence*:
    - Figure Selection
    - Dice Tasks
    - Matrices

Following the authors' recommendations for the application of the IST 2000R, two subscales that address the demands of the study were selected: verbal and spatial intelligence. According to Newcombe and Frick (2010), research on cognitive processes has established that spatial intelligence is a main complement to verbal intelligence. Moreover, authors such as Sternberg and Gastel (1989) have shown that information processing on verbal and figural reasoning tasks can be very similar.

Both science and mathematics deal with complex mental representations, for which they both depend on verbal and spatial abilities. Mental modeling includes explicit representation of knowledge, where entities of a domain are expressed, as well as the qualitative relations and processes between entities in that particular domain (Gentner, 2002). Moreover, mental models are often based on implicit or explicit analogies with other knowledge, helping expand knowledge from a well-known domain to a less familiar domain. Gentner (2001) further suggests that not only individual make use of analogy to expand their knowledge when modelling, but as well, the use of similarity. According to previous research on both analogy and similarity, a key factor for expanding knowledge, *and therefore a mental model of a particular domain*, is identifying direct similarities between objects, but as well, the similarities between the relations that are hold among objects. As mental models not only involve the representation of knowledge but also the relations between different elements of that particular domain and other domains, an individual's spatial abilities become a key factor for such correspondences. Spatial abilities help understand the ordered relations between metaphors and diagrams or complex hierarchical relations Newcombe and Frick (2010). Such abilities become thinking tools that help display the distribution of variables, complex processes, and structures.

Therefore, to fulfill the goals of the study, the following scales from the verbal intelligence subscale were selected:

- Analogies (20 items): the individual must identify the relationship between two words and then apply the rule governing the relationship by selecting a word that shows a similar relationship to another given word.
- Similarities (20 items): individual needs to select two words (from a group of six) which have a collective term.

Due to time constraints, only the scale of figure selection (20 items) was selected from the subscale of spatial intelligence. Such scale consists on identifying which whole shape can be produced by fitting together the geometrical shapes shown. Such scale taps into an individual's ability to deal with complex elements, identify their relations, and make a coherent order out of it.

Prior knowledge. Students' conceptual understanding as an indicator of prior knowledge was evaluated using the Thermal Concept Evaluation (Yeo & Zadnick, 2001). This assessment is designed for students in the age range of 15-18 years old, and consisted of 26 multiple-choice questions. The questions are presented as a situated example that allows students to apply either their "everyday" physics or "classroom" physics. The Thermal Concept Evaluation is originally designed in English, but was translated into German and revised by a physics expert.

Motivational variables. Students' motivation was assessed using the Questionnaire on Current Motivation (QCM) (Rheinberg, Vollemeyer & Burns 2001). The QCM, is theoretically grounded on the authors' cognitive-motivational process model, and attempts captures learners' current motivation after they are given the instructions to do a task and before they have started. Authors state that current motivation changes during time invested in the tasks, and therefore, learners' motivation should change according to the characteristics of the task. Previous research has demonstrated the QCM scales' validity and reliability[4]. The Questionnaire on Current Motivation has been standardized and validated in several languages including English, French, and German. Therefore, there was no need to make any translations or validation procedure for the German version.

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[4] For further information on the scales' validity and reliability please see the article Motivational Effects on Self-Regulated Learning with Different Tasks by authors Reinberg & Vollemeyer, 2006.

The questionnaire consists of 18 items, which were rated on a 7-point rating scale. Participants responded on a 1 (strongly disagree) to 7 (strongly agree scale. The QCM assesses four motivational variables before and after the task at hand: interest ("after having read the instruction, the task seems to be very interesting to me"), anxiety ("I feel under pressure to do this task well"), success expectancies ("I think everyone could do well on this task"), and challenge ("this task is a real challenge for me"). This instrument was used as a pre and post measure.

Flow. Flow was measured using the Flow Short Scale (FSS) (Rheinberg et al. 2003). This scale measures all components of flow experience using ten items using a 7-point Likert type scale. The scale also includes three additional items to measure perceived importance, experienced difficulty, and perceived balance. These three items were measured using a 9-point Likert type scale. The FSS has been validated [5] and successfully used in different applications and settings, ranging from experimental to correlational studies. The Flow Short Scale has been standardized and validated in several languages including English, French, and German. As a result, there was no need to make any translations or validation procedure for the German version.

Results

The following section presents the results concerning the first study. The first two sub-sections will introduce preliminary analysis concerning the Questionnaire on Current Motivation, and the second will focus on the descriptive information on the dependent variables.

In accordance with the research questions, the following sections on results is divided into three main sub-sections. Such sub-sections will provide a mixed analysis of variance developed within a two measurement points, a moderating analysis of covariates, and finally a regression

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[5] For further information on the validation of the Flow Short Scale, please see the article *Die Erfassung des Flow-Erlebens* (The assessment of flow experience by Rheinberg & Vollmeyer, 2003.

model predicting students' performance.

Preliminary analysis. Table 1 presents the alpha values for the pre and posttest measurements obtained from the Questionnaire on Current Motivation. Overall reliability for the first time measurement (pre-test) was of α= .793, while the reliability score of the second measurement point (post-test) was of α= .845. Reliability measures show that the Questionnaire on Current Motivation is a strong reliable questionnaire as an instrument and separately when observed each scale.

Furthermore, a confirmatory factor analysis was done in each of the measurement points in order to observe the behavior of the loadings. Three stable factors were extracted (please see Appendixes K and L): interest, anxiety, and success expectancies. Nevertheless, the factor of challenge showed to be unstable, and its factor loadings were different from one measurement point to another. As a result, it was decided to drop the scale in the further analysis. Furthermore, despite having a low loading for the post-test of success expectancies, the factor was accepted. According to Tabachnick & Fidell (2007), the rule of thumb for accepting a factor would be for its loading to give approximately a 10% of the overlapping variance. In this case, the loading surpasses the 10% of the sample size (211 students).

Table 2

Reliability scores per scale.

Scale	**Pre-test-**	**Post-test**
Interest	α= .803	α= .863
Anxiety	α= .811	α= .852
Success Expectancies	α= .831	α= .346
Challenge	α= .461	α= .656

Descriptive Statistics. The means of the dependent variables of interest, success expectancies, and anxiety, show that most of the groups had a change from measurement point 1 to measurement point 2 (see Table 2). This information confirms that there are differences between groups, such differences could be attributed to the varying task characteristics. An important observation should be highlighted: *every* motivational variable in group 8 presents a change during the measurement points. In addition, students' flow and perceived importance of the task is different throughout each of the groups, suggesting a possible influence from task characteristics. The variables of motivational state, perceived difficulty, skill, and balance, remain relatively stable throughout the groups.

Table 3

Descriptive statistics of dependent variables according to group.

Group	Dependent Variable Pre-test	Mean	SD	Dependent Variable Post-test	Mean	SD
1	Interest t1	3,21	1,31	Interest t2	3,10	1,49
	Success Expectancies t1	3,56	0,69	Success Expectancies t2	3,65	0,97
	Anxiety t1	2,83	1,48	Anxiety t2	2,61	1,43
2	Interest t1	2,84	1,29	Interest t2	2,78	1,49
	Success Expectancies t1	3,81	0,70	Success Expectancies t2	3,48	1,03
	Anxiety t1	2,87	1,39	Anxiety t2	2,51	1,45
3	Interest t1	2,94	1,58	Interest t2	2,90	1,51
	Success Expectancies t1	3,57	0,71	Success Expectancies t2	3,77	1,02
	Anxiety t1	2,52	1,61	Anxiety t2	2,57	1,51
4	Interest t1	2,85	1,20	Interest t2	2,81	1,54
	Success Expectancies t1	3,66	0,56	Success Expectancies t2	3,52	0,62
	Anxiety t1	2,46	1,13	Anxiety t2	2,14	1,25
5	Interest t1	2,54	0,96	Interest t2	2,50	1,25
	Success Expectancies t1	3,69	0,81	Success Expectancies t2	3,35	0,74
	Anxiety t1	2,19	1,28	Anxiety t2	2,27	1,17
6	Interest t1	3,19	1,31	Interest t2	2,63	1,39
	Success Expectancies t1	3,45	0,58	Success Expectancies t2	3,55	0,85
	Anxiety t1	2,70	1,29	Anxiety t2	2,56	1,41
7	Interest t1	3,46	1,47	Interest t2	3,25	1,69
	Success Expectancies t1	3,72	0,83	Success Expectancies t2	3,69	0,77
	Anxiety t1	2,60	1,45	Anxiety t2	2,29	0,13
8	Interest t1	2,94	1,01	Interest t2	2,50	1,13
	Success Expectancies t1	3,78	0,63	Success Expectancies t2	3,59	0,74
	Anxiety t1	2,74	1,34	Anxiety t2	2,47	1,45

Table 4

Descriptive statistics of dependent variables according to group.

Group	Dependent Variable	Mean	SD	Dependent Variable	Mean	SD	Dependent Variable	Mean	SD
1	Motivational State	3,67	1,50	Flow	3,97	1,28	Importance	2,38	1,69
2	Motivational State	3,60	1,38	Flow	3,78	1,31	Importance	2,18	1,52
3	Motivational State	3,51	1,72	Flow	3,74	1,34	Importance	1,90	1,06
4	Motivational State	3,51	1,36	Flow	4,11	1,10	Importance	1,92	1,05
5	Motivational State	3,15	1,38	Flow	3,58	1,29	Importance	1,88	1,05
6	Motivational State	3,29	1,69	Flow	3,56	1,37	Importance	2,07	1,14
7	Motivational State	3,55	1,59	Flow	3,93	1,40	Importance	2,18	1,52
8	Motivational State	3,15	1,27	Flow	3,50	1,11	Importance	2,13	1,42

Group	Dependent Variable	Mean	SD	Dependent Variable	Mean	SD	Dependent Variable	Mean	SD
1	Difficulty	4,62	1,65	Skill	4,85	1,78	Balance	4,77	1,65
2	Difficulty	4,54	2,06	Skill	4,31	2,25	Balance	4,88	1,96
3	Difficulty	5,15	2,41	Skill	4,27	2,25	Balance	5,41	2,02
4	Difficulty	4,18	1,98	Skill	4,96	1,77	Balance	5,11	1,79
5	Difficulty	5,26	2,47	Skill	3,70	2,01	Balance	5,89	1,62
6	Difficulty	5,12	1,74	Skill	3,96	2,05	Balance	5,32	1,74
7	Difficulty	5,13	2,05	Skill	4,61	2,16	Balance	5,38	2,08
8	Difficulty	4,96	1,92	Skill	4,08	1,83	Balance	5,04	1,70

The effects of task characteristics on students’ motivational variables. The effects of task characteristics on students’ motivational variables of interest, anxiety, and success expectancies were analyzed with mixed ANOVAs. A mixed ANOVA compares the mean differences of groups that are divided into two factors (Field, 2013), commonly referred as independent variables (i.e. within-subjects/between-subjects). The main goal of a mixed ANOVA is to examine whether there is an interaction between the independent variables and the dependent variables. Using mixed ANOVAs allows as use a time factor (i.e. pre/post-test measures) as a within-subject factor, and investigate the effects of it on the dependent variables.

The task characteristic of contextualization (high and low) as between-subject factor and measurement time as within-subject factor did not have a significant effect on anxiety ($F(3, 196)= .780$, $p= .378$, $p < .05$ partial $\eta 2 = .004$) or success expectancies ($F(3, 196)= .395$, $p= .531$, $p < .05$ partial $\eta 2 = .002$). For the motivational variable of interest, results show a main effect of time, $F(1, 204)= 6.894$, $p= .009$, $p < .05$ partial $\eta 2 = .03$, and a marginal interaction effect, $F(1, 204)= 2.934$, $p=.088$ partial $\eta 2 = .01$, of time and contextualization level. Results indicated that students’ situational interest in the two conditions (low and high contextualization) evolved slightly different over time. Students’ situational interest (see Fig. 9) in low contextualized tasks slightly decreased, while students’ situational interest in the highly contextualized tasks was maintained during the two measurement points.

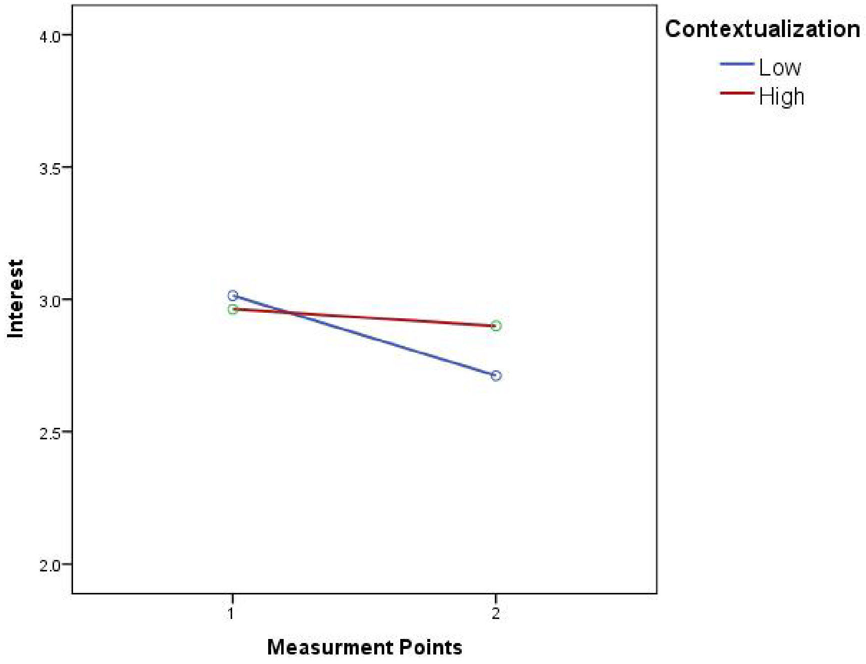

Fig. 9: Interest levels throughout measurement points for the task characteristic of contextualization.

The task characteristic of transparency (high and low) as between-subject factor and measurement time as within-subject factor did not have a significant effect on interest (*F*(3, 196)= .001, *p*= .982, $p < .05$ partial η2 = .000) or success expectancies (*F*(3, 196)= 2.341, *p*= .128, $p < .05$ partial η2 = .12). For the case of the motivational variable of anxiety, results showed a main effect of time, F(1, 202)= 6.723, p= .009, $p < .05$ partial η2 = .03, and a marginal interaction effect, F(1, 204)= 3.083, p= .077, $p < .05$ partial η2 = .01, of time and transparency level. Results indicate that students' anxiety in the two transparency conditions (low and high) changed over time. Students' anxiety slightly decreased in a low transparent task, while, students' anxiety in a highly transparent task maintained through the two measurement points.

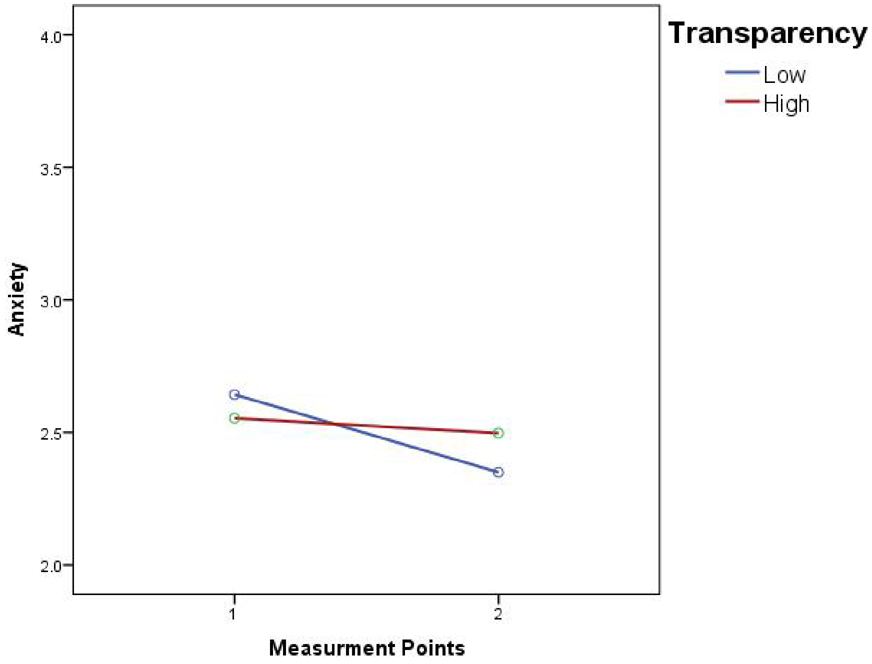

Fig. 10: Anxiety levels throughout measurement points for the task characteristic of transparency.

A three interaction effect was found for the task characteristics of contextualization and transparency, and time on the variable of success expectancies. Results show an interaction effect, F(1, 203)= 3.114, p= .056, p < .05 partial ɳ2 = .01, of time, contextualization, and transparency level. Results indicate that students' success expectancies slightly evolve in all conditions, that is in both high/low contextualization and high/low transparency. Students' success expectancies were maintained in the tasks where contextualization level was low and transparency levels were both low and high. On the other hand, in tasks where contextualization level is high, students' success expectancies slightly lowers when transparency is low, while students' success expectancies slightly increases when transparency level is high.

The task characteristic of complexity had no significant effect on either of the three motivational variables (interest, anxiety, and success expectancies). Moreover, it had no interaction effect with the other task characteristics of contextualization and transparency.

Finally, ANOVA analysis were conducted to investigate the effects of task characteristics on students' flow, experienced difficulty, perceived skill, perceived balance, and perceived importance. The task characteristics of contextualization, complexity, and transparency had no effect on the students' variables of perceived importance and perceived balance. However, the task characteristic of contextualization (high and low) show a marginal main effect on students' flow, $F(1, 4.56)= 3.09$, $p= .08$, $p < .05$ partial ɳ2 = .01, a marginal main effect on experienced difficulty, $F(1, 11.83)= 2.91$, $p=.089$ partial ɳ2 = .01, and a marginal main effect on perceived skill $F(1, 12.97)= 2.91$, $p=.066$ partial ɳ2 = .01. Results indicate that students experience higher levels of flow and perceived skill while answering a highly contextualized task. On the other hand, results show that students experience less difficulty when answering a highly contextualized task. Our results go in line with findings from Engeser and Rheinberg (2008), which indicate that flow depends on skill, and as well on difficulty. Results from our study suggest that highly contextualized tasks could help students perceive less difficulty and experience better flow.

Moderating effects of prior knowledge and cognitive abilities. The moderating effects of prior knowledge and cognitive abilities on students' motivational variables of interest, anxiety, and success expectancies were analyzed with a moderated linear regression. Results from the analysis showed no significant effect of moderators (i.e. prior knowledge and cognitive abilities) between task characteristics and students' interest and anxiety. Results, however, did show a marginal interaction effect, $F(7, 199)= 1.5382$, $p= .10$ partial ɳ2 = .003, of transparency and students' cognitive abilities on success expectancies. The expected success of low prior knowledge students was the same in both conditions, while the expectancies of success of students with high prior knowledge decreases in high transparent tasks.

Effects of students’ motivational variables on their performance. The effects of students’ motivational variables of interest, anxiety, and success expectancies on performance were analyzed through a linear regression analysis. Results showed a significant main effect of interest on students’ performance, $F(3, 203) = 3.209$, $p = .007$, $p < .05$ partial ɳ2 = .007, indicating that interest plays a role in predicting performance. There was also a marginal main effect of success expectancies on students’ performance, $F(3, 202) = 2.203$, $p = .09$, $p < .05$ partial ɳ2 = .005, suggesting that students’ beliefs concerning their success influences their performance. Finally, a significant interaction effect between interest and success expectancies on performance was found, $F(3, 202) = 6.676$, $p = .001$, $p < .05$ partial ɳ2 = .015, indicating that the two motivational variables can predict higher levels of performance. Nevertheless, no significant main effects or interaction effects were found in regards to the motivational variable of anxiety.

Discussion

The first study aimed to examine how task characteristics influence students’ motivational variables while working on a physics problem-solving task. It specifically explored the change of students’ interest, anxiety, and success expectancies as a result of the varying task characteristics of contextualization, transparency, and complexity (high and low). Furthermore, it was investigated whether the covariates of cognitive abilities and prior knowledge had a moderating effect on the motivational variables. Finally, it also explored the influence of students’ motivational variables on their performance. Findings indicate that only contextualization and transparency influence students’ motivational variables. However, the task characteristics influence each a specific motivational variable: contextualization has an effect on students’ interest, transparency influences students’ anxiety, while an interaction effect between contextualization and transparency has an effect on students’ success expectancies.

With respect to the effect of contextualization on students’ interest levels, contrary to our hypothesis, the results from our study show that contextualization does not increases interest through time. Nevertheless, results indicate that interest is maintained through the task. This finding is consistent with research developed by Durik and Harackiewicz (2007). In their research, the authors describe that certain task features such as contextualization, work according to a two phase process of catch and hold. From the results, one can observe that when answering a highly contextualized task, students’ interest was triggered (*catch*) and then held throughout the task. As theory suggests, the mechanism of catch promotes interest by the focused attention and stimulation from the context’s novelty, whereas, the mechanism of hold operates in a deeper level attributed to the context’s relevance and meaningfulness (Durik & Harackiewicz (2007).

Concerning the effect of transparency, results show that the task’s transparency level influences students’ overall effort and beliefs on how to solve the task. Previous research has showed that most students’ seemed confused when they encounter a problem which seems to “different” from traditional problems learned previously in class (Mandler, 1989). Students that believe that problems should be solve by using specific rules may feel stuck after trying to apply such rule and not being able to solve the problem. After trying too hard and knowing there is no other strategy to use, students’ might experience certain anxiety.

For the case of the last motivational variables, success expectancies, an interesting interaction was found. Our results indicate is that when high contextualization interacts with high transparency, students’ success expectancies is increased. Such result is quite interesting due to the fact that according to theory, high transparency influences students’ anxiety by increasing it, whereas a highly contextualized task triggers and holds interest. Our findings are in line to what Boekaerts

(1994) theorizes in her Adaptable Learning Model. According to the model, a task that seems exciting and interesting can help students reduce stress. As seen from our results, transparency interacting with contextualization work together to activate in students a coping mode. High levels of contextualization act as a “disguise” or a “buffer” to the abstract, complex, and “difficult” concepts used in highly transparent tasks that cause an increase in students’ anxiety levels.

Regarding the effects of moderators, our findings show no moderating effects of prior knowledge on students’ motivational variables. Results only show a marginally significant effect of students’ cognitive abilities on the motivational variable of success expectancies. What could be accounted for in this result is the fact that in highly transparent tasks the cues that link the surface feature with the deep structure, were more abstract, complex, and in other words more “difficult” to be perceived. As a result, high achieving students have the ability to identify such cues and this might cause an increased feeling of fear of failure.

It was also analyzed the effects of the motivational variables of interest, success expectancies, and anxiety on students’ performance, and it was shown how both interest and success expectancies were predictors of students’ final task achievement. In particular for the case of interest, it indicates that it can predict final performance, suggesting that students perform well on task they find meaningful and interesting to them. Despite having a relatively small effect of students’ success expectancies on performance, it is still consistent with previous research indicating that students’ own beliefs influences directly their behavior achievement and performance (Wigfield & Eccles, 2000). Students’ subjective beliefs of how well they will do on a task also influence the effort invested and the persistence to fulfil such task. Moreover the interaction found between interest and success expectancies is also in line with the idea that students feeling competent and able to succeed in a task may help them value and enjoy more what they do, consequently, leading to the developing of interest (Harackiewicz, Durik, Barron, Linnenbrink & Tauer, 2008).

Our findings yield information on how students’ motivation and performance is influenced by task characteristics. Nevertheless, some questions still remain open: 1) can such results be generalized to other physics’ topics such as mechanics, optics, or electricity? And if so, 2) would the task characteristics have the same effects as in this first study? Furthermore, in the first study only one task was developed during a limited period of time, would there be any other effects is students are faced to work different tasks during a longer period of time? Finally, it is necessary to highlight the fact that study´s results provide information on the online cognitive processing responses, in other words, the control decisions that are implemented via cognitive and metacognitive strategies. Nevertheless, as Efklides (2009) has stated, control has to be first monitored, which would then give direction to the control of cognitive processing, that is, the actions and behaviors. Monitoring is a basic step developed by metacognitive experiences, it provides sense and direction to action made by an individual. It would be of high importance to tap into learners’ metacognitive experiences, as they are the interface between person and task at hand (Efklides, 2009), and the input for developing any action.

Chapter 3

Study 2. The effects of task topic and task characteristics on students´ motivation and metacognitive experiences

The first study, provided important information concerning the change of students’ motivation as a result of task characteristic. However, several questions were raised: 1) how would task characteristics work in other physics’ topics, 2) would there be different effects on students’ motivation, and finally, 3) how are task characteristics affecting students’ metacognitive processing. The second study aims to examine how the task’s topic (i.e., mechanics and thermodynamics) and task characteristics interact and influence students’ motivation, metacognitive processing, and performance. The research questions to be answered are the following:

- *What are the effects of the variables of contextualization, complexity, and transparency on students’ interest and metacognitive experiences in physics problem-solving situations?*
- *How do task topic and task characteristics (i.e., contextualization, complexity, and transparency) influence students’ interest?*

Based on the theoretical framework described in the first section and the results from the first study, the hypotheses for the research questions are the following:

A) Interest after working with a highly contextualized task will stay stable. On the other hand, interest will decrease after working with a low contextualized task. Following our findings from the first study, it is expected our data to show how interest was caught and held throughout the tasks.

B) Liking after working with a highly contextualized task is higher than after working with a low contextualized task. Given the results from the first study, students are more interested and experience flow in a highly contextualized task. Therefore, one would expect students experience flow as a result of interest and liking of the task at hand (Nakamura & Csikzentmihalyi, 2005).

C) Feeling of difficulty and estimate of effort after working with a highly complex and transparent task are higher than after working with a low complex and transparent task. As examined in Study 1, students' anxiety was higher in highly transparent task. It is assumed that task difficulty is higher in such tasks and therefore will increase their effort.

D) Estimate of solution correctness after working with a highly complex and transparent task is lower than after working with a low complex and transparent task. Highly complex and transparent tasks are considered to be more difficult compared to a lower task. As observed from the first study´s findings, students' anxiety levels were higher when working with highly transparent tasks. As a result, students' subjective beliefs of how correct their answers or solutions are will be affected by how difficult they perceive the task.

E) Feeling of confidence and satisfaction after working with a highly complex and transparent task is lower than after working with a low complex and transparent task. It is expected that the feeling of difficulty will interfere with students' feeling of confidence and satisfaction. Because it is expected that students' estimate of solution correctness will be low while working on a highly complex and transparent task, this in return will affect their subjective feelings of confidence and satisfaction on the solutions they provided.

F) There is no previous research that states any type of topic effect on students' interest or metacognitive experiences. Therefore, there are no hypothesis regarding the effects of task topic.

Method

Study design and procedure. The study follows a quantitative pre-post approach, where different experimental conditions are tested. The independent variables of task topic and characteristics are tested to examine the effects on the dependent variables of the motivation and metacognitive experiences. Furthermore, the design takes into consideration students' metacognitive awareness and controls for the covariates of subject-specific interest and prior knowledge.

The study was developed in a 90 minutes time frame in normal school hours. Despite recognizing that time might have an influence on students' responses, it was no possible to extend the time frame for our second study. The study is limited to the time frame that teachers allows us to conduct the study in their classroom. The experimenters informed the participants that they would be taking part of a physics study in which they would have to answer some questionnaires and a physics' task. The experimenters randomly distributed one of the eight different booklets which contain 1) subject-specific interest questionnaire, 2) prior knowledge assessment, 3) a metacognitive awareness inventory, 4) two different physics tasks (thermodynamics and mechanics), and 5) the metacognitive experiences questionnaire (pre and posttest for each physics task.). Participants were informed that they would have to follow a time limit (for each section of the booklet), which would be managed by the experimenters. Explanations and instructions were also given at the beginning of every section. Participants were not familiar with any of the tests, thus preventing prior learning effects.

At the beginning, students' subject-specific interest and their prior knowledge in general physics were evaluated. Afterwards, students answered the metacognitive awareness inventory, which. Students then received instructions concerning the tasks and immediately after, students completed the metacognitive experiences questionnaire (first measurement point/pre-test). Students then started solving the task. After solving the task, students had to complete again the same metacognitive experiences questionnaire (second measurement point/posttest). Immediately after, students started answering the second task which followed the same procedure mentioned before.

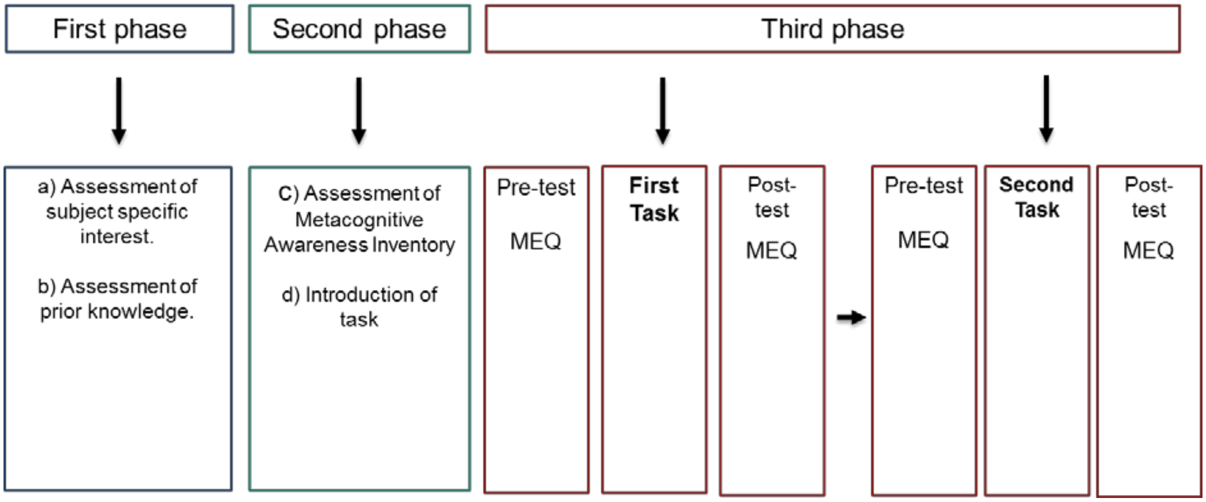

Fig. 11: Study design

The tasks used in the study described a convection (thermodynamics) and a force (mechanics) problem situation to be solved. The tasks were organized in such a way that each booklet contains two exactly opposite task; this means that the two task had a two different topics with the opposite task characteristics. For the thermodynamics task, the same task was used as the first study ("Ötzi" mummy/*Frozen Fritz*). For the mechanics task[6] (Pozas, Löffler, Schnotz & Kauertz, 2015), the topic of force was implemented. The highly contextualized versions compared two car crashes. The tasks contained an explanation concerning the type of cars, the material they were made of, the crash itself, and the damages of it. The low contextualized versions presented the same force problem, but using a traditional textbook approach, where as well to cases are presented using abstract and detailed information of objects, symbols, and numbers are given, and only one picture is included. The highly transparent versions include in the problem's description physics concepts,

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[6] The tasks used in this study were developed by *Patrick Löffler* (loeffler@uni-landau.de), please contact Dr. Patrick Löffler for further information.

terms, and measurements of force, while in the low transparent versions, less scientific and more common concepts are being used. The main difference is that in all tasks, physics concepts are explicitly varied throughout each of the tasks.

Sample and data collection. Calculations for the sample size were once again computed using software *G*-power (Faul, Erdfelder, Buchner, & Lang, 2009). The sample was collected through three schools from the state of *Rhineland-Palatine* which were contacted by email. Informal meetings were develop to present the research project and to discuss important information concerning time, dates, and the total classes to participate. The consent forms were also handed to the teachers during such meeting. Before the study started, the signed forms were picked up and revised.

The sample consisted of 250 tenth grade students from six high-track classes (101 males, 150 female; mean age 15.27, *SD* = .72). Participants were randomly assigned to one of the sixteen booklet versions (*in the results section booklets will be renamed as groups*):

Table 5

Sixteen booklet versions of the thermodynamics and mechanics task.

Booklet	**Participants**
I	n = 16
II	n = 16
III	n = 16
IV	n = 15
V	n = 16
VI	n = 16
VII	n = 16
VIII	n = 16
IX	n = 16
X	n = 16

XI	n = 16
XII	n = 15
XIII	n = 15
XIV	n = 15
XV	n = 15
XVI	n = 15

Measures

Subject-specific interest. Students' subject-specific interest was assessed using specific items from the student questionnaire for interest concerning physics and technology[7] by Hoffmann, Häußler, and Lehrke (1998) (*Schülerfragebogen zur Veränderung von Schülerinteressen an Physik und Technik vom 5. bis 10. Schuljahr*). The authors suggest using three items from the original questionnaire, these are: 1) students must rate (4 point Likert-scale) how interesting they find every school subject from a list, 2) describe and rate (4 point Likert-scale) the physics topics that the student has learned, 3) rate (4 point Likert-scale) how interesting students' find physics.

The questionnaire is originally in the German language, hence, there was no need to make any translations or validation procedure for the German version.

Prior Knowledge. Students' prior knowledge was measured using a selection of items from the *Institut zur Qualitätsentwicklung im Bildungswesen* (IQB) test. The IQB[8] develops test items based on the educational standards for primary schools and secondary level. A selection of items from the physics test were revised and selected to cover expected gymnasium tenth grade knowledge. Answers were marked as correct or incorrect; students received a point for ever correct answer. The

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[7] For further information on the validation of the questionnaire on students' interest concerning physics and technology, please refer to the article *Schülerfragebogen zur Veränderung von Schülerinteressen an Physik und Technik vom 5. bis 10. Schuljahr* by Hoffmann, Häußler, and Lehrke (1998).

[8] For further information on the validation of the test items for physics competences, please contact the *Institut zur Qualitätsentwicklung im Bildungswesen,* website: https://www.iqb.hu-berlin.de/institut.

questionnaire is originally in the German language, hence, there was no need to make any translations or validation procedure for the German version.

Metacognitive Awareness. Research has indicated that metacognitively aware learners are more strategic and have better performance than unaware learners. According to Schraw and Dennison (1994), metacognitive awareness allows individuals to plan, sequence, and monitor their own learning in such a way that it positively influences performance. Furthermore, the authors have found that differences in performance were related to differences in metacognitive awareness rather than differences concerning cognitive abilities. In light of such findings, the metacognitive awareness of students was also measured and controlled for using the Metacognitive Awareness Inventory[9] developed by Schraw and Dennison (1994). The inventory is a 52-item self-report instrument, which contains eight scales: 1) declarative knowledge, 2) procedural knowledge, 3) conditional knowledge, 4) planning, 5) information management strategies, 6) comprehension monitoring, 7) debugging strategies, and 8) evaluation of learning.

Individuals complete the inventory by selecting how *true* or *false* is the statement applicable to them. The inventory is originally developed, standardized, and validated in the English language, hence, translation to German was done. The instrument was first translated by a bilingual student assistant, then revised by an English language expert from the University of Koblenz-Landau *UpGrade* Graduate School. The final translation was revised and approved by Professor Doctor Wolfgang Schnotz, Professor for General and Educational Psychology of the University of Koblenz-Landau.

Metacognitive Experiences. Metacognition has a double role (Efklides, 2001): to develop a representation of cognition based on monitoring processes, and exercise control on cognition based

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[9] For further information on the validation of the Metacognitive Awareness Inventory, please refer to the article *Assessing Metacognitive Awareness* by Schraw and Dennison (1994).

on the representation of control. One of the two manifestations of the monitoring function is metacognitive experiences (ME). ME are quite precise, meaning that they focus on specific aspects of cognitive processing, and can be affectively stimulated: ME can influence how individuals affectively approach and cognitively develop a learning task.

To examine how students' ME were influenced by the learning task, the Metacognitive Experiences Questionnaire[10] (MEQ) (Efklides, 2002) was used. The MEQ consist of two sets of items measuring retrospective and prospective metacognitive experiences as well as interest and liking of the task. They comprised single item measures for each of the ME and interest and liking before and after problem-solving. Students responded on a 4-point Likert-scale. The ME assessed include: feeling of difficulty (FOD), estimate of effort (EOE), estimate of solution correctness (EOC), feeling of confidence (FOC), and feeling of satisfaction (FOS). The last two ME were measured only after the problem-solving task.

The questionnaire is originally developed, standardized, and validated in the English language, hence, translation to German was done. The instrument was first translated by a bilingual student assistant, then revised by an English language expert from the University of Koblenz-Landau *UpGrade* Graduate School. The final translation was revised and approved by Professor Doctor Wolfgang Schnotz, Professor for General and Educational Psychology of the University of Koblenz-Landau.

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[10] For further information on the validation of the Metacognitive Experiences Questionnaire, please refer to the article *The systemic nature of metacognitive experiences: Feelings, judgements, and their interrelations* by Efklides (2002).

Results

In accordance with the research questions, the section on results is divided into two main sections. First, after the descriptive information on the dependent variables, a mixed multivariate analysis of variance illustrating the effects of task characteristics on students’ interest and metacognitive experiences will be reported.

The second main sub-section will focus on changes in metacognitive experiences triggered by the different task topic and task characteristics. A mixed multivariate analysis of variance and analysis of variance concerning the effects of the independent variables will be reported.

Descriptive Statistics. The means of the dependent variables of interest, liking, and metacognitive experiences had a change in each group from measurement point 1 to measurement point 2 (see Table 2). This information confirms that there are differences between groups, such differences could be attributed to the varying task characteristics. It is necessary to note that in addition, when observed within each of the topic tasks (mechanics and thermodynamics) one can also find differences. This suggests that not only there is effects of task characteristics, but more importantly as well, differences between topics.

Table 6

Descriptive statistics of dependent variables according to group and task topic of mechanics

Group	Task	Dependent Variable Pre-test	Mean	SD	Dependent Variable Post-test	Mean	SD
1	**M**	Interest t1	3,06	0,85	Interest t2	3,00	0,73
		Liking t1	2,75	0,77	Liking t2	2,62	0,80
		Feeling of Difficulty t1	2,75	0,77	Feeling of Difficulty t2	2,88	0,88
		Estimate of Effort t1	2,81	0,75	Estimate of Effort t2	2,81	0,65
		Estimate of Solution Correctness t1	2,63	0,61	Estimate of Solution Correctness t2	2,75	0,77
2	**M**	Interest t1	3,00	0,73	Interest t2	2,69	1,13
		Liking t1	2,69	0,87	Liking t2	2,31	1,01
		Feeling of Difficulty t1	2,62	0,50	Feeling of Difficulty t2	2,87	0,71
		Estimate of Effort t1	2,81	0,75	Estimate of Effort t2	3,00	0,81
		Estimate of Solution Correctness t1	2,69	0,70	Estimate of Solution Correctness t2	2,44	1,03
3	**M**	Interest t1	2,69	1,01	Interest t2	2,56	1,03
		Liking t1	3,06	1,91	Liking t2	2,25	0,85
		Feeling of Difficulty t1	2,56	0,81	Feeling of Difficulty t2	2,81	0,91
		Estimate of Effort t1	2,88	0,80	Estimate of Effort t2	2,81	0,65
		Estimate of Solution Correctness t1	3,19	1,83	Estimate of Solution Correctness t2	2,25	1,18
4	**M**	Interest t1	2,53	0,91	Interest t2	2,33	0,97
		Liking t1	2,87	1,84	Liking t2	1,87	0,83
		Feeling of Difficulty t1	2,60	0,91	Feeling of Difficulty t2	2,87	0,91
		Estimate of Effort t1	2,73	0,96	Estimate of Effort t2	2,87	0,83
		Estimate of Solution Correctness t1	2,47	0,74	Estimate of Solution Correctness t2	2,00	0,75
5	**M**	Interest t1	2,69	0,79	Interest t2	2,44	0,72
		Liking t1	2,44	0,96	Liking t2	2,13	0,71
		Feeling of Difficulty t1	2,94	0,77	Feeling of Difficulty t2	3,06	0,92
		Estimate of Effort t1	3,19	1,68	Estimate of Effort t2	3,38	1,74
		Estimate of Solution Correctness t1	2,75	1,91	Estimate of Solution Correctness t2	2,06	0,99
6	**M**	Interest t1	2,69	0,94	Interest t2	2,38	0,88
		Liking t1	2,25	1,00	Liking t2	2,31	0,79
		Feeling of Difficulty t1	2,56	0,89	Feeling of Difficulty t2	2,81	0,75
		Estimate of Effort t1	2,87	0,80	Estimate of Effort t2	3,00	0,89
		Estimate of Solution Correctness t1	2,44	0,81	Estimate of Solution Correctness t2	2,31	0,87
7	**M**	Interest t1	2,31	0,87	Interest t2	1,87	0,95
		Liking t1	2,00	0,63	Liking t2	1,75	0,77
		Feeling of Difficulty t1	2,81	0,98	Feeling of Difficulty t2	2,94	0,99
		Estimate of Effort t1	2,75	0,77	Estimate of Effort t2	2,94	0,99
		Estimate of Solution Correctness t1	2,69	0,87	Estimate of Solution Correctness t2	2,50	2,00
8	**M**	Interest t1	2,50	0,89	Interest t2	2,44	0,96
		Liking t1	2,25	0,85	Liking t2	2,25	0,77
		Feeling of Difficulty t1	2,81	0,83	Feeling of Difficulty t2	2,81	0,75
		Estimate of Effort t1	2,81	0,91	Estimate of Effort t2	2,81	0,83
		Estimate of Solution Correctness t1	2,69	0,94	Estimate of Solution Correctness t2	2,56	0,72

Group	Task	Dependent Variable Pre-test	Mean	SD	Dependent Variable Post-test	Mean	SD
9	**M**	Interest t1	2,44	0,72	Interest t2	2,31	0,79
		Liking t1	2,44	0,81	Liking t2	2,38	0,88
		Feeling of Difficulty t1	3,38	1,66	Feeling of Difficulty t2	3,00	0,89
		Estimate of Effort t1	3,13	0,71	Estimate of Effort t2	2,81	0,91
		Estimate of Solution Correctness t1	2,50	0,51	Estimate of Solution Correctness t2	2,56	0,62
10	**M**	Interest t1	2,06	0,85	Interest t2	2,00	1,03
		Liking t1	2,13	0,80	Liking t2	2,06	0,85
		Feeling of Difficulty t1	3,06	0,85	Feeling of Difficulty t2	3,00	0,81
		Estimate of Effort t1	3,25	0,85	Estimate of Effort t2	2,75	0,85
		Estimate of Solution Correctness t1	2,25	0,68	Estimate of Solution Correctness t2	1,87	0,61
11	**M**	Interest t1	2,06	0,99	Interest t2	2,19	1,10
		Liking t1	2,00	0,89	Liking t2	2,12	1,02
		Feeling of Difficulty t1	2,94	0,68	Feeling of Difficulty t2	3,00	0,63
		Estimate of Effort t1	3,13	0,71	Estimate of Effort t2	3,06	0,77
		Estimate of Solution Correctness t1	2,31	0,79	Estimate of Solution Correctness t2	2,56	1,03
12	**M**	Interest t1	2,13	0,91	Interest t2	2,40	1,05
		Liking t1	2,13	0,74	Liking t2	2,20	0,86
		Feeling of Difficulty t1	3,13	0,64	Feeling of Difficulty t2	3,13	0,64
		Estimate of Effort t1	3,00	0,53	Estimate of Effort t2	3,13	0,83
		Estimate of Solution Correctness t1	2,20	0,67	Estimate of Solution Correctness t2	2,00	0,75
13	**M**	Interest t1	3,53	1,68	Interest t2	2,80	0,84
		Liking t1	3,40	1,72	Liking t2	2,73	0,96
		Feeling of Difficulty t1	3,67	2,22	Feeling of Difficulty t2	2,67	0,61
		Estimate of Effort t1	3,20	1,74	Estimate of Effort t2	2,73	0,70
		Estimate of Solution Correctness t1	3,13	1,76	Estimate of Solution Correctness t2	2,53	0,99
14	**M**	Interest t1	2,87	0,83	Interest t2	2,80	0,86
		Liking t1	2,67	0,81	Liking t2	2,33	0,81
		Feeling of Difficulty t1	2,80	0,56	Feeling of Difficulty t2	2,67	0,81
		Estimate of Effort t1	2,80	0,86	Estimate of Effort t2	2,73	0,88
		Estimate of Solution Correctness t1	2,53	0,74	Estimate of Solution Correctness t2	2,53	0,99
15	**M**	Interest t1	2,33	0,97	Interest t2	2,40	0,92
		Liking t1	2,13	0,83	Liking t2	2,40	0,82
		Feeling of Difficulty t1	2,87	0,74	Feeling of Difficulty t2	2,73	0,88
		Estimate of Effort t1	3,20	0,67	Estimate of Effort t2	2,60	0,63
		Estimate of Solution Correctness t1	2,53	0,83	Estimate of Solution Correctness t2	2,60	1,05
16	**M**	Interest t1	2,67	0,90	Interest t2	2,53	0,99
		Liking t1	2,60	0,98	Liking t2	2,47	0,91
		Feeling of Difficulty t1	3,27	1,83	Feeling of Difficulty t2	2,93	1,10
		Estimate of Effort t1	3,13	0,74	Estimate of Effort t2	3,07	0,88
		Estimate of Solution Correctness t1	2,60	0,98	Estimate of Solution Correctness t2	2,40	0,98

Table 7

Descriptive statistics of dependent variables according to group and task topic of thermodynamics

Group	Task	Dependent Variable Pre-test	Mean	SD	Dependent Variable Post-test	Mean	SD
1	T	Interest t1	2,44	0,96	Interest t2	2,38	0,95
		Liking t1	2,00	0,73	Liking t2	2,06	0,99
		Feeling of Difficulty t1	2,88	0,88	Feeling of Difficulty t2	3,50	1,71
		Estimate of Effort t1	3,06	0,68	Estimate of Effort t2	3,00	0,81
		Estimate of Solution Correctness t1	2,50	0,73	Estimate of Solution Correctness t2	2,13	0,88
2	T	Interest t1	2,50	1,03	Interest t2	2,31	1,07
		Liking t1	2,19	0,75	Liking t2	2,19	0,91
		Feeling of Difficulty t1	2,94	0,68	Feeling of Difficulty t2	3,00	0,89
		Estimate of Effort t1	3,06	0,68	Estimate of Effort t2	2,94	0,99
		Estimate of Solution Correctness t1	2,25	0,77	Estimate of Solution Correctness t2	2,19	0,91
3	T	Interest t1	2,44	0,96	Interest t2	2,19	0,91
		Liking t1	2,31	0,87	Liking t2	1,94	0,99
		Feeling of Difficulty t1	3,50	0,51	Feeling of Difficulty t2	3,19	0,75
		Estimate of Effort t1	3,31	0,60	Estimate of Effort t2	3,13	0,71
		Estimate of Solution Correctness t1	2,81	1,75	Estimate of Solution Correctness t2	2,38	1,14
4	T	Interest t1	2,40	1,05	Interest t2	2,20	1,01
		Liking t1	2,40	1,18	Liking t2	2,13	1,06
		Feeling of Difficulty t1	2,60	1,05	Feeling of Difficulty t2	2,67	1,04
		Estimate of Effort t1	2,53	0,99	Estimate of Effort t2	2,73	4,03
		Estimate of Solution Correctness t1	2,47	1,06	Estimate of Solution Correctness t2	2,80	1,01
5	T	Interest t1	2,94	0,92	Interest t2	3,25	1,80
		Liking t1	2,69	1,01	Liking t2	3,00	1,86
		Feeling of Difficulty t1	3,13	1,74	Feeling of Difficulty t2	3,94	2,14
		Estimate of Effort t1	3,38	1,70	Estimate of Effort t2	3,69	2,24
		Estimate of Solution Correctness t1	2,25	0,85	Estimate of Solution Correctness t2	2,38	1,96
6	T	Interest t1	2,88	0,88	Interest t2	2,75	1,00
		Liking t1	2,44	0,96	Liking t2	2,31	1,07
		Feeling of Difficulty t1	2,87	0,71	Feeling of Difficulty t2	3,00	0,63
		Estimate of Effort t1	3,19	0,83	Estimate of Effort t2	3,06	0,77
		Estimate of Solution Correctness t1	2,56	1,86	Estimate of Solution Correctness t2	2,06	0,85
7	T	Interest t1	2,50	0,81	Interest t2	2,37	0,80
		Liking t1	2,25	0,77	Liking t2	2,19	0,91
		Feeling of Difficulty t1	2,81	0,91	Feeling of Difficulty t2	3,19	1,72
		Estimate of Effort t1	2,81	0,75	Estimate of Effort t2	3,06	1,76
		Estimate of Solution Correctness t1	2,38	0,95	Estimate of Solution Correctness t2	2,56	0,81
8	T	Interest t1	3,00	0,81	Interest t2	2,75	1,18
		Liking t1	2,75	0,68	Liking t2	2,19	1,04
		Feeling of Difficulty t1	3,00	0,73	Feeling of Difficulty t2	3,13	0,80
		Estimate of Effort t1	3,19	0,54	Estimate of Effort t2	2,81	1,04
		Estimate of Solution Correctness t1	2,25	0,68	Estimate of Solution Correctness t2	2,37	1,02

Group	Task	Dependent Variable Pre-test	Mean	SD	Dependent Variable Post-test	Mean	SD
9	**T**	Interest t1	3,06	0,44	Interest t2	2,44	0,81
		Liking t1	2,75	0,57	Liking t2	2,44	0,72
		Feeling of Difficulty t1	3,06	0,57	Feeling of Difficulty t2	2,94	0,85
		Estimate of Effort t1	3,13	0,50	Estimate of Effort t2	3,00	0,81
		Estimate of Solution Correctness t1	2,50	0,51	Estimate of Solution Correctness t2	2,44	0,62
10	**T**	Interest t1	3,25	0,44	Interest t2	2,75	1,06
		Liking t1	2,69	0,79	Liking t2	2,25	0,93
		Feeling of Difficulty t1	3,06	0,99	Feeling of Difficulty t2	3,00	0,89
		Estimate of Effort t1	3,06	0,92	Estimate of Effort t2	3,13	0,61
		Estimate of Solution Correctness t1	2,25	0,93	Estimate of Solution Correctness t2	1,88	0,95
11	**T**	Interest t1	2,88	0,71	Interest t2	2,38	0,95
		Liking t1	2,69	0,70	Liking t2	2,19	0,92
		Feeling of Difficulty t1	2,63	0,71	Feeling of Difficulty t2	2,88	0,61
		Estimate of Effort t1	2,75	0,85	Estimate of Effort t2	2,81	0,83
		Estimate of Solution Correctness t1	2,31	0,70	Estimate of Solution Correctness t2	2,50	1,96
12	**T**	Interest t1	3,13	0,74	Interest t2	2,87	0,99
		Liking t1	2,73	0,70	Liking t2	2,47	0,83
		Feeling of Difficulty t1	2,73	0,79	Feeling of Difficulty t2	2,93	0,88
		Estimate of Effort t1	3,00	1,00	Estimate of Effort t2	3,00	0,85
		Estimate of Solution Correctness t1	2,67	0,81	Estimate of Solution Correctness t2	2,33	1,04
13	**T**	Interest t1	2,47	0,91	Interest t2	2,27	0,88
		Liking t1	2,33	0,90	Liking t2	2,07	0,88
		Feeling of Difficulty t1	2,93	0,59	Feeling of Difficulty t2	3,27	0,70
		Estimate of Effort t1	3,00	0,65	Estimate of Effort t2	3,33	0,72
		Estimate of Solution Correctness t1	2,73	0,70	Estimate of Solution Correctness t2	2,20	0,94
14	**T**	Interest t1	2,47	0,83	Interest t2	2,60	1,95
		Liking t1	2,20	0,86	Liking t2	2,40	1,95
		Feeling of Difficulty t1	3,07	0,59	Feeling of Difficulty t2	3,53	1,72
		Estimate of Effort t1	3,53	0,51	Estimate of Effort t2	3,53	1,59
		Estimate of Solution Correctness t1	2,47	0,74	Estimate of Solution Correctness t2	2,47	1,95
15	**T**	Interest t1	3,13	0,64	Interest t2	3,20	1,78
		Liking t1	2,53	0,74	Liking t2	2,87	1,84
		Feeling of Difficulty t1	2,80	0,56	Feeling of Difficulty t2	3,27	1,66
		Estimate of Effort t1	3,07	0,59	Estimate of Effort t2	3,07	1,75
		Estimate of Solution Correctness t1	2,53	0,64	Estimate of Solution Correctness t2	3,13	1,76
16	**T**	Interest t1	2,53	0,74	Interest t2	2,33	0,90
		Liking t1	2,13	0,64	Liking t2	2,33	1,17
		Feeling of Difficulty t1	3,20	1,74	Feeling of Difficulty t2	2,87	0,74
		Estimate of Effort t1	3,07	0,96	Estimate of Effort t2	2,93	0,79
		Estimate of Solution Correctness t1	2,60	0,63	Estimate of Solution Correctness t2	2,67	1,95

Table 8

Descriptive statistics of feeling of confidence and satisfaction according to group and task topic

Group	Task	Dependent Variable	Mean	SD	Task	Dependent Variable	Mean	SD
1	**M**	Feeling of Confidence	2,44	0,72	**T**	Feeling of Confidence	2,06	0,99
		Feeling of Satisfaction	2,81	0,65		Feeling of Satisfaction	2,38	0,88
2	**M**	Feeling of Confidence	2,13	1,02	**T**	Feeling of Confidence	2,13	1,08
		Feeling of Satisfaction	2,63	1,08		Feeling of Satisfaction	2,19	0,91
3	**M**	Feeling of Confidence	2,31	1,07	**T**	Feeling of Confidence	2,06	1,12
		Feeling of Satisfaction	3,06	1,87		Feeling of Satisfaction	2,31	1,07
4	**M**	Feeling of Confidence	2,13	0,91	**T**	Feeling of Confidence	2,53	0,91
		Feeling of Satisfaction	2,6	0,98		Feeling of Satisfaction	3,00	0,92
5	**M**	Feeling of Confidence	2,5	2,03	**T**	Feeling of Confidence	2,63	2,6
		Feeling of Satisfaction	2,19	0,98		Feeling of Satisfaction	2,63	1,96
6	**M**	Feeling of Confidence	2,06	0,99	**T**	Feeling of Confidence	1,87	0,71
		Feeling of Satisfaction	2,5	1,03		Feeling of Satisfaction	2,88	1,89
7	**M**	Feeling of Confidence	2,44	1,96	**T**	Feeling of Confidence	2,62	0,95
		Feeling of Satisfaction	2,50	1,21		Feeling of Satisfaction	2,81	0,98
8	**M**	Feeling of Confidence	2,44	0,81	**T**	Feeling of Confidence	2,37	1,02
		Feeling of Satisfaction	2,94	0,92		Feeling of Satisfaction	2,62	1,08
9	**M**	Feeling of Confidence	2,44	0,72	**T**	Feeling of Confidence	2,13	0,71
		Feeling of Satisfaction	2,63	0,88		Feeling of Satisfaction	2,37	0,88
10	**M**	Feeling of Confidence	1,75	0,57	**T**	Feeling of Confidence	1,88	0,8
		Feeling of Satisfaction	2,44	0,96		Feeling of Satisfaction	2,31	0,94
11	**M**	Feeling of Confidence	2,44	1,09	**T**	Feeling of Confidence	2,06	1,12
		Feeling of Satisfaction	2,31	0,94		Feeling of Satisfaction	2,44	1,09
12	**M**	Feeling of Confidence	1,87	0,74	**T**	Feeling of Confidence	2,07	0,88
		Feeling of Satisfaction	2,40	0,82		Feeling of Satisfaction	2,33	1,04
13	**M**	Feeling of Confidence	2,53	0,91	**T**	Feeling of Confidence	2,07	0,88
		Feeling of Satisfaction	2,87	0,74		Feeling of Satisfaction	2,33	1,04
14	**M**	Feeling of Confidence	2,40	1,05	**T**	Feeling of Confidence	2,60	1,88
		Feeling of Satisfaction	2,60	0,98		Feeling of Satisfaction	2,73	1,94
15	**M**	Feeling of Confidence	2,67	1,11	**T**	Feeling of Confidence	2,93	1,87
		Feeling of Satisfaction	3,00	1,00		Feeling of Satisfaction	3,27	1,79
16	**M**	Feeling of Confidence	2,20	0,94	**T**	Feeling of Confidence	2,00	0,84
		Feeling of Satisfaction	2,73	1,1		Feeling of Satisfaction	2,33	1,11

**Note: M stands for Mechanics, T stands for Thermodynamics.*

It is important to note that the *Metacognitive Experiences Questionnaire (MEQ)* (Efklides, 2002) uses single items to measure each of the metacognitive experiences in addition to interest and liking. Due to time restrictions in data collection (and other reasons needed to be considered), it was only possible to collect metacognitive experiences with a single-item measure. As a result, it is not possible to report reliability measures such as *Cronbach's* alpha, and moreover, perform a confirmatory factor analysis. According to Diamantopoulos, Sarstedt, Fuchs, Wilczynski & Kaiser

(2012), multiple-item measures help to average out errors that are inherent in single-items, thus leading to higher reliability and construct validity. Nevertheless, there has been a trend to use more and more single-item measures. To address the discussions raised by the use of single-items vs. multiple-items, Diamantopoulos et al. (2012) conducted a study to investigate when single-items measures are likely to have comparable prediction ability as multiple-item measures. Their findings suggest that single-item measures can have predictive ability as multiple-item scales, especially when the items have been previously tested; meaning that there is unanimous agreement that the construct is very concrete. Furthermore, they suggest that when studies are by nature exploratory and its objective is to map out the effects, single item-measures seem to be a viable option.

It is necessary to highlight that the MEQ is a well-published instrument and been used in research settings in multiple occasions, and follows a test-retest procedure to measure reliability (please refer to Dina & Efklides, 2009; Efklides, Kourkoulou, Mitsiou & Ziliaskopoulou, 2006). Moreover, in line with Diamantopoulos et al. (2012), our study focuses on exploring the effects of the independent variables of task characteristics and task topic on the dependent variables, it was then decided to keep it and use it for the purpose of our study.

Effects of task characteristics on students' interest and metacognitive experiences. For interest, results of mixed MANOVA analysis indicated a significant interaction effect of time and contextualization ($F(1) = 4.780$, $p = .030$ partial $\eta_2 = .021$). Moreover a marginal main effect of contextualization on interest ($F(1) = 1.388$, $p = .067$, partial $\eta_2 = .015$) was also found. Students' situational interest decreased in low contextualized tasks, while students' situational interest in highly contextualized tasks was maintained during the measurement points. This finding follows the mechanism of *catch and hold* developed by Durik & Harackiewicz (2007). Our results indicate that contextualization triggers and catches students' interest, and holds it throughout the task.

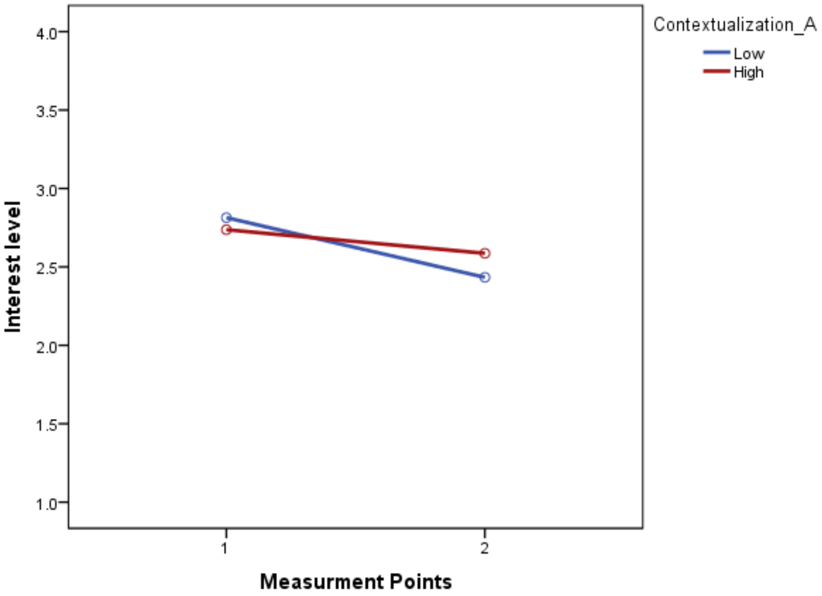

Fig. 12: Interest levels throughout measurement points for the task characteristic of contextualization and task topic of mechanics.

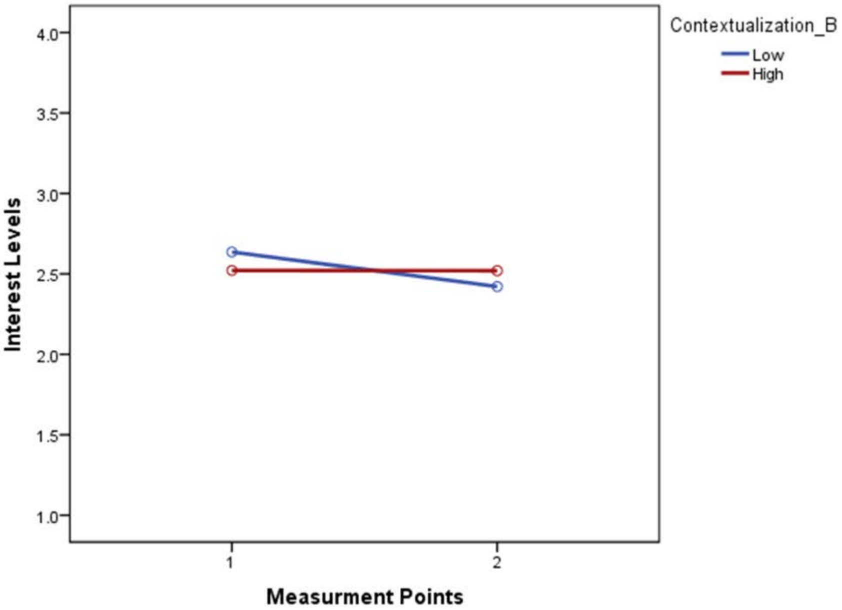

Fig. 13: Interest levels throughout measurement points for the task characteristic of contextualization and task topic of thermodynamics.

For liking, results of mixed MANOVA analysis showed an interaction effect of time, contextualization, and complexity (*F*(1) = 2.1849, p = .039 partial η_2= .019), and a main effect of complexity on liking (*F*(1) = 3.8429, p = .003, partial η_2= .037). Data indicates that students' liking of the task was higher when faced with a higher complexity. When students however face a highly complex *and* highly contextualized task, their liking is significantly decreased. The results suggest that how contextualization and complexity interact can either favor students or work as a disadvantage by overwhelming students' learning process.

Contrary to our hypothesis, there were no results that indicated any influence of task characteristics on students' metacognitive experiences of difficulty, estimate of effort, and solution correctness.

Effects of task topic and its varying task characteristics on students' motivation and metacognitive experiences. Results of mixed MANOVA indicated *only an effect of the task topic and characteristics of heat transfer on students' metacognitive experiences*. A significant interaction effect of complexity and transparency was found on students' feelings of difficulty (*F*(1) = 3.932, p = .027, partial η_2= .021); their estimate of effort (*F*(1) = 1.926, p = .061, partial η_2= .015); and estimate of solution correctness (*F*(1) = 2.346, p = .064, partial η_2= .015).

Results of ANOVA show only an effect of the task topic of heat transfer on student feelings of confidence and satisfaction. A significant interaction effect of contextualization, complexity, and transparency (*F*(5, 224) = 1.990, p = .036) partial η_2= .040) on students' feelings of confidence and as well as on their satisfaction (*F*(1, 5.534) = 3.632, p = .059) partial η_2= .030). Results indicate that when students are faced with a highly contextualized, complex, and transparent task, they feel confident and satisfied with their responses. Despite being a highly demanding task due to the high complexity and transparency (and in line with our context model), high levels of contextualization activate a coping mode that can help students tackle a difficult task (Boekaerts, 1994). Results show a possible topic effect, which could be due to the deep structure of thermodynamics.

Discussion

The second study aimed to examine how the task's topic (i.e., mechanics and thermodynamics) and task characteristics interact and influence students' motivation and metacognitive processing. It specifically explored the effects of the variables of contextualization, complexity, and transparency on students' interest and metacognitive experiences in physics problem-solving situations. Furthermore, it was investigated how do task topic and task characteristics (i.e., contextualization, complexity, and transparency) influence students' motivational variables. Our findings support our first study's results concerning interest. Moreover, data from our second study show that regardless the task topic (in our case mechanics and thermodynamics), interest evolves quite similarly. An important finding from our study is that the metacognitive experiences of feeling of difficulty, estimate of effort, estimate of solution correctness, feeling of confidence and satisfaction, were only significant for the topic of thermodynamics.

With respect to the effect of contextualization on students' interest levels, results support our previous study's findings, and are consistent with the mechanism of catch and hold (Durik & Harackiewicz, 2007). An important key result is that regardless of the task topic students were working on, a highly contextualized version would catch students' interest and hold it. Necessary to mention is that while students answered both, a highly contextualized task and then a low contextualized version (or *vice versa*), the changes in students' interest levels are quite visible. As observed in figure 12 and figure 13, one can see that a highly contextualized version will present a more stable interest level versus a low contextualized version.

Concerning the effects of task characteristics on students' liking of the task, one can observe a curious influence. For the first task, an interaction effect of complexity and contextualization was found; when students answer a low complexity and low contextualized version, students liking decreases significantly. On the other hand, when answering a low complexity but highly contextualized version, students' enjoyment of the task is kept stable. Nevertheless, when complexity is high, students' liking of the task is affected by the task's context level. Results show an important decrease in students liking in both cases, but the drop is quite significant for a highly contextualized version. Results for the second task only show an effect of the level of complexity on students' liking of the task. For this case, one can observe that when faced with a low complex version, students enjoy working more on the task compared to a more complex problem situation.

Taking into consideration our previous results regarding contextualization level and interest, one could assume that having a highly contextualized tasks, regardless of the other task characteristics, would me more enjoyable, meaningful, and relevant for students. Nevertheless, as determined by our findings, the interaction of the high levels of the task characteristics of contextualization and complexity can negatively affect students' affective response of liking. When faced with highly complex and contextualized tasks, students will be overwhelmed, and not being able to cope affectively with the challenging task at hand (Efklides, 2001).

A key finding of our second study was the fact that no effects of task characteristics were found for the metacognitive experiences of feeling of difficulty, estimate of effort, estimate of solution correctness, feeling of confidence and satisfaction. However, when task topic was included into the statistical model, results showed *only* an effect of the *task topic of thermodynamics* on all metacognitive experiences. When working on a task concerning heat transfer concepts and faced with a highly complex and transparent version, students' feelings of difficulty is increased. Needless to say is that learners need to invest more effort into their work. Our findings clearly show this direct connection between feelings of difficulty and the effort: *the more difficult, the more effort needed to be invested*. Moreover, students' estimate of how correct their answer will be, was also negatively affected. Students' estimate of solution correctness if affected by the overall perceived difficulty (Efklides, 2009); if accessing their metacognitive knowledge was severely interrupted, students' might not consider that the quality of the response will be good enough.

Despite being faced with a highly demanding task due to the high complexity, transparency, and contextualization students feel confident and satisfied with their responses. According to Efklides (2009), both feelings of confidence and satisfaction are related to each other by providing information about the individual's ability to successfully deal with a task. In line with the results from our first study, students' felt confident enough with the outcome of the task and satisfied with what they produced regardless of the challenging task at hand. One could assume that students develop the same coping mechanism as in first study: despite having a high complex and transparent task that decreases students' enjoyment of the problem and increases the difficulty and effort invested; the high level of contextualization is keeping students interested and motivated enough work positively with the task.

To finalize, it is important to highlight the fact that there is a topic effect. A possible assumption for the fact that metacognitive experiences were affected only for the thermodynamics task is that such topic deals with more complex and abstract physical concepts and principles. Mechanics, on the other hand, deals with observable objective principles concepts. As a result, the interaction of the task characteristics of complexity, transparency, and contextualization are beneficial for the cognitive processing of abstract principles rather than objective concepts.

Chapter 4: General Discussion

Research in science education has shown contradictory results when using context-based tasks (Bennett, Lubben & Hogarth, 2007). There is some evidence that indicates that students do respond positively to such tasks, nevertheless, it is still unclear how they influence the level of students' motivation, especially interest. The primary purpose of this dissertation was to examine the effects of context-based problem-solving task characteristics on students' motivational variables, flow, and metacognitive experiences. The main purpose of the dissertation was carried out by examining the relationships expected from our task-learner interactions model. The model (Fig. 14) provided evidence as to how task characteristics work either independently (as main effects) or dependently (interaction effects) with one another, as well as, the effects they have on learners' motivational variables, flow state, metacognitive experiences, and performance.

The following paragraphs describe the effects of each task characteristics (contextualization, complexity, and transparency) on students' motivational variables and metacognitive experiences. Additionally, it presents a shorter version of the original task-learner interactions model to highlight each relationships.

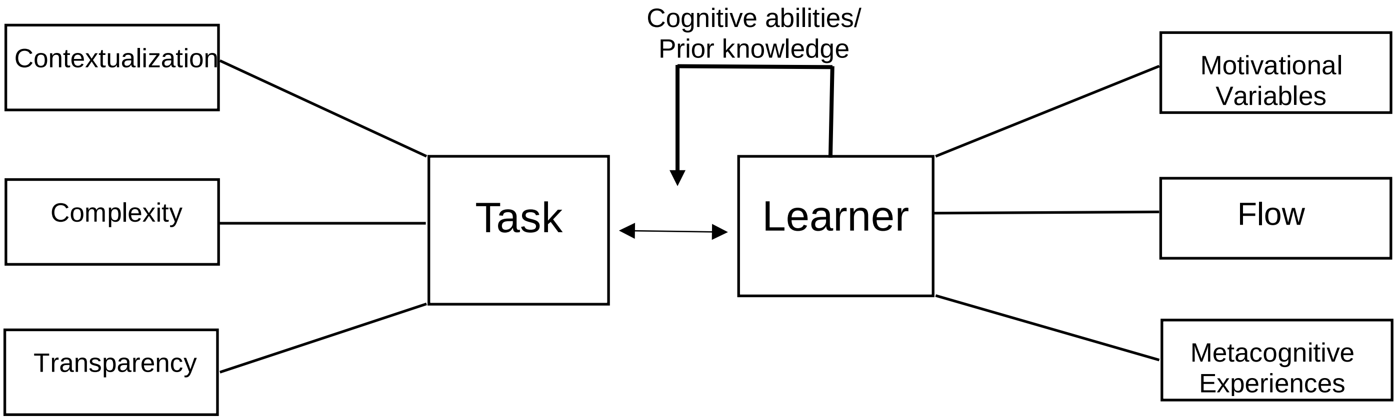

Fig. 14: Task-learner interactions model

Results from both studies show the effect of high levels of contextualization on students' situational interest. Contrary to our hypothesis and to previous research (Bennett, Hogarth, & Lubben, 2003), highly contextualized tasks do not increase students' situational interest. On the other hand, our results prove to go in line with the four-phase model of interest development established by Hidi, & Renninger (2006). Accordingly to the model, situational interest was triggered and maintained as a result of the highly contextualized task. On the contrary, low levels of contextualization, failed to catch students' situational interest, resulting in an important reduction of interest by the end of the task. Our findings suggest (Study 2) that the effects of the levels of contextualization and students' situational interest are not particularly bounded to the task topic, as a similar trend of triggered and maintained interest throughout the two task of thermodynamics and mechanics is observed. In addition, results of Study 1 indicate that students experience higher levels of flow and perceived skill while answering a highly contextualized task. Our results support previous research and claims that given the appropriate conditions, flow may be experienced during interest-based activities; in this specific case highly contextualized tasks are the interest-based activities that establish the optimal situation for flow state.

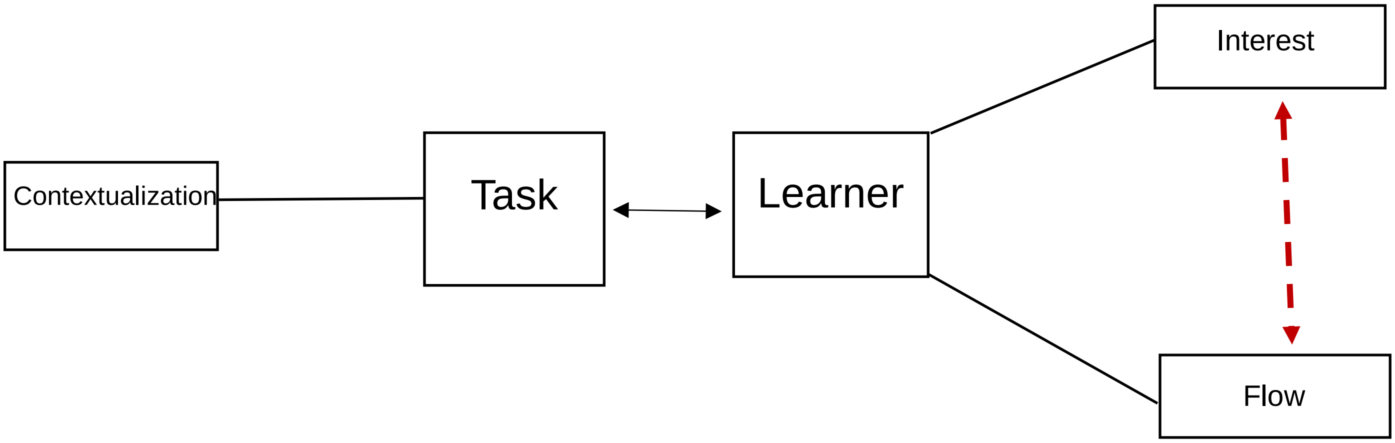

Fig. 15: Model of effects of contextualization on students' interest and flow state

Concerning the effects of the task characteristics of transparency and complexity, results (Study 1 and Study 2) show how the level and interaction of such task characteristics, influences students' overall effort, and beliefs on how to solve the task, the perceived difficulty, and their anxiety. Results from Study 1 show that the level of transparency influenced students' levels of anxiety. The more inclusion of technical terms or scientific principles in the surface structure increased students' anxiety and fear of failure. With the results of Study 2 one can understand why such levels of anxiety were raised. Transparency and complexity seem to raise the level of difficulty, to which students' need to invest more effort. As a result, students' estimate of solution correctness seems to also be altered as a consequence of the perceived task difficulty. This results go in line with Efklides (2001) description of how perceived difficulty might work on students: a difficult task could increase negative affect, in this case, increase the level of anxiety.

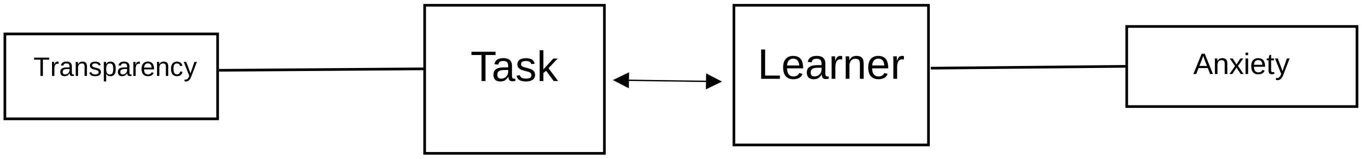

Fig. 16: Model of effects of transparency on students' anxiety

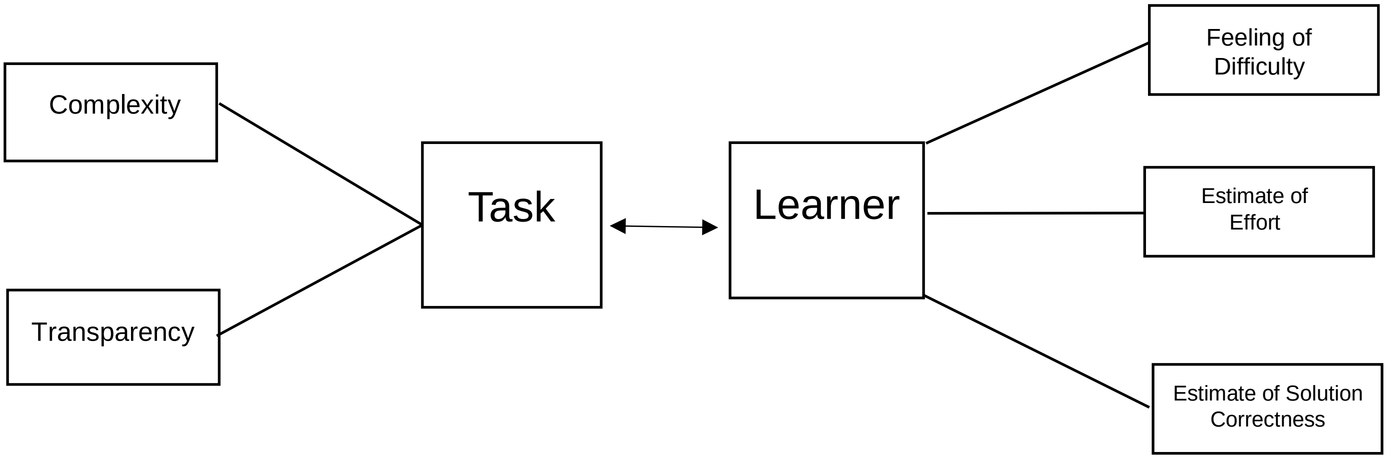

Fig. 17: Model of effects of complexity and transparency on students' feeling of difficulty, estimate of effort, and estimate of solution correctness Study 1 and 2

Despite complexity and transparency raising the task difficulty and therefore, increasing students' anxiety, when combined with contextualization, the task characteristics seem to be beneficial for task processing. Results showed (Study 1 and Study 2) that when a task contains high levels of each of the three task characteristics, students in return feel confident and sure they will succeed in the tasks. To this interesting results, it is assumed that student develop a coping mechanism that allows them to overcome the challenging demands of the task. Such assumptions seem to follow the same line of reasoning behind the *Adaptable Learning Model* by Boekaerts (1994). It seems that when students face an interesting and exciting task, such positive affect and motivation can help students reduce stress and fear.

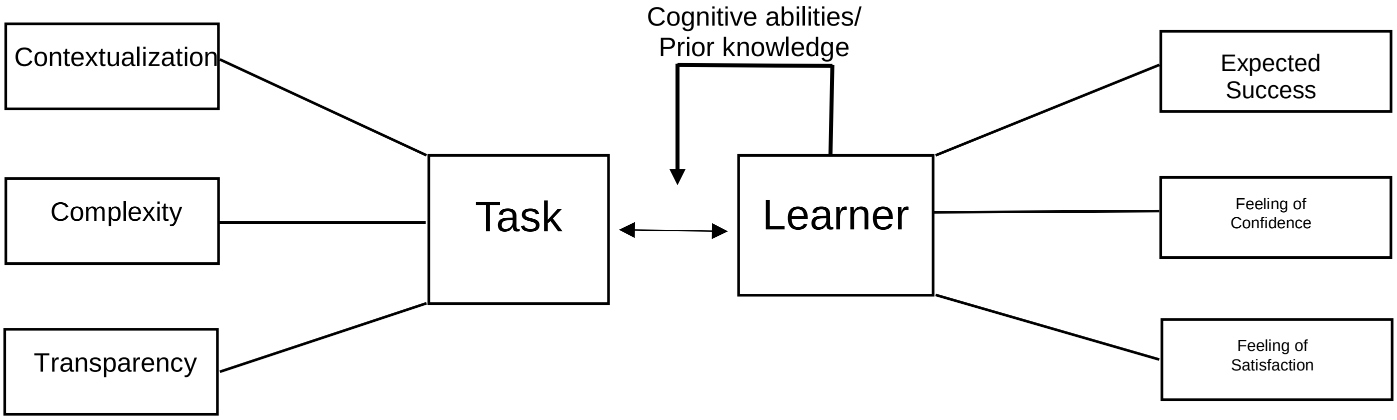

Fig. 18: Model of effects of contextualization, complexity, and transparency on students' expected success, feeling of confidence, and feeling of satisfaction Study 1 and 2

An additional and unique aspect of this research was that the effects of task topic on students' motivational variables and metacognitive experiences were also examined. This focus allowed an examination into the differences between the differences of deep structures between topics in physics (Löffler & Kauertz, 2014). For the case of interest, similar results were found between the task topic of thermodynamics and mechanics: higher levels of contextualization trigger and hold interest (Hidi & Renninger, 2006; Durik & Harackiewicz, 2007). However, the findings showed also an interesting topic effect: the task topic of thermodynamics had an effect on all metacognitive experiences. Our findings suggest that when working on a task concerning heat transfer concepts and faced with a highly complex and transparent version, students' feelings of difficulty is increased, effort was increased, and their estimate of solution correctness was negatively affected. A possible assumption for the fact that metacognitive experiences were affected only for the thermodynamics task is that such topic deals with more complex and abstract physical concepts and principles. Mechanics, on the other hand, deals with observable objective principles concepts. This goes in line with research suggesting that topics in physics have a different underlying deep structure (Löffler & Kauertz, 2014), which in return has an effect on the complexity and difficulty of the task. As a result, the interaction of the task characteristics of complexity, transparency, and contextualization are beneficial for the cognitive processing of abstract principles rather than objective concepts.

Finally, it is important to mention that although our experiments yielded small effects in regards to students' performance, as the data was able to show that both interest and success expectancies (Study 1) were predictors of students' final task achievement. Such results are in line with previous studies that focused on examining the relationship between interest and performance (Krapp & Prenzel, 2011).

Limitations of the Studies of this Dissertation and Further Research

There are several noteworthy limitations to our studies. First, in both studies, such tasks were answered during one class; students have had no other exposure to this type of tasks and will not continue to have any exposure to them. Thus, any assumptions that such tasks could help students maintained the same levels of interest during longer learning periods, or that individual interest can be promoted by such task, may be limited. In order to make such generalizations, a quasi-experimental approach (Kuhn & Müller, 2014) would be suggested. Using a quasi-experimental (pre-, post-, follow-up-test) approach with the different treatment conditions, one could examine how the levels of situation interest vary across time, providing information as to whether students get too used to the tasks or bored with them. In our case, such tasks were a completely new learning experience, and therefore, the impact could have been higher after longer experience. Another suggestion would be to follow a longitudinal approach, which might explore whether or not exposure to "an interesting topic" can develop maintained situational interest into a developed individual interest.

Second, the sample sizes for both studies was small. In order to carry out the experiments, one relies on school voluntariness to participate. Having teachers agree to participate can be complicated due to the various school activities which influences the teachers' schedule, as well as important school projects, etc. Therefore, the studies had to proceed with the number of willing participants. As a result, it was not possible to test the model as a whole using appropriate statistical procedures such as structural equation modelling. Literature on structural equation modelling agrees on: a) a minimum sample size of 100 or 200, b) 5 or 10 observations per estimated parameter, and c) 10 cases per variables. Nevertheless, according to Wolf, Harrington, Clark, and Miller (2013), these rules are quite problematic because they are not model-specific and may lead to an important over or underestimation of sample size or can affect the accuracy of the model fit. In order to prevent any over or underestimations that would severely affect the accuracy of our model, it was decided to test relationships between variables using analysis of variance (ANOVA) and multivariate analysis of variance (MANOVA). Thus, a third important limitation is the fact that it was not possible to statistically test our task-learner interaction model.

Accordingly, our limitation in this case would be our main suggestion for further research: ***collecting a larger sample size that would allow statistically testing our model***. More importantly, having a larger sample size would be expected to mirror more accurately the behavior of the whole group and increase the significance level of findings. Another important suggestion would be to test whether this model can also have a predictive value over students' performance. A last area of research should focus on not only examining the metacognitive experiences of students when answering context-based problem-solving tasks, but as well, develop a calibration analysis. Such analysis could provide deeper information as to the accuracy of judgements, and furthermore, whether the task characteristics influence the underestimation or overestimation of students' metacognitive judgements.

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Appendices

Appendix A. Example Consent Form

. Pozas, Graduiertenkolleg, Th.-Nast-Str. 44, 76829 Landau

An die Eltern der XXXX

Sehr geehrte Eltern,

am XXX (XX) soll im "XXXX" eine Studie unter der Leitung des Graduiertenkollegs „Unterrichtsprozesse“ der Universität Koblenz-Landau durchgeführt werden. Das Projekt wird durch die Deutsche Forschungsgemeinschaft finanziert und beachtet deren wissenschaftliche Standards.

Gegenstand der Untersuchung sind die Auswirkungen unterschiedlicher Gestaltungen von Physikaufgaben auf die Bearbeitungsprozesse. Das Ziel ist es dabei, Eigenschaften von Sachaufgaben zu identifizieren, die den Schülerinnen und Schülern das Bearbeiten erleichtern oder auch erschweren. Auf diese Weise können die Aufgabenqualität verbessert und Erkenntnisse über motivationale Aspekte sowie das Interesse gewonnen werden. Die Schüler/innen sollen dazu im Klassenverband mehrere Fragebögen ausfüllen. Im Anschluss folgen dann zwei Sachaufgaben zur Bearbeitung; insgesamt stehen ihnen dazu 90 Minuten zur Verfügung. Es werden dabei außer Alter und Geschlecht keine personenbezogenen Daten gespeichert (z.B. wird an keiner Stelle der Name angegeben), die Anonymität bleibt vollständig gewahrt. Die Studie beinhaltet keine Leistungsüberprüfung und trägt nicht zur Benotung der Schüler/innen bei. Es stehen die

Auswirkungen der unterschiedlichen Aufgabenpräsentationen im Vordergrund. Daher gibt es innerhalb der Klasse nach dem Zufallsprinzip unterschiedlich schwierige Aufgabenvariationen. Lehrkräfte des "XXXXX" werden nicht in die Auswertung der Fragebögen eingebunden sein und erhalten keine personenbezogene Rückmeldung. Rückmeldungen zu Mittelwerten der ganzen Klasse sind auf Wunsch möglich.

Die Teilnahme an der Studie ist freiwillig. Sie können Ihre Zusage jederzeit und ohne Angabe von Gründen zurückziehen. Die Daten werden vollständig anonymisiert und nicht an Dritte oder für andere Zwecke weitergegeben.

Sollten Sie weitere Fragen haben, können Sie sich unter der rechts aufgeführten Internetadresse über das Projekt und die Studienleiter informieren. Für zusätzliche Informationen oder Rückfragen stehen wir unter den angegebenen Kontaktdaten gerne zur Verfügung.
Wir freuen uns, unsere Forschung für Kinder und Jugendliche mit Ihrer Unterstützung durchführen zu können.

Mit freundlichen Grüßen

Marcela Pozas, M.Ed.

Einverständniserklärung

zur Teilnahme an der wissenschaftlichen Studie

„Die Bedeutung des Kontexts für die Modellanwendung im Physikunterricht“

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Vor- und Nachname des Schülers / der Schülerin

Ich habe das Informationsschreiben der genannten Studie gelesen und verstanden. Eine Kopie dieses Schreibens wurde mir ausgehändigt. Außerdem hatte ich ausreichend Gelegenheit, Fragen (z.B. zu Inhalt, Ziel, Verlauf) zu stellen. Ich weiß, dass die Studienteilnahme meines Kindes freiwillig ist und dass ich jederzeit ohne Angabe von Gründen meine Zusage zur Teilnahme zurückziehen kann und dass meinem Kind daraus keine Nachteile entstehen. Ich erkläre, dass ich mit der im Rahmen der Studie erfolgenden Aufzeichnung von Studiendaten und ihrer Verwendung in anonymisierter Form einverstanden bin.

Ich gebe hiermit meine freiwillige Zustimmung zur Teilnahme meines Kindes an dieser Studie.

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Ort, Datum, Unterschrift des Erziehungsberechtigten

Appendix B. Study 1 Guidelines/Protocol

I. Pilot Study's Main Objective: the main objective of the pilot study is to test the quality of the contextualized tasks and measurement instruments.

Research Question

How do features of context –based tasks influence students' problem-solving processes and transfer of learning?

Hypothesis

The following hypothesis will be tested with the pilot study:

1. Interest and Motivation are higher in contextualized tasks.
2. The contextual characteristics of complexity and transparency affect performance in the following ways:
    a. High Transparency (T+) has a positive influence on performance (Perf).
    b. Low Complexity (C-) has a positive influence on performance.
    c. T+ has a negative influence on perceived relevance (PR).
    d. C+ and T- have no effect on interest and motivation on low performers, but have a positive effect for high performers, and a negative effect for average performers.
    e. C- and T+ have a positive effect on interest and motivation for low performers, no effect for average performance, and a negative effect for high performers.
    f. C- and T- have no effect on interest and motivation for low performers, positive effect for average performers, and a negative effect for high performance.

II. **Research Approach:** the pilot study follows an experimental design.

III. **Variables, Subjects, and Research Design**

Dependent Variables: complexity, transparency, and contextualization.

Independent Variables: performance and motivation.

Covariates: prior conceptual knowledge and cognitive abilities.

- **Conceptual definitions of variables**
    - **Complexity:** following the assumption that isolated physics facts are less complex than the connections among them - and such connections in return are less complex than generic concepts - complexity refers to the number of elements to be integrated and the hierarchical categorization of the elements. Such hierarchical categorization is divided into six levels: individual fact, several unconnected facts, one relation, several unconnected relations, several interconnected relations, and generic concept/basic concept (Kauertz & Fischer, 2006).
    - **Transparency:** refers to the cues that provide links between the surface features and the deep structure. It influences the ability (ease) of students to identify and link the correct elements that would help them solve and map the problem.
        - High transparency = usage of physics terms and/or methods
        - Low transparency = usage of everyday concepts
    - **Contextualization:** refers to a physics problem which is naturally embedded into a meaningful every-day situation.
    - **Performance:** refers to students' achievement which depends on the quality and quantity of the learning activities, as well as on students' functional state during the learning process (Engeser, Rheinberg, Vollmeyer, & Bischoff, 2005)
    - **Motivation:** following a cognitive-motivational framework, motivation is defined as what provides the impulse to achieve a goal for all present processes (Rheinberg, 1997). The definition follows the theoretical framework of Vollmeyer and Rheinberg's (1998) cognitive-motivational model and its four motivational factors: challenge, interest, probability of success, and anxiety.
    - **Prior knowledge:** refers to the previous encounters or experiences related to a particular concept, work, material, etc. of a specific field.
    - **Cognitive Abilities:** ability/capacity to perform higher mental processes such as reasoning, remembering, understanding, problem solving and imagining.

- **Operational definitions of variables**
    - **Complexity:** results from the number of facts or - if there are - relations.
    - **Transparency:** results from the number of constructive links between surface features and the deep structure (i.e. the part of the deep structure that includes the solution).
    - **Contextualization:** results from the design of physics problems which are embedded into every-day situations.

- **Performance:** results from students' achievements[11] in the administered experimental task (problem solving process).
- **Motivation:** motivation is measured based on the four factors from the Questionnaire on Current Motivation (FAM), which are, challenge, probability of success, interest, and anxiety (Rheinberg, Vollmeyer & Burns, 2001).
- **Prior knowledge:** results from students' achievements in the administered Thermal Concept Evaluation (Yeo & Zadnick, 2001)
- **Cognitive Abilities:** results from students' achievements at the administered I-S-T 2000R (analogies, similarities, figure selection, and matrices) (Amtheur, Brocke, Liepmann & Beauducel, 2001)

Subjects

For the purpose of this study, the target population consists on 10th grader students from higher track secondary schools. Using the statistical program G Power, the sample size was determined and will consist of at least 210 students. Participants will be grouped in their own classrooms, which will be randomly assigned into an experimental group and task (see Figure 1).

Design Description

To investigate the research questions, the topic of thermodynamics, more specifically the concepts of conduction and convection were selected. Following a schema of 2 x 2 x 2, a total of 8 conduction and convection problem-solving tasks were developed.

Transparency Complextiy	Contextualized		Non-contextualized	
	High	**Low**	**High**	**Low**
Low	Group 1	Group 2	Group 5	Group7
High	Group 3	Group 4	Group 6	Group 8

In accordance with the schema, a total of 4 tasks are contextually based and are constructed in regards to a specific level of complexity (high or low) and transparency (high or low), while 4 tasks are non-contextualized and are also constructed with specific levels of complexity or transparency (high or low).

To measure context effects as well as the factors' effects (complexity and transparency) a pre-post design will be used. As an initial step, all control variables will be collected in the pre-test. Such

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[11] Student responses should be graded based on a right and wrong scale, but as well, as identified as constructive or non-constructive.

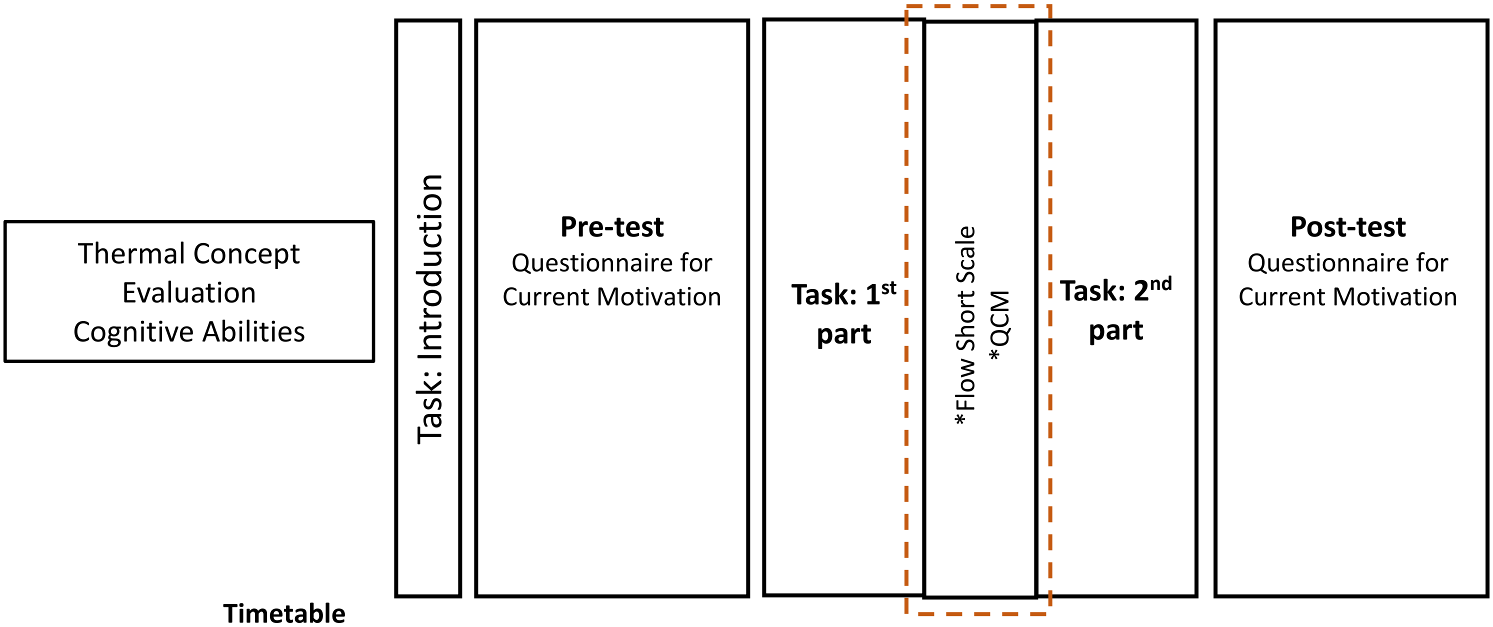
control variables are: conceptual understanding, cognitive abilities, and motivation. The following table presents the instruments[12] that will be used for the purposes of this study:

Variable	Instrument	Author
Conceptual Understanding	Thermal Concept Evaluation	Yeo & Zadnick (2001)
Cognitive Abilities Test	Intelligenz-Struktur-Test 2000R	Amtheur, Brocke, Liepmann & Beauducel (2001)
Motivation	Questionnaire for Current Motivation Flow Short Scale	Rheinberg, Vollmeyer & Burns (2001) Rheinberg, Vollmeyer & Engeser (2003)

Procedure

1. Students answer the Thermal Concept Evaluation (Yeo & Zadnick, 2001) and the Cognitive Abilities Test I-S-T 2000R (analogies, similarities, figure selection, and matrices) (Amtheur, Brocke, Liepmann & Beauducel, 2001).
2. Students receive the task.
3. Students answer the Questionnaire on Current Motivation (QCM).
4. Students begin first part of the pilot task.
5. When students finish the first part of the task, they must answer the Flow Short Scale (FSS)(Rheinberg, Vollmeyer & Engeser, 2003) and the QCM (Rheinberg, Vollmeyer & Burns, 2001).
6. Students continue answering the last part of the task: Open answer.
7. Students answer again the complete version of the QCM.

See Figure 2 for an overview of the pilot study procedure.



Timetable

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[12] Instruments will be adapted to fit the purposes of the study, as well as to the specific abilities of the participants.

The following table presents an estimation of the total duration of the pilot study.

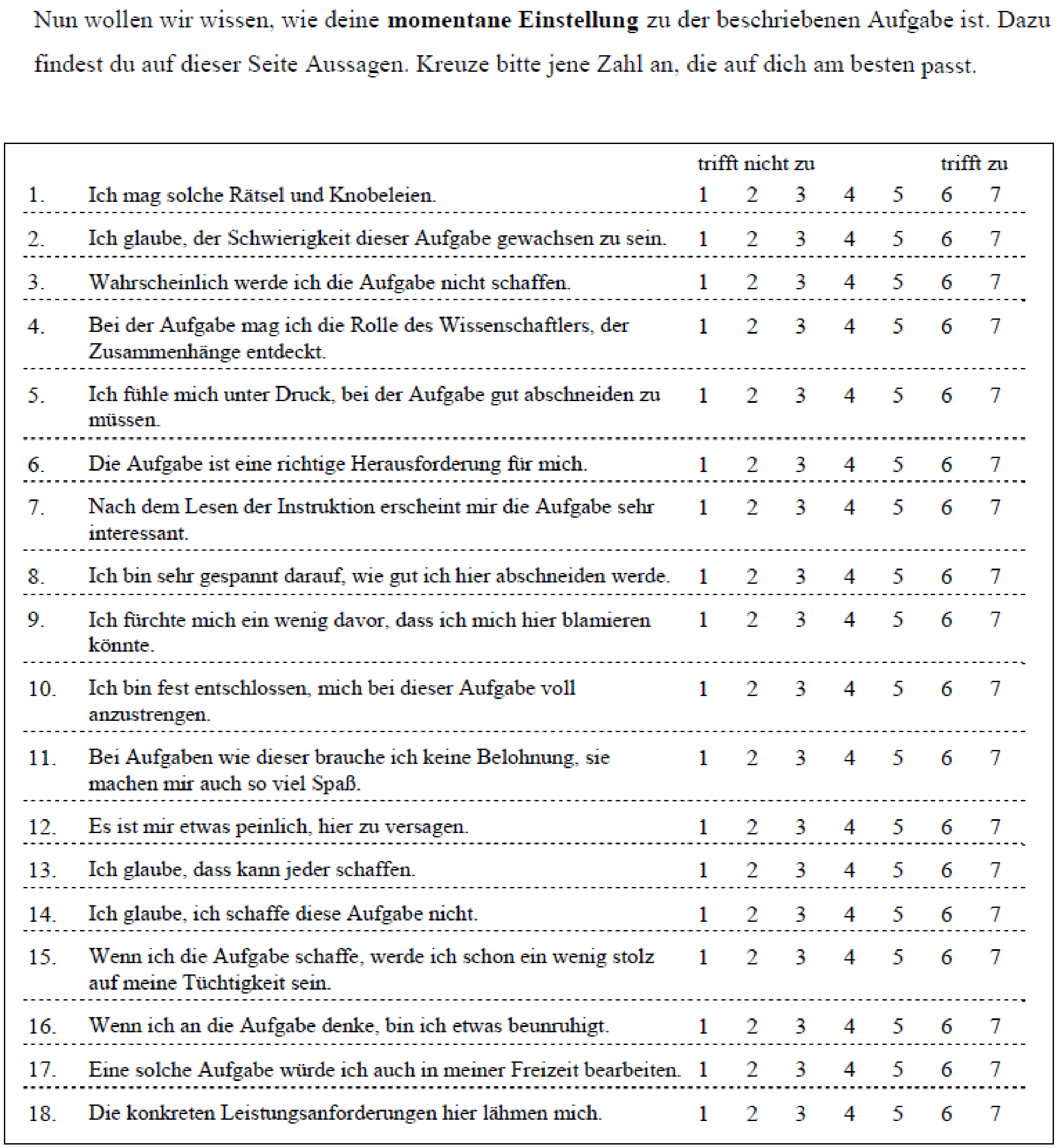
Task	**Duration**
Thermal Concept Evaluation	30 mins.
Cognitive Abilities Test	20 mins.
Introduction of Task	10 mins.
Questionnaire for Current Motivation	2 mins.
Task: Part 1	15 mins.
Short QCM and Flow Short Scales	3 mins.
Task: Part 2	8 mins.
Questionnaire for Current Motivation	2 mins.
Total time	**90 mins.**

Analysis of Data

The analysis of data collect will be focused on:

- Developing an analysis to check group differences: contextualized vs. non-contextualized, between the different levels of complexity and transparency.
- Developing an analysis of variance with interest, intelligence, and prior knowledge (conceptual understanding).
- Developing an analysis of covariance with context (contextualized/non-contextualized) and students’ intelligence.
- Developing an analysis of covariance with context (contextualized/non-contextualized) predicting students’ motivation.
- Developing an analysis of covariance with performance and flow experience.
- Develop an analysis of motivation throughout the 3 times test.

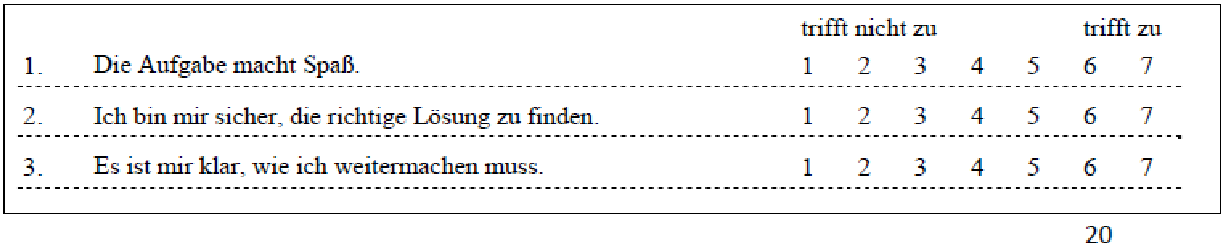
Appendix C. Questionnaire on Current Motivation (pre-postest forms)



Nun wollen wir wissen, wie deine **momentane Einstellung** zu der beschriebenen Aufgabe ist. Dazu findest du auf dieser Seite Aussagen. Kreuze bitte jene Zahl an, die auf dich am besten passt.

		trifft nicht zu					trifft zu	
1.	Ich mag solche Rätsel und Knobeleien.	1	2	3	4	5	6	7
2.	Ich glaube, der Schwierigkeit dieser Aufgabe gewachsen zu sein.	1	2	3	4	5	6	7
3.	Wahrscheinlich werde ich die Aufgabe nicht schaffen.	1	2	3	4	5	6	7
4.	Bei der Aufgabe mag ich die Rolle des Wissenschaftlers, der Zusammenhänge entdeckt.	1	2	3	4	5	6	7
5.	Ich fühle mich unter Druck, bei der Aufgabe gut abschneiden zu müssen.	1	2	3	4	5	6	7
6.	Die Aufgabe ist eine richtige Herausforderung für mich.	1	2	3	4	5	6	7
7.	Nach dem Lesen der Instruktion erscheint mir die Aufgabe sehr interessant.	1	2	3	4	5	6	7
8.	Ich bin sehr gespannt darauf, wie gut ich hier abschneiden werde.	1	2	3	4	5	6	7
9.	Ich fürchte mich ein wenig davor, dass ich mich hier blamieren könnte.	1	2	3	4	5	6	7
10.	Ich bin fest entschlossen, mich bei dieser Aufgabe voll anzustrengen.	1	2	3	4	5	6	7
11.	Bei Aufgaben wie dieser brauche ich keine Belohnung, sie machen mir auch so viel Spaß.	1	2	3	4	5	6	7
12.	Es ist mir etwas peinlich, hier zu versagen.	1	2	3	4	5	6	7
13.	Ich glaube, dass kann jeder schaffen.	1	2	3	4	5	6	7
14.	Ich glaube, ich schaffe diese Aufgabe nicht.	1	2	3	4	5	6	7
15.	Wenn ich die Aufgabe schaffe, werde ich schon ein wenig stolz auf meine Tüchtigkeit sein.	1	2	3	4	5	6	7
16.	Wenn ich an die Aufgabe denke, bin ich etwas beunruhigt.	1	2	3	4	5	6	7
17.	Eine solche Aufgabe würde ich auch in meiner Freizeit bearbeiten.	1	2	3	4	5	6	7
18.	Die konkreten Leistungsanforderungen hier lähmen mich.	1	2	3	4	5	6	7

Appendix D. Motivational State Questionnaire



		trifft nicht zu					trifft zu	
1.	Die Aufgabe macht Spaß.	1	2	3	4	5	6	7
2.	Ich bin mir sicher, die richtige Lösung zu finden.	1	2	3	4	5	6	7
3.	Es ist mir klar, wie ich weitermachen muss.	1	2	3	4	5	6	7

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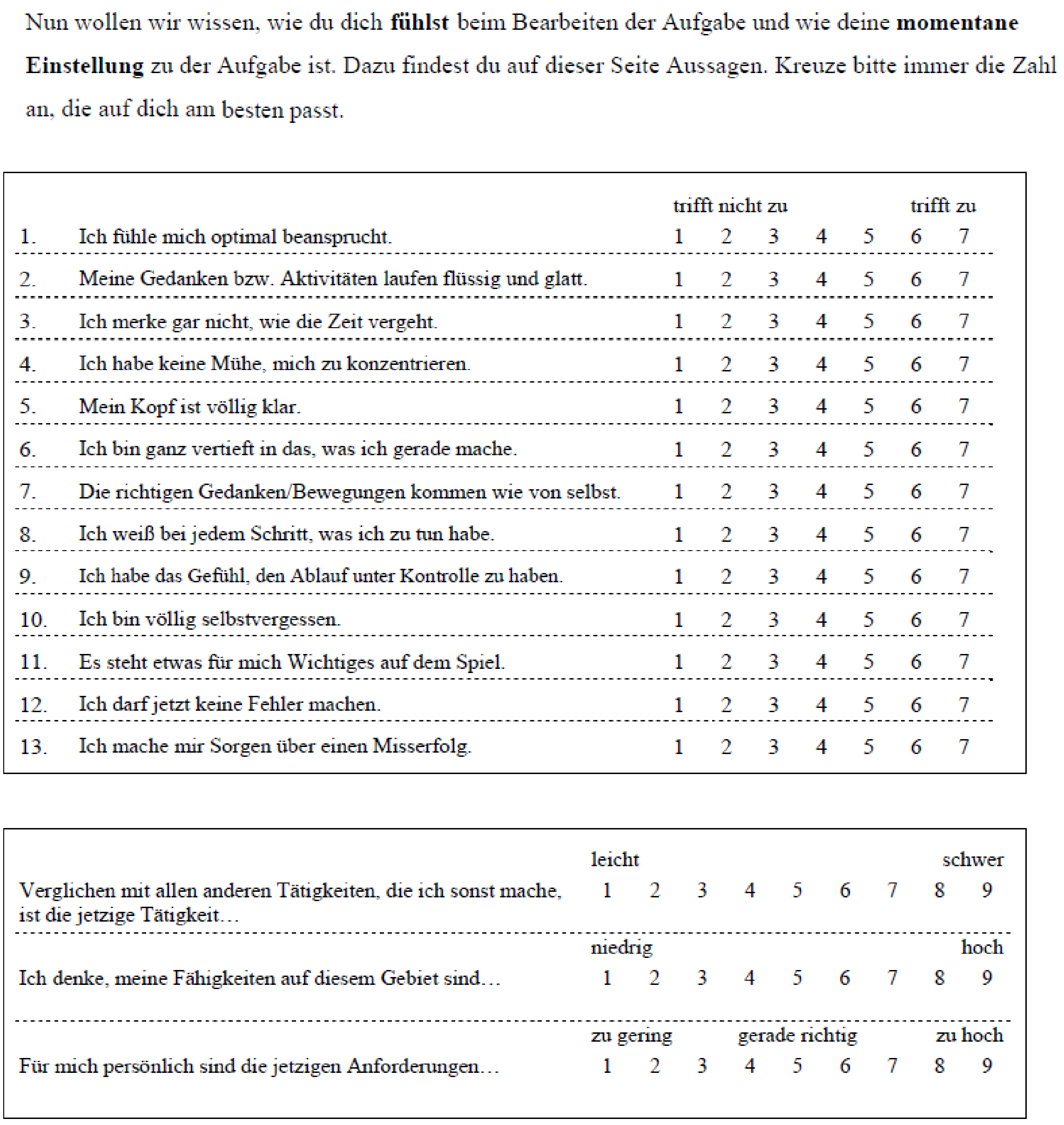
Appendix E. Flow Short Scale



Nun wollen wir wissen, wie du dich **fühlst** beim Bearbeiten der Aufgabe und wie deine **momentane Einstellung** zu der Aufgabe ist. Dazu findest du auf dieser Seite Aussagen. Kreuze bitte immer die Zahl an, die auf dich am besten passt.

		trifft nicht zu					trifft zu	
1.	Ich fühle mich optimal beansprucht.	1	2	3	4	5	6	7
2.	Meine Gedanken bzw. Aktivitäten laufen flüssig und glatt.	1	2	3	4	5	6	7
3.	Ich merke gar nicht, wie die Zeit vergeht.	1	2	3	4	5	6	7
4.	Ich habe keine Mühe, mich zu konzentrieren.	1	2	3	4	5	6	7
5.	Mein Kopf ist völlig klar.	1	2	3	4	5	6	7
6.	Ich bin ganz vertieft in das, was ich gerade mache.	1	2	3	4	5	6	7
7.	Die richtigen Gedanken/Bewegungen kommen wie von selbst.	1	2	3	4	5	6	7
8.	Ich weiß bei jedem Schritt, was ich zu tun habe.	1	2	3	4	5	6	7
9.	Ich habe das Gefühl, den Ablauf unter Kontrolle zu haben.	1	2	3	4	5	6	7
10.	Ich bin völlig selbstvergessen.	1	2	3	4	5	6	7
11.	Es steht etwas für mich Wichtiges auf dem Spiel.	1	2	3	4	5	6	7
12.	Ich darf jetzt keine Fehler machen.	1	2	3	4	5	6	7
13.	Ich mache mir Sorgen über einen Misserfolg.	1	2	3	4	5	6	7

	leicht								schwer
Verglichen mit allen anderen Tätigkeiten, die ich sonst mache, ist die jetzige Tätigkeit…	1	2	3	4	5	6	7	8	9
	niedrig								hoch
Ich denke, meine Fähigkeiten auf diesem Gebiet sind…	1	2	3	4	5	6	7	8	9
	zu gering			gerade richtig				zu hoch	
Für mich persönlich sind die jetzigen Anforderungen…	1	2	3	4	5	6	7	8	9

Appendix F. Study 2 Guidelines/Protocol

Main Objective: The main aim of the study is to investigate how task features, such as transparency and contextualization, influence performance and metacognitive experiences.

Research Questions

1. Which types of tasks (contextualized or non-contextualized) are associated with higher task performance? And, which level of transparency fosters higher levels of task performance?

2. What are the effects of the variables of contextualization and transparency on students' metacognitive experiences in physics problem-solving situations?

IV. **Research Approach:** the study follows an experimental design.

V. **Variables**

Dependent Variables: performance, metacognitive experiences, affect, and motivation.

Independent Variables: transparency, and contextualization.

- **Conceptual definitions of variables**
  - **Complexity:** following the assumption that isolated physics facts are less complex than the connections among them - and such connections in return are less complex than generic concepts - complexity refers to the number of elements to be integrated and the hierarchical categorization of the elements. Such hierarchical categorization is divided into six levels: individual fact, several unconnected facts, one relation, several unconnected relations, several interconnected relations, and generic concept/basic concept (Kauertz & Fischer, 2006).
  - **Transparency:** refers to the cues that provide links between the surface features and the deep structure. It influences the ability (ease) of students to identify and link the correct elements that would help them solve and map the problem.
    - High transparency = usage of physics terms and/or methods
    - Low transparency = usage of everyday concepts
  - **Contextualization:** refers to a physics problem which is naturally embedded into a meaningful every-day situation.
  - **Performance:** refers to students' achievement which depends on the quality and quantity of the learning activities, as well as on students' functional state during the learning process (Engeser, Rheinberg, Vollmeyer, & Bischoff, 2005)
  - **Metacognitive experiences:** consists on metacognitive feelings and metacognitive judgments/estimates that are based on the monitoring of task-processing features (Efklides, 2001). More specifically, ME are what the person is aware of and what she or he feels with the task at hand and while processing the information related to it.
- **Operational definitions of variables**
  - **Complexity:** results from the number of facts or - if there are - relations.

- **Transparency:** results from the number of constructive links between surface features and the deep structure (i.e. the part of the deep structure that includes the solution).
- **Contextualization:** results from the design of physics problems which are embedded into every-day situations.
- **Performance:** results from students' achievements in the administered experimental task (problem solving process).
- **Metacognitive experiences:** students' ratings to the prospective and retrospective Metacognitive Experiences Questionnaire (Efklides, 2002).

VI. Method

Design: Two groups of students will be randomly formed: one of the groups will answer a contextualized version of a thermodynamics tasks, while the other will answer a non-contextualized version of the same task. Students will be tested in one occasion with the same tasks (see figure 1). After instructions have been given, and students read the task, participants will answer a metacognitive experiences questionnaire. Afterwards, students must answer the task and finally answer a retrospective metacognitive experiences questionnaire. The same procedure will be followed for the two groups of students. Before the instructions of the task are given, students will complete a series of questionnaires tapping their motivation towards physics and interest.

Study Design				
1	2	3	4	5
Assessment Subject-specific motivation Subject-specific interest	**Presentation of Task**	**Prospective Assessment** Metacognitive Experiences Questionnaire	**Task Development**	**Retrospective Assessment** Metacognitive Experiences Questionnaire
	Researcher presents the task. Students read the task.	Items: - Interest - Like - Feeling of difficulty - Estimate of effort - Estimate of solution correctness	Students solve the task at hand.	Items: - Interest - Like - Feeling of difficulty - Estimate of effort - Estimate of solution correctness **+** - Feeling of confidence - Feeling of satisfaction

Participants: The sample will comprise 10th grader students from higher track secondary schools, consisting on approx. 50 students.

Measures

Subject-specific motivation

Subject-specific interest

Metacognitive experiences questionnaire (MEQ; Efklides, 2002) and emotions: The MEQ consists on two sets of items which measures retrospective and prospective metacognitive experiences, as well as interest in and liking of the task. Each set comprises single item measures for each metacognitive experience and each of the two activity-related emotions (interest and like), before and after the task. Responses are on a 4-point Likert-type scale. The set of items will be translated from English to German. The MEQ items assess the feeling of difficulty (FOD), estimate of effort (EOE), estimate of solution correctness (EOC), feeling of confidence (FOC), and feeling of satisfaction (FOS). The two last metacognitive experiences will only be measured after the task.

Thermodynamics' tasks: Each of the two groups of students need to solve a set of four thermodynamics (conduction/convection) tasks; one set consists of contextualized tasks while the other of non-contextualized tasks. Furthermore, the four tasks are also constructed with a varying transparency. Tasks one through four are contextualized, and tasks five through 8 are non-contextualized. Students will be presented with a problem-solving tasks and will provide an answer following a set of questions.

Procedure: Students will be tested in their classrooms during regular school hours. Instructions concerning the purpose of research, general guidelines and procedure will be given orally and will be the same for all students in the classrooms. Students will be instructed to answer the subject-related motivation and interest instrument, and then will be given instructions concerning the tasks. The experimenter will instruct students to read carefully the task, and answer the first MEQ, after doing so they can then answer the task. Finally, after answering the task, they should respond the MEQ again. Experimenter will explain that such procedure should be followed in every of the four tasks.

Appendix G. Subject-Specific Interest Questionnaire

I.Gib bitte an, wie interessant Du die folgenden Unterrichtsfächer findest.
Bei Fächern, die Du noch nicht gehabt hast, kreuze bitte nur “noch nicht gehabt” an.

	noch nicht gehabt	sehr interessant	interessant	weniger interessant	ganz uninteressant
Deutsch					
Fremdsprachen					
Mathematik					
Biologie					
Musik					
Kunst					
Sport					
Religion					
Physik					
Chemie					
Geschichte					
Geographie/Erdkunde					
Politik/Gesellschaftslehre/ Sozialkunde/Gemeinschaftskunde					

1. A) Welches Thema behandelt Ihr gerade im Physikunterricht?

____

B) Wie interessant ist dieses Thema für Dich?

☐ sehr interessant
☐ interessant
☐ langweilig
☐ sehr langweilig

2. Ich finde das Fach Physik:
   - ☐ sehr interessant
   - ☐ interessant
   - ☐ langweilig
   - ☐ sehr langweilig

Appendix H. Metacognitive Awareness Inventory

III. Kreuze bitte für jede der folgenden Aussagen an, ob sie für dich eher zutrifft (wahr ist) oder eher nicht (falsch).

	WAHR	**FALSCH**
1. Ich frage mich regelmäßig, ob ich meine Ziele erreiche.		
2. Ich ziehe verschiedene Alternativen zu einem Problem in Betracht, bevor ich antworte.		
3. Ich versuche Strategien zu nutzen, die in der Vergangenheit funktioniert haben.		
4. Ich teile meine Kräfte beim Lernen ein, um genug Zeit zu haben.		
5. Ich kenne meine intellektuellen Stärken und Schwächen.		
6. Ich denke darüber nach, was ich wirklich lernen muss, bevor ich eine Aufgabe beginne.		
7. Ich weiß, wie gut ich abgeschnitten habe, sobald ich einen Test beende.		
8. Ich setze mir genaue Ziele, bevor ich eine Aufgabe beginne.		
9. Ich werde langsamer, wenn ich auf wichtige Informationen stoße.		
10. Ich weiß, welche Art von Information am wichtigsten zu lernen ist.		
11. Ich frage mich selbst, ob ich alle Optionen in Betracht gezogen habe, wenn ich ein Problem löse.		
12. Ich bin gut darin Informationen zu organisieren.		
13. Ich richte meine Aufmerksamkeit bewusst auf wichtige Informationen.		
14. Ich verfolge mit jeder genutzten Strategie eine bestimmte Absicht.		
15. Ich lerne am besten, wenn ich etwas über das Thema weiß.		
16. Ich weiß, was der Lehrer von mir erwartet, was ich lernen soll.		
17. Ich bin gut darin Informationen zu erinnern/behalten.		
18. Ich nutze verschiedene Lernstrategien abhängig von der Situation.		
19. Ich frage mich, ob es einen einfacheren Weg gegeben hätte, nachdem ich eine Aufgabe beendet habe.		
20. Ich habe Kontrolle darüber, wie gut ich lerne.		
	WAHR	**FALSCH**
21. Ich wiederhole regelmäßig, um wichtige Beziehungen zu verstehen.		
22. Ich stelle mir selbst Fragen zu dem Aufgabenmaterial, bevor ich anfange.		
23. Ich betrachte verschiedene Wege um ein Problem zu lösen, und wähle den besten.		

24. Ich fasse zusammen, was ich gelernt habe, nachdem ich fertig bin.		
25. Ich bitte andere um Hilfe, wenn ich etwas nicht verstehe.		
26. Ich kann mich selbst dazu motivieren zu lernen, wenn ich es muss.		
27. Ich bin mir bewusst, welche Strategien ich benutze, wenn ich lerne.		
28. Ich ertappe mich selbst dabei, die Nützlichkeit von Strategien zu analysieren, während ich lerne.		
29. Ich nutze meine intellektuellen Stärken, um meine Schwächen auszugleichen.		
30. Ich konzentriere mich auf die Bedeutung und Wichtigkeit neuer Informationen.		
31. Ich denke mir eigene Beispiele aus, um Informationen besser zu verstehen.		
32. Ich kann gut beurteilen, wie gut ich etwas verstanden habe.		
33. Ich bemerke manchmal, dass ich nützliche Lernstrategien automatisch nutze.		
34. Ich ertappe mich dabei, regelmäßig zu pausieren, um mein Verständnis zu überprüfen.		
35. Ich weiß, wann jede Strategie, die ich nutze, am effektivsten sein wird.		
36. Ich frage mich selbst, wie gut ich meine Ziele erreicht habe, sobald ich fertig bin.		
37. Ich zeichne Skizzen oder Diagramme als Verständnishilfe, während ich lerne.		
38. Ich frage mich selbst, ob ich alle Optionen in Betracht gezogen habe, nachdem ich ein Problem gelöst habe.		
39. Ich versuche, neue Informationen in meine eigenen Worte zu übersetzen.		
40. Ich wechsle meine Strategien, wenn ich nichts verstehe.		
41. Ich nutze die Organisationsstruktur des Textes, um mir beim Lernen zu helfen.		
	WAHR	**FALSCH**
42. Ich lese die Anweisungen sorgfältig durch, bevor ich eine Aufgabe beginne.		
43. Ich frage mich selbst, ob das, was ich lese, in Beziehung steht zu etwas, das ich bereits weiß/kenne.		
44. Ich bewerte meine Vermutungen neu, wenn ich durcheinander komme.		
45. Ich organisiere meine Zeit, um meine Ziele bestmöglich zu erreichen.		
46. Ich lerne mehr, wenn ich mich für das Thema interessiere.		

47. Ich versuche, das Lernen in kleinere Schritte einzuteilen.		
48. Ich konzentriere mich eher auf das Gesamtbild als auf Einzelheiten.		
49. Ich stelle mir selbst Fragen darüber, wie gut ich abschneide, während ich etwas Neues lerne.		
50. Ich frage mich selbst, ob ich so viel gelernt habe, wie ich gekonnt hätte, sobald ich eine Aufgabe beende.		
51. Ich gehe zurück und lese meine Information noch einmal, wenn sie mir nicht klar ist.		
52. Ich stoppe und lese nochmal, wenn ich durcheinander komme.		

Appendix I. Metacognitive Experiences Questionnaire (Pretest)

IV. Kreuze bitte für jede Frage jenes Kästchen an, das auf Dich am besten passt.

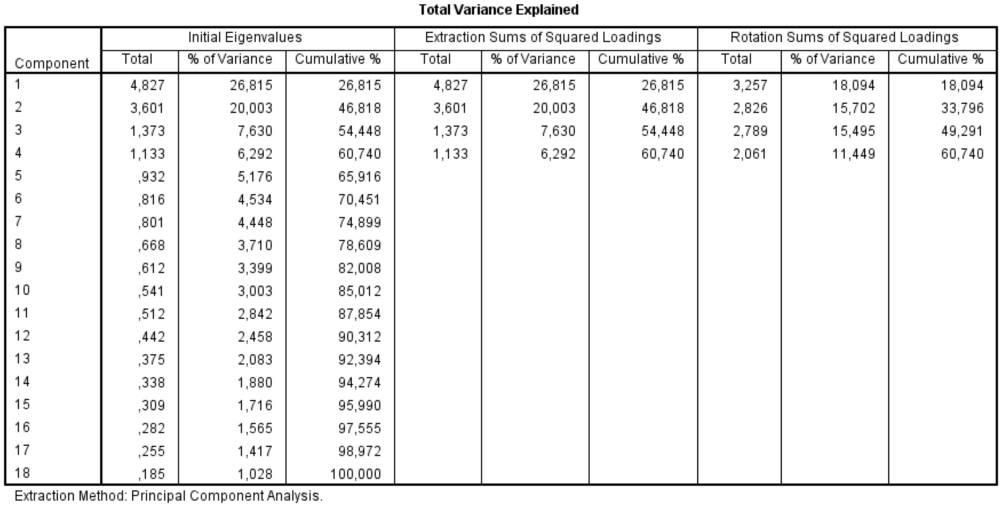
	Gar nicht	**Kaum**	**Etwas**	**Viel**
1. Wie interessant ist die Aufgabe?	☐	☐	☐	☐
2. Wie sehr magst Du die Aufgabe?	☐	☐	☐	☐
3. Wie schwierig findest Du die Aufgabe?	☐	☐	☐	☐
4. Wie sehr musst Du Dich anstrengend, um die Aufgabe zu lösen?	☐	☐	☐	☐
5. Wie korrekt denkst Du, wirst Du die Aufgabe lösen können?	☐	☐	☐	☐

Appendix J. Metacognitive Experiences Questionnaire (Postest)

VI. Kreuze bitte für jede Frage jenes Kästchen an, das auf Dich am besten passt.

	Gar nicht	**Kaum**	**Etwas**	**Viel**
6. Wie interessant fandest Du die Aufgabe?	☐	☐	☐	☐
7. Wie sehr mochtest Du die Aufgabe?	☐	☐	☐	☐
8. Wie schwierig fandest Du die Aufgabe?	☐	☐	☐	☐
9. Wie sehr musstest Du Dich anstrengen, um die Aufgabe zu lösen?	☐	☐	☐	☐
10. Wie korrekt denkst Du, hast Du die Aufgabe gelöst?	☐	☐	☐	☐
11. Wie sicher bist Du, dass Du die Aufgabe richtig gelöst hast?	☐	☐	☐	☐
12. Wie zufrieden bist du mit der Aufgabenlösung, die Du angegeben hast?	☐	☐	☐	☐

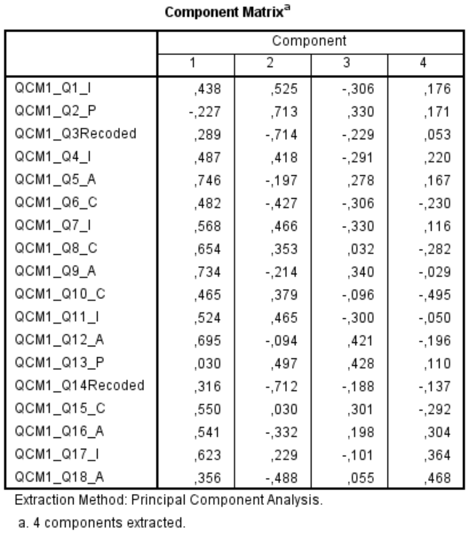
Appendix K. Factor Analysis Pre-Test Questionnaire on Current Motivation



Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4,827	26,815	26,815	4,827	26,815	26,815	3,257	18,094	18,094
2	3,601	20,003	46,818	3,601	20,003	46,818	2,826	15,702	33,796
3	1,373	7,630	54,448	1,373	7,630	54,448	2,789	15,495	49,291
4	1,133	6,292	60,740	1,133	6,292	60,740	2,061	11,449	60,740
5	,932	5,176	65,916						
6	,816	4,534	70,451						
7	,801	4,448	74,899						
8	,668	3,710	78,609						
9	,612	3,399	82,008						
10	,541	3,003	85,012						
11	,512	2,842	87,854						
12	,442	2,458	90,312						
13	,375	2,083	92,394						
14	,338	1,880	94,274						
15	,309	1,716	95,990						
16	,282	1,565	97,555						
17	,255	1,417	98,972						
18	,185	1,028	100,000						

Extraction Method: Principal Component Analysis.

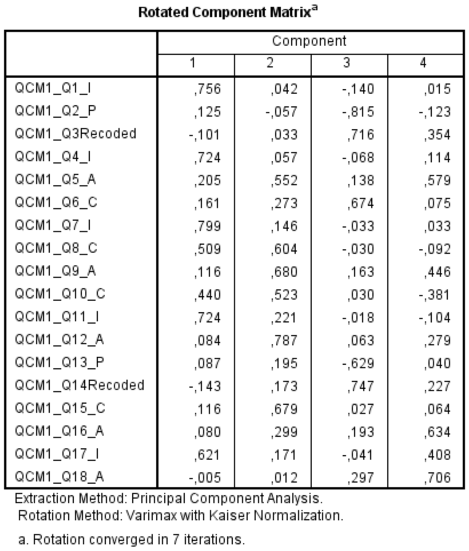


Component Matrix[a]

	Component			
	1	2	3	4
QCM1_Q1_I	,438	,525	-,306	,176
QCM1_Q2_P	-,227	,713	,330	,171
QCM1_Q3Recoded	,289	-,714	-,229	,053
QCM1_Q4_I	,487	,418	-,291	,220
QCM1_Q5_A	,746	-,197	,278	,167
QCM1_Q6_C	,482	-,427	-,306	-,230
QCM1_Q7_I	,568	,466	-,330	,116
QCM1_Q8_C	,654	,353	,032	-,282
QCM1_Q9_A	,734	-,214	,340	-,029
QCM1_Q10_C	,465	,379	-,096	-,495
QCM1_Q11_I	,524	,465	-,300	-,050
QCM1_Q12_A	,695	-,094	,421	-,196
QCM1_Q13_P	,030	,497	,428	,110
QCM1_Q14Recoded	,316	-,712	-,188	-,137
QCM1_Q15_C	,550	,030	,301	-,292
QCM1_Q16_A	,541	-,332	,198	,304
QCM1_Q17_I	,623	,229	-,101	,364
QCM1_Q18_A	,356	-,488	,055	,468

Extraction Method: Principal Component Analysis.

a. 4 components extracted.

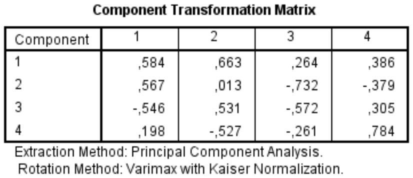


Rotated Component Matrix[a]

	Component			
	1	2	3	4
QCM1_Q1_I	,756	,042	-,140	,015
QCM1_Q2_P	,125	-,057	-,815	-,123
QCM1_Q3Recoded	-,101	,033	,716	,354
QCM1_Q4_I	,724	,057	-,068	,114
QCM1_Q5_A	,205	,552	,138	,579
QCM1_Q6_C	,161	,273	,674	,075
QCM1_Q7_I	,799	,146	-,033	,033
QCM1_Q8_C	,509	,604	-,030	-,092
QCM1_Q9_A	,116	,680	,163	,446
QCM1_Q10_C	,440	,523	,030	-,381
QCM1_Q11_I	,724	,221	-,018	-,104
QCM1_Q12_A	,084	,787	,063	,279
QCM1_Q13_P	,087	,195	-,629	,040
QCM1_Q14Recoded	-,143	,173	,747	,227
QCM1_Q15_C	,116	,679	,027	,064
QCM1_Q16_A	,080	,299	,193	,634
QCM1_Q17_I	,621	,171	-,041	,408
QCM1_Q18_A	-,005	,012	,297	,706

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 7 iterations.



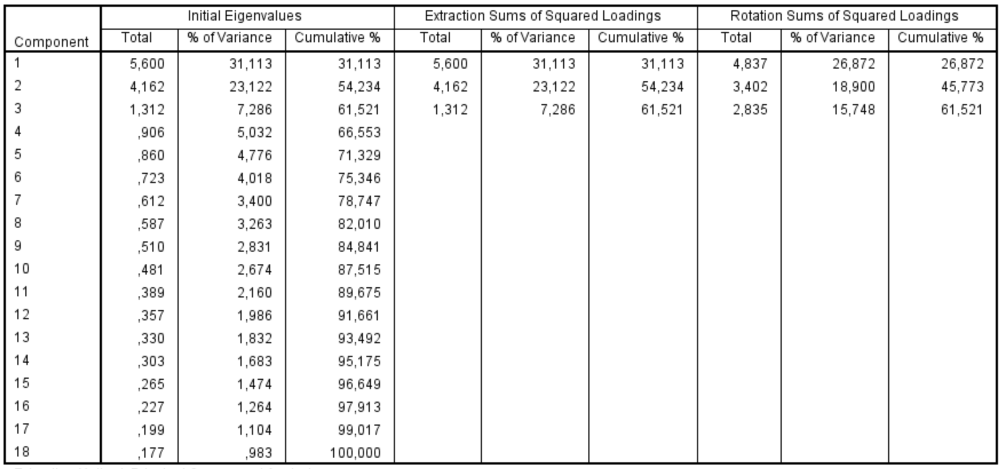
Component Transformation Matrix

Component	1	2	3	4
1	,584	,663	,264	,386
2	,567	,013	-,732	-,379
3	-,546	,531	-,572	,305
4	,198	-,527	-,261	,784

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

Appendix L. Factor Analysis Post-Test Questionnaire on Current Motivation

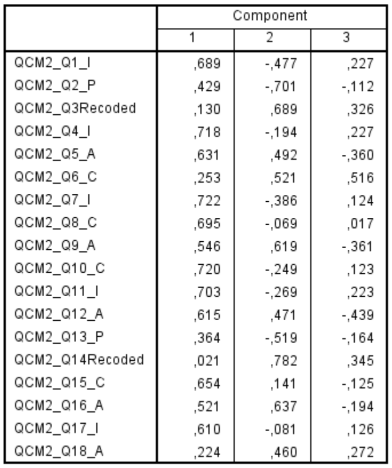
Total Variance Explained



Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5,600	31,113	31,113	5,600	31,113	31,113	4,837	26,872	26,872
2	4,162	23,122	54,234	4,162	23,122	54,234	3,402	18,900	45,773
3	1,312	7,286	61,521	1,312	7,286	61,521	2,835	15,748	61,521
4	,906	5,032	66,553						
5	,860	4,776	71,329						
6	,723	4,018	75,346						
7	,612	3,400	78,747						
8	,587	3,263	82,010						
9	,510	2,831	84,841						
10	,481	2,674	87,515						
11	,389	2,160	89,675						
12	,357	1,986	91,661						
13	,330	1,832	93,492						
14	,303	1,683	95,175						
15	,265	1,474	96,649						
16	,227	1,264	97,913						
17	,199	1,104	99,017						
18	,177	,983	100,000						

Extraction Method: Principal Component Analysis.

Component Matrix[a]

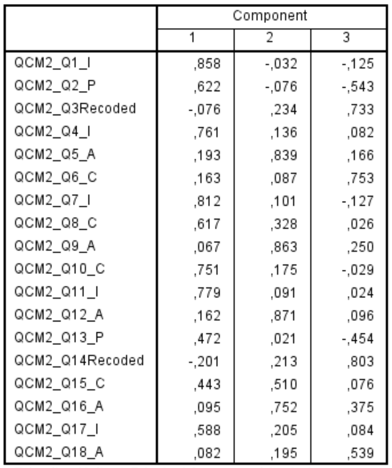


	Component		
	1	2	3
QCM2_Q1_I	,689	-,477	,227
QCM2_Q2_P	,429	-,701	-,112
QCM2_Q3Recoded	,130	,689	,326
QCM2_Q4_I	,718	-,194	,227
QCM2_Q5_A	,631	,492	-,360
QCM2_Q6_C	,253	,521	,516
QCM2_Q7_I	,722	-,386	,124
QCM2_Q8_C	,695	-,069	,017
QCM2_Q9_A	,546	,619	-,361
QCM2_Q10_C	,720	-,249	,123
QCM2_Q11_I	,703	-,269	,223
QCM2_Q12_A	,615	,471	-,439
QCM2_Q13_P	,364	-,519	-,164
QCM2_Q14Recoded	,021	,782	,345
QCM2_Q15_C	,654	,141	-,125
QCM2_Q16_A	,521	,637	-,194
QCM2_Q17_I	,610	-,081	,126
QCM2_Q18_A	,224	,460	,272

Extraction Method: Principal Component Analysis.

a. 3 components extracted.

Rotated Component Matrix[a]

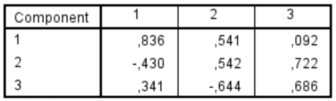


	Component		
	1	2	3
QCM2_Q1_I	,858	-,032	-,125
QCM2_Q2_P	,622	-,076	-,543
QCM2_Q3Recoded	-,076	,234	,733
QCM2_Q4_I	,761	,136	,082
QCM2_Q5_A	,193	,839	,166
QCM2_Q6_C	,163	,087	,753
QCM2_Q7_I	,812	,101	-,127
QCM2_Q8_C	,617	,328	,026
QCM2_Q9_A	,067	,863	,250
QCM2_Q10_C	,751	,175	-,029
QCM2_Q11_I	,779	,091	,024
QCM2_Q12_A	,162	,871	,096
QCM2_Q13_P	,472	,021	-,454
QCM2_Q14Recoded	-,201	,213	,803
QCM2_Q15_C	,443	,510	,076
QCM2_Q16_A	,095	,752	,375
QCM2_Q17_I	,588	,205	,084
QCM2_Q18_A	,082	,195	,539

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 5 iterations.

Component Transformation Matrix



Component	1	2	3
1	,836	,541	,092
2	-,430	,542	,722
3	,341	-,644	,686

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

Declaration of Oath

(Eidesstattliche Erklärung)

I, Marcela Pozas, declare under oath that the submitted dissertation “*Interest: a person – “context” relationship? Examining the effects of context-based task characteristics on students’ interest.*” has be written by myself only. Furthermore, I have not and will not submit the dissertation as an examination paper or as part of any other scientific examination. Lastly, the document has not and will not be submitted to another university as a dissertation.

18.01.2016

(Ort, Datum)

(Unterschrift)

Curriculum Vitae

EDUCATION

University of Koblenz-Landau **2013-in progress**
DFG Graduate School Teaching and Learning Processes (*Graduiertenkollegs Unterrichtsprozesse, UpGrade*)
PhD. In Psychology
Thesis: “Contextualized Physics”

University of Leuven, Belguim **2011-2013**
Master in Educational Sciences
Thesis: “Understanding what defines a good teacher: building a framework for General Pedagogical Knowledge”

University of Monterrey, Mexico **2005-2009**
Bachelor in Psychology
Thesis: “Successful Psychological Strategies for Couples Interaction” Honors: Dissertation approved “with Excellence”
Advance studies in Education
Magna Cum Laude award

RESEARCH EXPERIENCE

University of Koblenz-Landau **PhD. Research**
DFG Graduate School Teaching and Learning Processes (*Graduiertenkollegs Unterrichtsprozesse, UpGrade*)
Thesis: “Contextualized Physics” focus on examining the influence of task characteristics on students’ interest, anxiety, and success expectancies and overall performance.

PROFESSIONAL EXPERIENCE

University of Trier **2015-in progress**
Research assistant
Faculty of Education

Mi Mundo, Belgium **2012-2013**
English teacher
Development of course syllabus and structure.

University of Monterrey (UDEM), Mexico **2010-2011**
Faculty Recruitment Administrator
Recruitment of international faculty (professors, chair of departments, etc.).
Main responsibilities were recruiting, selecting possible candidates and assessing them with specific psychometric evaluation (according to the profile of the job position), interviewing (because most of the candidates were international scholars interviews were often made through skype), organizing meetings between faculty’s deans and candidates, revise candidates’ evaluations, and supporting final decisions.
Other responsibilities: screening checkups (mainly in the USA and Mexico), developed reports based on candidates’ psychometrical evaluations, deans’ observation and screening checkups.

Main language of usage: English.
Participation in the Strategic Planning development strategies for the Department of Human Capital and Visiting Professors program.

Colegio Ingles (English School), Monterrey, Mexico **2009-2010**
Preschool Teacher Assistant
Main responsibilities: prepare material and develop syllabus for values class. In charge of developing academic material, classroom management, students' achievement progress, and managing student presentation.
Participation in teacher training program “Learn to think”.

Ativa Business Consultant, Monterrey, Mexico **2009-2011**
Consultant
Main responsibilities: development of professional training courses for *individual contributors, managers, andmanagers of managers*, of international organizations such as PepsiCo International and Adidas Latinoamerica.
Other responsibilities: developing research for the development of training programs, supervise graphic design, contacting providers, contacting clients, and create resources, tools and materials for the program.
Translator (English to Spanish, Spanish-English) of the official competencies manual of Heneiken; specific departments: Human resources, Sales & Marketing, etc.

Hansen, Academic Support Center **2006-2010**
Teacher
Main responsibilities: development of syllabus and course structure according to the specific needs of students, which were identified by the application of educational and psychometrical evaluations. Main responsibilities were assessing students, developing reports, having meetings with parents, developing course materials and instruction for students.
Other responsibilities: management activities.

AWARDS AND HONORS

- Scholarship from the DFG Graduate School Teaching and Learning Processes (*Graduiertenkollegs Unterrichtsprozesse, UpGrade*)
- University of Monterrey Magna Cum Laude Recognition
- University of Monterrey Excellence Dissertation Recognition
- Universidad de Monterrey Scholarship
- Three times Distinguished UDEM Scholarship Grantee

LANGUAGES

- Spanish: Native speaker
- English: Native speaker (bilingual education)
- Nederlands (Dutch): read, write, and speak with proficiency
- German: read, write, and speak with proficiency
- French: read, write, and speak with basic competence