Adding Value to Self-regulated Learning through Situative Learning Support

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Statutory Declaration

I hereby declare that the thesis submitted is my own unaided work, that I have not used other than the sources indicated, and that all direct and indirect sources are acknowledged as references.

This printed thesis is identical with the electronic version submitted.

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Abstract

Considering the cognitive and social dimension as equally balanced and interdependent has become increasingly important in constructivist learning designs. This may not be due to changes in the conceptualizations of learning, but mainly is concerned with developments outside of learning theories, such as the role of technology or changes in learners and teaching methods. In spite of these developments, however, self-regulated learning still is focused on a static individual level, neglecting the importance of an integrative (situative) perspective and therefore situational factors (i.e., learning context). In this thesis, self-regulated learning is investigated from a situative perspective, including aspects and properties relevant to constructivist learning designs as well as the conceptualization of learning context. On the basis of these findings, a learning tool is proposed and evaluated with respect to its applicability and usefulness in real learning situations. The results indicate potential benefits to self-regulated learning when being provided with situative learning support. In particular, the relevance of the social dimension and learning context respectively could be demonstrated.
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1. Introduction

Constructivism is considered the predominant view on learning today and refers to a set of individual theories which attempt to explain the nature of knowledge and how people learn (Harasim, 2012). Although constructivism has its roots in cognitivism (both understand learning as a mental activity), various distinguishing characteristics exist, in particular with respect to the conception of the mind (Ertmer & Newby, 2013). While cognitive theories assume the mind to be a reflection of the real world, constructivist perspectives argue that reality is individually constructed by the mind as it filters input from the world dependent on the respective situation. Knowledge therefore is not acquired, but created by each and every individual based on prior experiences and interactions. “Our encounters with new ideas [and] perspectives”, Harasim (2012, p. 60) argues, “requires us to reconcile the new with our previous understanding: does the new fit with our previous understanding and if not, do we discard it, integrate it with our existing views or change our existing beliefs? This process is one of asking questions, exploring, engaging in dialog with others and reassessing what we know.”

Since the beginnings of constructivism, two main schools of thought – social and cognitive constructivism – have emerged based on work of Jean Piaget and Lev S. Vygotsky. While both theorists were investigating human development, different emphases were given to one’s individual cognitive performance (cognitive constructivism) and the social context (social constructivism) respectively. Even though a common understanding of the fundamental principles exists (Duffy & Cunningham, 1996), both schools are considered full-fledged theories with distinct approaches of what to consider relevant in learning. Potential mutual influences, however, have been matter of debate in the learning literature (Schcolnik et al., 2016). Although Fosnot & Perry (1996) take the view that only individuals are capable of thinking (i.e., society does not think), Schcolnik et al. (2016, p. 13) argue that “[...] we cannot possibly understand how individuals think without an appreciation of the cultural context in which their thoughts developed. Thus, cognition and culture influences are inextricably entwined; both are involved in the process of learning and have implications for education.” Guiding principles with respect to educational methodology and the construction of learning materials may therefore include (Schcolnik et al., 2016):

- Supporting spontaneous interactions in an open and collaborative learning environment (e.g., communication and exchange of ideas, etc.)
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- Accepting or provoking temporary disturbances which upset the equilibrium (cf. Piaget (1964)); providing resources based on which disturbances can be resolve and which support reflective thinking

- Encouraging knowledge construction through a learner-centered and task-based curriculum

Although the presented controversy is relevant when addressing cognitive and social constructivism as equally important and interacting, the fundamental theories and theoretical approaches have not changed (Ertmer & Newby 2013). Instead, it becomes necessary to take into account the wider context, that is the world outside of these theories with respect to the way students conceive learning and how knowledge is stored and accessed. Ertmer & Newby (2013) have identified three major forces that have become relevant in this context, including the role of technology, changes in learners, and teaching methods.

The Role of Technology

Technology in the learning domain has been object of research ever since it has become accessible in the 1960s, at that time primarily used in formal settings by a very limited number of students (Cox 2013). Since then, technological developments have advanced significantly, in particular due to increasing connectivity (i.e., Internet) and therefore availability of resources and people. Learning subsequently has become more interactive and has led to an increasingly distributed way of creating content. Ertmer & Newby (2013, p. 66) note that "[...] the 'participatory' web has enabled a knowledge-building and knowledge-sharing system whose value now stems from many small contributions [...]", instead from one centralized place (i.e., the instructor).

From an e-learning perspective, technological advances have implications on different dimensions, including the software architecture, the pedagogical foundation, content management, and dominant affordances (Adams & Morgan 2007; Laanpere et al. 2013). While primarily related to technology (e.g., cloud and web-based architectures, mobile clients, etc.), the dimensions concerned with software architecture and content management provide the basis for fundamental changes in terms of the pedagogical foundation and dominant affordances. Besides learner-centered learning designs (e.g., reflection, sharing, tagging, etc.), social interactions become increasingly important to the learning process. "[T]he web, [therefore], has functioned as a transformative technology, comprising not only an informational and social resource, but a learning medium as well, where learning with and from others is both supported and facilitated" (Ertmer & Newby 2013, p. 66).
Changes in Learners

More and more people now are deeply engaged with technology and are permanently connected to their peers, both in formal and informal learning settings (Prensky, 2010). Cognitive and social aspects become increasingly integrated, in particular since students preferably learn in authentic contexts so as to gain a better understanding of the task at hand. “Then, when it is important to test and process [...] new knowledge”, Ertmer & Newby (2013, p. 67) argues, “digital natives turn to their own learning communities, which oftentimes remain relatively disconnected from their formal educational communities”. This statement particularly is important as it shows that learning not only takes place in formal and informal settings, but may also overcome the scope of the pedagogical setting, as for instance the learning group.

Reframing Teaching Methods

Teaching methods referring to constructivist approaches (e.g., social constructivism, situated learning, etc.), in general, support learners in investigating complex topics and problems and eventually enable them to develop ways of thinking as an expert of that domain (Ertmer & Newby, 2013). Knowledge therefore is not considered abstract, but rather closely related to the situation at hand including prior experiences which are associated by the learner. Not until learners have become increasingly interactive due to technological advances, however, the understanding of learning has evolved to consider both individual and social factors as equally important and interacting (Ertmer & Newby, 2013). A similar but a little more differentiated conceptualization is presented by Laanpere et al. in that he not only investigates the development of learning platforms from the perspective of underlying pedagogical foundations, but also with respect to software architecture, content management, and dominant affordances. He describes that in current e-learning environments social constructivism is the primary pedagogical foundation, but is equally important to cognitive aspects, such as reflective thinking.

Reflective thinking is considered one relevant capability of learners today, but is just part of a set of skills which are referred to as 21st-century skills in literature (cf. Barell (2010); Ertmer & Newby (2013); Kay (2010); Lankshear & Knobel (2011)). Ertmer & Newby (2013) particularly identify two skills as relevant, that is problem solving and the ability to work collaboratively. While the former is focused on teaching methods which aim to engage students in authentic and real-world problem situations and then challenge to propose relevant solutions, the latter copes with the increasing complexity of these situations and the need of working in teams.
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Although technological progress provides a wide range of different benefits, said advances at the same time expose learners to new challenges with respect to regulation and self-management. Being able to strategically regulated one’s own learning processes therefore has become a crucial capability and is considered an important aspect in learning processes (cf. Järvenoja et al. (2015); Liaw et al. (2007)). Self-regulated learning capabilities, for instance, are needed when being involved in multiple projects at the same time or when becoming significantly unsatisfied with the current job situation (e.g., too many administrative responsibilities or concerned with work-life balance). According to Järvenoja et al. (2015, p. 204), in suchlike situations “[...] through regulation, it is possible to influence and adjust one’s cognitive, motivational, and emotional behaviors, as well as those of others, for optimal learning and working.” Self-regulated learning capabilities therefore not only help to develop one’s own knowledge (e.g., through goal setting and strategic planning), but also ensure the achievement of objectives by continuous assessment of learning strategies and outcomes (cf. Pintrich et al. (2000); Zimmerman (1998b)). The effect is that one who engages in self-regulated learning more effectively can select proper learning strategies to better control his or her cognition, motivation, and emotions in the context of specific learning goals.

Considering the developments from the perspective of constructivism, in particular with respect to equality of the cognitive and social dimension, theories addressing self-regulated learning mainly has focused on a static individual level (Järvenoja et al., 2015). Although respective theories address self-regulated learning from a socio-cognitive and socio-cultural perspective (the cognitive and social perspective is focused respectively, while the other dimension only is considered as an supplement), the relevance of integrating both perspectives as equally important has been identified only recently. Järvenoja et al. (2015) in their seminal paper on understanding regulated learning in situative and contextual frameworks address respective shortcomings and argue that an integrated approach would contribute to the understanding of learning today. “[The situative perspective”, Järvenoja et al. (2015, p. 206) claims, “takes an integrative approach to regulated learning that understands the individual and social levels to be equally balanced and interdependent. That is, individual and social regulation processes are understood to promote each other, exist in parallel, and function equally without either being subordinated to the other.”

Taking into account ongoing developments with respect to the role of technology, changes in learners, and teaching methods, being able to regulated one’s learning processes has become crucial to learners. Self-regulated learning as being conceptualized mainly from a static individual level, however, shows limitations in considering the social dimension as equally important and therefore insufficiently addresses current developments, that is that learning is increasingly interactive, collaborative, and technologically enhanced. The main objective of this work can be derived accordingly as providing situative learn-
1.1. Specification of the Objective

Adding value to self-regulated learning through situative learning support requires to not only consider both the individual and social dimension as equally important, but additionally asks for investigating both dimensions as being interdependent. Järvenoja et al. (2015, p. 206) state that “[…] individual and social learning processes are understood to promote each other, exist in parallel, and function equally without either being subordinated to the other.” The first subgoal can be derived accordingly as interdependence of the cognitive and social dimension in learning.

Subgoal 1

Interdependence of cognitive and social dimension in learning

The research questions associated with the first subgoals concern the latest state of the art with respect to learning theories and respective conceptualizations of learning. In particular, the relevant properties in constructivist learning designs (RQ 1) as well as related to the learning context (RQ 2) are investigated.

RQ 1. What to consider in constructivist learning designs?

The first research question addresses the latest state of the art regarding what to consider in constructivist learning designs, in particular not only considering the cognitive and social dimension, but also situational factors, that is the learning context (e.g., technology support, pedagogical designs, etc.).
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RQ 2. How to conceptualize learning context?

The second research question focuses on the learning context and respective properties relevant to its conceptualization within the scope of constructivist learning designs. The learning context as linking factor needs to be reflected as mediating component between the cognitive and social dimension, that is either engaging with other learners or content.

Considering the cognitive and social dimension as equally important and interdependent (situative perspective), the learning context as linking factors between these dimensions becomes relevant to learning processes. Since the situative perspective, however, is specific to time and place (i.e., situational factors, such as technology support or pedagogical designs, may change over time), support measures need to be able to cope with dynamic changes in the learning situation. The second subgoal is concerned with suchlike adaptability and can be derived accordingly as adaptive support in learning processes.

Subgoal 2

Adaptive support in learning processes

The research question associated with the second subgoal concerns how to operationalize an integrated learning design which meets the requirements defined by constructivist learning designs considering the learning context as linking factor between the cognitive and social dimension in learning.

RQ 3. How to operationalize an integrated learning design?

The third research question focuses on the question of how to operationalize an integrated learning design which suffices the requirements defined by the first and second research question. In this regard, not only the cognitive and social dimension need to be addressed accordingly, but also dynamic aspects associated with the situative perspective (i.e., the learning context) need to be taken into account.

Figure 1.1 illustrates the main objectives (gray rectangles) of this work including the respective research questions (white rectangles) to be investigated. The hierarchical structure is shown with the aid of directed arrows, where the orientation shows the dependence of the subgoal. For instance, the first subgoal contributes to the main objective in that it allows considering the cognitive and social dimension in learning from an interdependent perspective. Associated research questions are shown in direct relation to the respective subgoal.
1.2. Key Terms & Concepts

Key terms and concepts which are considered most relevant to this work are introduced and put into context in this section. Starting with the basic foundation of current constructivist learning theories (i.e., cognitive and social constructivism), the concepts referring to self-regulated learning and the situative perspective on learning are defined subsequently.

1.2.1. Cognitive & Social Constructivism

Two main schools of thought have emerged based on the work of Jean Piaget and Lev S. Vygotsky in the context of constructivist thought. Although both theorists were focusing on human development, different emphases were given to one’s individual cognitive performance (cognitive constructivism [Piaget (1964)]) and the social context (social constructivism [Vygotsky (1986)]) respectively.

Jean Piaget studied the different stages of human development and, according to Harasim (2012, p. 61), “posited that humans learn through the construction of progressively complex logical structures, from infancy through adulthood.” Piaget claimed that all humans go through the same developmental stages at about the same age and proposed a four stage sequence of cognitive development including the sensory-motor (0 – 2 years), the pre-operational (2 – 7 years), the concrete operational (7 – 11 years), and the formal operational (12+ years).
years) stage (cf. Piaget (1964)). The development of knowledge alongside these four stages is mainly driven by cognitive efforts of the individual combining prior knowledge with current experiences. Piaget in this context defined three essential components, that is equilibration, assimilation, and accommodation. While equilibration is concerned with establishing and maintaining a consistent balance between internal cognitive structures and the external environment, assimilation and accommodation processes are means to the state of equilibrium. Theories and approaches linked to cognitive constructivism include but are not limited to meta-cognition and self-regulated learning, problem-based learning, or project-based learning.

Lev S. Vygotsky coined the social constructivist perspective, in particular in the course of his work on cognitive development commonly referred to as cultural-historical psychology (cf. Vygotsky (1986)). In contrast to Piaget, however, his focus was not on the individual learner, but rather on the underlying processes and their relationship with the learner's social activities within the cultural context (Crawford, 1996; Harasim, 2012). “Learning”, as Vygotsky (1980, p. 90) argued, “is a necessary and universal aspect of the process of developing culturally organized, specifically human, psychological functions.” As an important concept in his work, Vygotsky introduced the zone of proximal development in which he proposed that learning occurs when a learner is situated between his or her actual development level and future potential. A learner therefore does not act on its own, but collaborative with more knowledgeable others (e.g., adults or capable peers) for the purpose of completing tasks or solving problems. Eventually, the actual development level increases in the sense that the learner expands his or her capabilities (i.e., what can be done without guidance). Theories and approaches linked to social constructivism include but are not limited to situated and experiential learning, learning communities, and informal learning.

1.2.2. Self-regulated Learning

Constructivism views learning as an active process in which new knowledge is constructed by the learning individual (cf. Duffy & Cunningham (1996); Hadwin & Oshige (2011); Mayes & De Freitas (2004)). The traditional role model of the instructor (i.e., more knowledgeable other) has been replaced by knowledge construction processes among peers. As a consequence, learning not only relies on the knowledge of the instructor, but also depends on what the learner already knows or what the learner can already do (Mayes & De Freitas, 2004). The degree to which learners are responsible for building their own knowledge therefore increases, which requires one to strategically regulated his or her own learning processes in the context of specific learning goals (Jarvenoja et al., 2015). Self-regulated learning, for instance, is needed when being involved in multiple projects at the same time or when becoming significantly unsatisfied with the current job situation. According to Jarvenoja et al. (2015, p. 204),
1.3. Structure of the Work

Although various different models and conceptualizations exist on self-regulated learning, three elements or phases remain consistent among those (Puustinen & Pulkkinen, 2001). The preparation phase in the beginning is concerned with goal setting and planning procedures (e.g., tasks analysis and self-motivation). The performance or execution phase then follows in which the tasks to be done are actually executed. Finally, the appraisal phase allows for adaptations with respect to the applied learning strategies and plans for the purpose of increasing one’s performance in subsequent learning processes. In the course of these phases, students are required to constantly monitor and assess their learning progress and outcomes which makes metacognition an important aspect in this regard. Azevedo et al. (2012, p. 173f.) argue that “[during] self-regulated learning, students need to deploy several metacognitive processes to determine whether they understand what they are learning, and perhaps modify their plans, goals, strategies, and efforts in relation to dynamically changing contextual conditions.” Conceptualizations of metacognition (cf. Pintrich et al., 2000) therefore contribute to further explain self-regulated learning.

1.2.3. Situative Perspective on Learning

Despite the importance of self-regulated learning and metacognitive capabilities, learning has become increasingly interactive and collaborative. Conceptualizations of self-regulated learning and metacognition, however, do not inherently address these conditions due to their static individual approach (Järvenoja et al., 2015). The situative perspective recognizes these shortcomings by taking into account both the individual and social dimension and, according to Järvenoja et al. (2015 p. 204), “[…] aims to better understand situational variation in relation to regulated learning processes by identifying and highlighting a complex web of situational factors.” Important in this context is that individual and social regulation processes are considered equally important, in particular as to both dimensions can exist in parallel without either one being subordinated to the other. A situative perspective on a particular topic, for instance, is one that considers individual beliefs and behaviors as being the results of social and cultural interactions in the context of a system (Turner & Nolen, 2015).

1.3. Structure of the Work

An overview of this work is presented in this section with regards to the coherence of content and the chapter structure. While the first part mainly is
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concerned with the line of arguments underlying this work, the second part focuses on illustrating the relationship structure among chapters.

1.3.1. Coherence of Content

This work is structured into three main parts, each of which contributes to answering the research questions introduced above. While the first part presents the theoretical foundation relevant to this work, the second part utilizes these findings in order to conceptualize a web-based learning tool supporting situative self-regulated learning. Eventually, the third part reviews and evaluates the learning tool from both a technical and empirical perspective. Below, the different parts are outlined by reference to the individual chapters. Each chapter is represented by means of its starting point and outcome as well as its main content.

− The starting point describes the initial conditions which are relevant to the contents of the chapter. In particular, previous findings (i.e., preceding chapters) are related and illustrated with respect to their relevance.

− The main content outlines the specific contents of the chapter in the context of the work.

− The outcome eventually describes the contribution of the chapter and therefore forms the basis for subsequent chapters.

Part 1 Theoretical Aspects on (Situative) Learning

The first part illustrates the latest state of the art with reference to the situative perspective on self-regulated learning. A literature review on existing learning theories (cf. Chapter 2) provides the basis for investigating self-regulated learning considering both the cognitive and social dimension (cf. Chapter 3). Finally, a literature review on current trends in e-learning is presented and put into context of situative self-regulated learning (cf. Chapter 4).

Chapter 2 Learning Theories: A Short Introduction

The historical development of learning theories (i.e., conceptualizations of learning) is presented in this chapter, involving behaviorism, cognitivism, and constructivism. Relevant theories and theoretical approaches are reviews and presented as to better understand the latest state of the art in learning theories and current challenges considering the cognitive and social dimension as equally important and interdependent in learning. The chapter
1.3. Structure of the Work

concludes with findings relating to the relevant properties to be considered in constructivist learning designs.

Chapter 3. A Situative Perspective on Self-regulated Learning

This chapter builds on the relevant properties in constructivist learning designs and continues with current developments beyond the scope of traditional learning theories. Learning as being highly interactive, collaborative, and technology-enhanced is considered in particular. The chapter concludes with an integrated approach covering not only requirements from the cognitive and social dimension, but also situational factors as defined by the learning context.

Chapter 4. E-Learning

The situative perspective acknowledges the role of information technology as relevant constituent in the educational research agenda and claims a more integrative perspective by considering the situational factors (i.e., context) as crucial to learning processes. This chapter reviews the current e-learning literature and outlines the development of the field by means of different generations, ranging from standard desktop software to cloud architectures and mobile clients allow for highly interactive learning settings. The chapter concludes with findings on the current state of the art of e-learning systems, in particular with respect to the situative perspective on self-regulated learning.

Part II: Situative Learning Support

The second part builds on previous findings and operationalizes a web-based learning tool for supporting situative self-regulated learning. Development goals are identified in order to guide the requirements analysis process (cf. Chapter 5), which is then followed by the description of the middleware framework AEOLION (cf. Chapter 6) and the web-based learning tool Ueber Learn (cf. Chapter 7).

Chapter 5. Tool Conceptualization

The theoretical findings from the chapters concerned with constructivist learning design (cf. Chapter 2) and the situative perspective (cf. Chapter 3) are used as foundation for the conceptualization of a respective tool. Development goals are derived as high-communication objectives so as to ensure the specification of requirements aligned with the needs and demands from the literature. The chapter concludes with the operationalization of an integrated learning design (i.e., list of requirement bundles) in the context situative self-regulated learning support.
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Chapter 6. AEOLION: Enabling Middleware Framework
The requirement bundles (cf. Chapter 5) provide the basis for the design and implementation of a middleware framework supporting situative learning processes. The framework is based on the Actor model allowing for flexible application development and provides the basis for any further implementations in the context of learning. The chapter concludes with the design of a specific service choreography providing situative self-regulated learning support.

The requirement bundles (cf. Chapter 5) and AEOLION (cf. Chapter 6) are used to design and implement a web-based learning tool supporting situative self-regulated learning. Features relevant in this context are arranged and provided in an integrated manner which not only increases usability but also allows situation-specific applicability. The chapter concludes with a web-based tool proposed for supporting situative self-regulated learning.

Part III. Review & Evaluation

The third part is concerned with the review and evaluation of the proposed tool. The software architecture and design is reviewed based on the completeness of implementation (cf. Chapter 8) with respect to the requirement bundles introduced in Chapter 5. The usefulness of the web-based learning tool eventually is tested in the context of two learning scenarios (cf. Chapter 9).

Chapter 8. Technical Analysis
The software architecture and design of the proposed middleware framework (cf. Chapter 6) and the web-based learning tool (cf. Chapter 7) are reviewed based on the requirement bundles introduced in Chapter 5. Each requirement bundle is assessed by means of its individual constituents, that is specific features are reviewed for completeness with respect to implementation. The chapter concludes with a verified operationalization of an integrated learning design (i.e., requirement bundles) in the context of situative self-regulated learning support.

Chapter 9. Empirical Evaluation
The learning tool is evaluated with respect to its applicability and usefulness in the context of two specific learning scenarios. While the first study focuses on the usability of proposed features from an integrative perspective (i.e., features are not tested individually), the second study evaluates the learning tool in the context of a specific learning setting. The chapter concludes with findings
1.3. Structure of the Work

on the usefulness of the learning tool and respective features as related to supporting situative self-regulated learning.

Finally, Chapter 10 summarizes the findings of the work with respect to the main objective as well as associated subgoals and research questions. The chapter concludes with a discussion on potential limitations as well as an outlook on future research questions and activities.

1.3.2. Chapter Structure

In Figure 1.2, the chapter structure is illustrated in addition to the coherence of content presented above. The separate parts of the work are shown as horizontal dotted lines (gray) and indicate the belonging of chapters. Each chapter (white rectangle) is represented by means of its heading and put into context with respect to its relations to other chapters.
Part I.

Theoretical Aspects of (Situative) Learning
Introduction

The conceptualization of learning is a difficult task and has led researchers, theorists, and practitioners to a variety of different theories and theoretical approaches. Starting with the behaviorist perspective, learning was defined in the scope of the scientific method and the principles of positivism (Harasim, 2012). It was based on rigorous objectivity and rejected introspective and intuitive knowledge as not being scientifically valid (cf. Harasim (2012); Winn (2004)). Later, due to limitations concerned with the direct link between stimulus and response, cognitivist theories emerged which did not entirely reject behaviorist elements, but shifted the focus from external stimuli to internal mental processes. Cognitive psychologists argued that there were various other factors involved interfering the predictability of responses based on environmental stimuli (Winn, 2004). The constructivist perspective of learning, eventually, challenged the assumption of knowledge being objectivistic and emphasized the individual as being responsible for the construction of ideas and concepts based on prior experiences (Ertmer & Newby, 1993). Two main schools of thought — social and cognitive constructivism — have emerged in this context focusing on one’s individual cognitive performance (cognitive constructivism) and the social context (social constructivism) respectively. Although both schools share a common understanding of the fundamental constructivist principles, both are considered full-fledged theories with distinct approaches of what to consider relevant in learning. Potential mutual influences, however, have been matter of debate in the learning literature, in particular with respect to the consideration of the cognitive and social dimension as equally important (Scholnik et al., 2016). It therefore has become necessary to take into account not only the individual, but also the wider (social) context which oftentimes is not directly addressed in learning theories (Järvenoja et al., 2015; Turner & Nolen, 2015).

In this part, relevant theories and theoretical approaches are reviewed and presented as to better understand the latest state of the art in learning theories and current challenges considering the cognitive and social dimension as equally important and interdependent in learning. Chapter 2 gives an short overview on the development history of learning theories, including behaviorism, cognitivism and constructivism. While the social dimension was recognized as important to learning as early as in the 1970s in the context of behaviorism (cf. Bandura (1976)), cognitivism then reinforced focusing on the mind and mental processes as mainly responsible in learning. Today as the most prominent theory, constructivism considers the individual construction of knowledge based on prior experiences as crucial to learning, referring to either cognitive or social constructivism. Taking into account the two theoretical approaches, Chapter
addresses challenges in the integration of both, in particular as driven by the role of technology as well as changes in learners and teaching methods. An integrated approach is proposed, not only addressing the cognitive and social dimension but also situational factors recognizing the learning context. Finally in Chapter 4, technological developments in particular with reference to e-learning and mobile learning are reviewed. Although not affecting constructivist principles directly, it is considered one of the driving factors changing the context in which learning occurs (Ertmer & Newby, 2013).

Figure 1.3 shows the overall context of chapters as well as associated research questions, including (RQ 1) what to consider in constructivist learning designs and (RQ 2) how to conceptualize learning context. The individual chapters are argued on the basis of their individual contributions in the following:

**RQ 1. What to consider in constructivist learning designs?**

Chapter 2 and 3 investigate the question of what to consider in constructivist learning design, in particular when not only considering the cognitive and social dimension, but also situational factors recognizing the learning context. While Chapter 2 mainly focuses on the historical development and current learning theories (e.g., constructivism), Chapter 3 addresses the wider context concerned with how students conceive learning and the way knowledge is stored and accessed today.

**RQ 2. How to conceptualize learning context?**

Chapter 3 investigates how to conceptualize learning context with respect to the constructivist perspective on learning. It particularly focuses on approaches integrating not only the cognitive and social dimension, but also situational factors (e.g., technology, pedagogical design, etc.) relevant to learning.

Figure 1.3.: Overall context of the theoretical aspects of (situative) learning

Chapter 2 gives an overview of the historical development of learning theories, in particular focusing on the three main approaches including behaviorism (cf. Section 2.1), cognitivism (cf. Section 2.2), and constructivism (cf. Section 2.3).
While constructivist approaches subsume current theories and conceptualizations of learning, previous theories are reviewed with respect to the consideration of the cognitive and social dimension.

From the perspective of constructivism, Chapter 3 further investigates the aspect of self-regulated learning under the consideration of situative conditions. The development from individually oriented to collaborative approaches is discussed with particular focus on the situative perspective (cf. Section 3.1), the latter considering learning as highly interactive, participative, and pervasive processes which are sensitive to their contexts. A theoretical analysis of existing theories addressing the situative aspect gives theoretical insights on the current body of knowledge and lays the foundation for bringing together the different perspectives (cf. Section 3.2). In Chapter 3.3 an integrative approach to supporting self-regulated learning under the consideration of situative conditions is introduced by means of the community of inquiry model. Focusing on aspects concerned with individuals’ cognitive capabilities (cognitive presence), the openness of communication and level of group cohesion (social presence), as well as underlying structures and processes related to the design and organization of courses (teaching presence), the model is used as conceptual framework towards improving the educational experience.

Finally, Chapter 4 presents the role of technology in the context of e-learning and reviews respective developments from the very beginning in the 1970s until today. Both, the social and cognitive perspective is discussed by reference to collaborative learning environments and design principles of e-learning systems respectively. Based on two different generation models, current drivers behind recent developments are presented, in particular referring to more open and participative approaches with regards to constructivist and collaborative perspectives (cf. Section 4.1). Eventually, mobile learning is addressed as a relevant concept allowing to access information and learning artifacts from anywhere and at any time (cf. Section 4.2).
2. Learning Theories: A Short Introduction

Learning, as defined in the Oxford dictionary, is “[the] acquisition of knowledge or skills through study, experience, or being taught.”\(^1\) Defining a concept as broad and abstract as learning, however, is a challenging task and has led many researchers, theorists, and practitioners to various explanatory approaches. In the field of psychology, for instance, learning has been a central topic ever since but, according to Lachman (1997), often is addressed by researchers superficially as mere changes in behavior due to prior experiences. In response to this, De Houwer et al. (2013, p. 663) propose a functional definition of learning which defines learning “as changes in the behavior of an organism that are the result of regularities in the environment of that organism.”

Learning theories consider learning as a process rather than a product. In the early 20th century, behaviorism was introduced as the first conceptualization of learning – prior discussions were rooted in philosophy and religious thought – following the principles of positivism and the scientific method (Harasim, 2012). Later, due to limitations concerned with the direct link between stimulus and response, cognitivist theories emerged which did not entirely reject behaviorist elements but shifted the focus from external stimuli to internal mental processes. The constructivist perspective of learning finally challenged the assumption of knowledge being objectivistic and emphasized the individual as being responsible for the construction of ideas and concepts. Table 2.1 summarizes the learning theories with respect to the different conceptualizations of learning. Behaviorism views the learner as passive participant which only receives information and content from a more knowledgeable other (i.e. a teacher). The learners therefore are not considered responsible for their learning processes. In contrast, both, cognitivism and constructivism assume learners to be active and responsible for their learning processes. Learners are viewed as active participants. Differences in how information and content transferred exist since cognitivism follows a processed-based approach. Constructivism, however, focuses on the individual and holds that knowledge is individually constructed based on prior experiences. According to Fosnot (2001, p. 54), constructivism is considered a “philosophy and a cognitive, developmental psychology that explains learning as a case of interpreting and inferring about the world.”

\(^1\)\url{http://www.oxforddictionaries.com/definition/english/learning} (accessed on February 16, 2016)
Chapter 2. Learning Theories: A Short Introduction

Table 2.1.: A comparison of learning theories (Mankel, 2008, p. 18)

<table>
<thead>
<tr>
<th>Behaviorism</th>
<th>Cognitivism</th>
<th>Constructivism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learner as passive participant</td>
<td>Learner as active participant</td>
<td></td>
</tr>
<tr>
<td>Receiving learning content</td>
<td>Process-based handling of learning content</td>
<td>Individual construction of teaching content</td>
</tr>
</tbody>
</table>

In this chapter, the different learning theories including behaviorism (cf. Section 2.1), cognitivism (cf. Section 2.2), and constructivism (cf. Section 2.3) are presented.

2.1. Behaviorist Theories of Learning

In the early 20th century, behaviorist learning theory emerged in the context of positivism as an explanatory approach to the understanding of human behavior. In compliance with the principles of positivism, the behaviorist research methodology was based on rigorous objectivity, and therefore rejected introspective and intuitive knowledge as not being scientifically valid (Harasim, 2012; Winn, 2004). Accordingly, behaviorism adheres to the two key principles of positivism which state that “[…] knowledge of the world can only evolve from the observation of objective facts and phenomena […]” as well as that “[…] theory can only be built by applying [observations] in experiments where the experimenter manipulates only one or two factors at a time” (Winn, 2004, p. 83).

Following this notion, behaviorism explains learning as being observable behavior patterns and therefore open to conditioning (Harasim, 2012). Conditioning describes learning as a process in which a given environmental stimulus becomes increasingly effective in causing a specific response. For instance, a teacher rewards a student by dropping his or her lowest grade once all assignments are completed. The reward of dropping the lowest grade serves as stimulus for the desired response of a student completing all assignments. The key elements are the stimulus and response as well as the association between the two (Ertmer & Newby, 2013). Learning, therefore, is the process of establishing, strengthening, and maintaining the association between a given environmental stimulus and a specific response. Consequently, the mind is viewed as “black box” (cf. 22
2.1. Behaviorist Theories of Learning

Figure 2.1) and hence as not being relevant for research (cf. Harasim (2012); Mankel (2008)).

![Behaviorist model](image)

In this section, the two main conceptualizations of learning in the context of behaviorism are presented including classical and operant conditioning (cf. Section 2.1.1). Social learning theory as the first approach challenging the fundamental principles of behaviorism is discussed subsequently (cf. Section 2.1.2).

2.1.1. Classical and Operant Conditioning

Behaviorist learning theory distinguishes between two main types of conditioning, namely classical conditioning and operant conditioning. Developed by Ivan P. Pavlov and Burrhus F. Skinner respectively, the two types of conditioning are considered as the foundation of behaviorism (Harasim 2012).

**Classical Conditioning**

Classical conditioning, also known as Pavlovian or respondent conditioning, is a behaviorist learning theory developed by the Russian physiologist Ivan P. Pavlov (1849 – 1936) who is considered the intellectual founder of behaviorist learning theory (Harasim 2012). Although primarily involved in medical research with respect to the physiology of digestion, Pavlov accidentally discovered what he would later call conditioned reflexes. While studying the physiology of digestion in dogs, he observed that dogs would not only salivate in the presence of food, but had already begun to salivate in the presence of the lab assistant who was responsible for feeding. He subsequently began studying the relationship between stimulus and response in dog salivation, which later became the foundation of his theory of classical conditioning. He found out that the salivation in dogs could be manipulated through conditioning and caused by neutral other than natural stimuli (e.g., presence of food) as well. The following example illustrates the three-step process of conditioning:

1. **Before conditioning** the dog is presented with food (unconditioned stimulus) which causes him to salivate (unconditioned response). The ringing of a bell (neutral stimulus) does not cause any salivation (no conditioned response associated).
Chapter 2. Learning Theories: A Short Introduction

2. During conditioning a bell is rung just before the dog is fed. The dog starts to salivate (unconditioned response).

3. After conditioning the ringing of a bell (conditioned stimulus) eventually causes the dog to salivate (conditioned response).

Based on the work of Pavlov, John B. Watson (1878 – 1958) was the first American psychologist to use his findings in the context of human psychology. With his experiment Albert B., better known as Little Albert, he demonstrated empirical evidence of classical conditioning with respect to emotional reactions (cf. Beck et al. (2009); Harris (1979); Watson & Rayner (1920)). Watson published his seminal work on the behavioristic view in psychology in 1913, not only coining the term behaviorism but also proposing a major shift in the field of human psychology. Watson (1913, p. 158) wrote:

“Psychology as the behaviorist views it is a purely objective experimental branch of natural science. Its theoretical goal is the prediction and control of behavior. Introspection forms no essential part of its methods, nor is the scientific value of its data dependent upon the readiness with which they lend themselves to interpretation in terms of consciousness.”

Operant Conditioning

Operant conditioning, also known as voluntary or instrumental conditioning, was proposed by the American psychologist Burrhus F. Skinner (1904 – 1990) as an alternative to Pavlov’s classical conditioning (cf. Skinner (1938)). In contrast to classical conditioning where a neutral stimulus is used to cause a condition, Skinner’s work focused on voluntary behavior by using positive and negative reinforcement. One of his most famous experiments is that of a laboratory rat learning to navigate through a maze by using cheese as a positive reinforcement. The experiment starts with placing the rat in a maze with a wedge of cheese located nearby. The cheese serves as reward (positive reinforcement) conditioning the rat to eventually complete the maze. Once the intended behavior becomes ingrained, that is the rat moving forward until the first turn, the cheese is relocated after the next turn. This same procedure is repeated until the rat is trained to complete the maze without any further guidance.

In operant conditioning, reinforcement and punishment are the key elements through which operant behavior is manipulated, each subdivided into a positive and negative branch respectively (cf. Figure 2.2).

- Positive reinforcement rewards behavior that is to be strengthened during
2.1. Behaviorist Theories of Learning

conditioning by adding a positive stimulus. For instance, a student is rewarded with bonus points (positive stimulus) when behaving well in class (response).

- **Negative reinforcement** rewards behavior that is to be strengthened during conditioning by removing a positive stimulus. For instance, a student is exempted from the final exam (positive stimulus) when completing all assignments (response).

- **Positive punishment** punishes behavior that is to be weakened during conditioning by adding a negative stimulus. For instance, a student is given extra homework (negative stimulus) when misbehaving in class (response).

- **Negative punishment** punishes behavior that is to be weakened during conditioning by removing a negative stimulus. For instance, a student is exempted from a school trip (negative stimulus) for misbehaving in class (response).

![Operant Conditioning](image)

Figure 2.2.: The types of operant conditioning ([Harasim, 2012](#)).

During his experiments, Skinner found that changes in operant behavior of laboratory animals, such as mice and rats, require numerous successive repetitions. Significant changes in behavior even would need to be broken down into smaller ones which are required to be repeated over a long period of time ([Harasim, 2012](#)). Later, Skinner was criticized for his research, in particular with respect to inconsistencies among his theoretical model and empirical results ([Harasim, 2012](#)). [Chomsky, 1959](#) argued that Skinner could not empirically demonstrate causalities between specific stimuli and the observed responses.

Although classical and operant conditioning is considered limited in its significance related to current conceptualizations of learning, the design and application of respective pedagogical elements still could be considered as a way to induce some sort of change in behavior. In a classroom setting, for instance, bonus points would possibly engage students to collaborate during the semester.
Chapter 2. Learning Theories: A Short Introduction

already, instead of waiting until the final exam to study the learning materials.

2.1.2. Social Learning Theory

Social learning theory was developed by the Canadian/American psychologist Albert Bandura (1925–) as he was studying learning processes in interpersonal settings which could not adequately be explained by existing learning theories, such as classical and operant conditioning. Bandura & Walters (1963) argued that learning theories at that time were having significant weaknesses in explaining the acquisition of novel behavior due to the neglecting of social factors. In social learning, however, inadequacies of those learning theories were addressed by taking into account one’s cognitive functioning as crucial to the learning process. The mind was no longer being rejected as “black box”, instead, it was considered as part of a process responsible for the transition of an environmental stimulus to a specific response or behavior (cf. Figure 2.3).

According to social learning theory, novel behavior can be acquired either through learning by direct experience or learning through modeling, of which the former represents the more basic form of learning. In direct experience learning is mainly driven through positive or negative consequences which allow for immediate evaluation whether the response was successful or unsuccessful. “Through this process of differential reinforcement”, Bandura (1976, p. 3) wrote, “successful modes of behavior are eventually selected from exploratory activities, while ineffectual ones are discarded.” Differential reinforcement with its informative (informative function of reinforcement) and incentive (motivational function of reinforcement) characteristic therefore is crucial, but at the same time considered insufficient in the context of social learning. As Skinner found in the course of his work on operant conditioning already, differential reinforcement allows for changes in behavior, however, requires numerous successive repetitions using trial-and-error strategies. Such strategies not only are limited in their usefulness in cases of potential hazards (e.g., life-threatening situations), but also show significant constraints in learning complex behaviors, such as speaking. Bandura (1976, p. 5) extended on this concept and introduced the notion of vicarious reinforcements, which allow the development of

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2Besides the informative and motivational function, reinforcement also has response-strengthening capabilities, which are referred to as cognitive mediation of reinforcement effects and reinforcing effects of response consequences.
2.1. Behaviorist Theories of Learning

“[...] new modes of response [...] without needles errors by providing competent models who demonstrate how the required activities should be performed.” Models are the primary concern of learning through modeling and are divided into the following three categories:

- **Live model.** A live model is an individual actually performing a desired behavior. Modeling occurs by observing the individual.

- **Verbal instruction.** The desired behavior is not performed but only described by an individual. Modeling occurs by listening to the detailed instructions on how to perform the respective behavior.

- **Symbolic model.** The desired behavior is communicated via media, such as movies, television, Internet, and the literature. Modeling occurs by seeing and/or listing to either real or fictional characters.

In social learning theory, individuals are considered active information processors in the sense that information obtained while observing the environment is processed by the mind (e.g., attention, perception, short-term memory, etc.). Cognitive processes therefore determine whether novel behavior is acquired. According to Bandura (1976), these cognitive processes are called mediational processes and are mainly governed by the following four sub-processes:

- **Attention.** Bandura (1976, p. 6) states that “[an individual] cannot learn much by observation if he [or she] does not [...] recognize the essential features of the model’s behavior.” Therefore, attentional processes are crucial to learning, as simply exposing models does not necessarily mean that the relevant characteristics of the desired behavior can be identified.

- **Retention.** A model’s behavior typically is not performed immediately after observation. It therefore is necessary that a symbolic memory of the behavior is stored and available to an individual in the respective situation anytime after without the presence of the actual model.

- **Reproduction.** The imitation of a behavior requires the physical capabilities of an individual to perform the various actions involved. Even if a symbolic representation is acquired and retained, an individual may be unable to successfully perform the desired behavior.

- **Reinforcement and Motivation.** Motivational factors influence the actual performance of a behavior. If an individual does not see any advantages in performing the behavior (e.g., rewards) or even expects negative consequences (e.g., punishments), he or she will most likely refuse performing the behavior.

Due to the focus on mediational processes and therefore mental (cognitive)
Chapter 2. Learning Theories: A Short Introduction

factors, social learning theory often is seen as the link between behavioristic and cognitive approaches to learning.

In contrast to other theories associated with behaviorism, social learning theory was the first to consider individuals as active information processors including the environment as relevant factor to learning. With respect to its relevance in the context of current theories on learning, in particular the concept of modeling could help to reflect on the different roles in collaborative learning process.

2.2. Cognitivist Theories of Learning

Cognitive approaches to learning began to emerge as a response to the limitations of behaviorist theory by the mid-1950s, in particular due to the emphasis on the direct link between stimulus and response (Miller 2003). Cognitive psychologists argued that there were various other factors involved interfering the predictability of responses based on environmental stimuli (Winn 2004). Behaviorist elements and approaches, however, were not entirely rejected, but the focus was shifted from external stimuli to internal mental processes which were considered responsible for learning. “Cognitive learning theory”, as Harasim (2012, p. 47) described, “was concerned with the mental processes that operated on the stimulus, and which intervened to determine whether or not a response was made and, if so, which response.”

Due to advances in fields such as linguistics, neurology, psychology, education, and computer science, cognitive learning theory soon became the major school of thought and experimental paradigm (Harasim 2012). In particular the invention of the computer had a significant influence on cognitivist theory, leading to metaphors such as mind as computer or human information processing. Accordingly, the term stimuli was replaced by inputs, being the informational source to be transformed by mental processes to respective outputs, formerly referred to as responses (cf. Figure 2.4).

In this section, the information processing theory (cf. Section 2.2.1) is presented as one of the main schools of thought related to cognitivist theories of learning. Cognitive load theory (cf. Section 2.2.2) as one important contribution to the understanding of the working memory\(^3\) is discussed subsequently. Finally, situated cognition theory (cf. Section 2.2.3) is presented as the first approach considering the situation and context as being relevant to learning.

\(^3\)The general model of memory as proposed by the information processing theory include three different components of memory, namely the sensory, the working, and the long-term memory. Research on the cognitive load theory further examined the working memory, since it was considered to be limited with respect to its processing capabilities.
2.2. Cognitivist Theories of Learning

2.2.1. Information Processing Theory

Information processing theory emerged in the context of computer science and is commonly associated with cognitivism and its perspective on the mind as information processor. Learning is understood through attention and mental processes, both of which are explained by mechanisms of a computer. Input gathered from the senses therefore is received and processed by an individual who eventually decides whether to perform a specific behavior (output) or not.

Various different approaches following the principles of information processing theory have been developed since then, most notably the stage theory. Atkinson & Shiffrin (1968) described that memory is information which is passed along a system consisting of a series of “stores” (i.e., sensory memory, working memory, and long-term memory). Information is gathered by the senses and enters the sensory memory. If consciously perceived (attention) information is passed along to the short-term memory, otherwise it is discarded (forgotten). Information is transferred further to the long-term memory only if rehearsed. Alternatively, information from short-term memory is lost (forgotten) through processes of displacement or decay. Although stage theory is considered influential, the model tends to oversimplify the complexity of the human brain, in particular with respect to the consideration of both the short-term and long-term memory as unidimensional. Baddeley & Hitch (1974), for instance, found that short-term memory is a more complex entity as previously thought, consisting of multiple components, such as central executive and visuo-spatial. Addressing these shortcomings, Craik & Lockhart (1972) developed the level of processing model in the context of their work on memory processes, claiming that short-term and long-term memory need to be considered more coherently rather than treated as separate entities. In their model, memory is described

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Figure 2.4.: The transition from behaviorism to cognitivism (Harasim, 2012, p. 48)
as dependent on the depth of information processing, namely shallow (structural and phonemic) and deep (semantic) processing. Bransford (1979) further extended this approach, suggesting that not only the processing of information, but also the way it is accessed is crucial to remembering and therefore learning.

Despite the different approaches to information processing theory, three main components describing the different types of memory are considered relevant. Figure 2.5 shows the theory’s general model including the different types of memory (sensory, working, and long-term) as well as the transitions important to the involved learning processes. The different memory types are described in the following:

- **Sensory Memory.** Information is gathered by the senses and enters the sensory memory through a process which is called transduction.\(^5\) Due to the vast amount of information constantly gathered by the senses, the sensory memory additionally serves as a filter, only passing along the most relevant information to the working memory.

- **Working Memory.** According to Baddeley (2000), the working memory consists of four main components, that is the central executive, the visuo-spatial sketchpad, the episodic buffer, and the phonological loop (cf. Baddeley (2001); Baddeley & Hitch (1974)). Information transferred from the sensory memory is processed in the working memory either through repetition (rehearsal) or structuring\(^6\) (elaborative) and potentially passed along to the long-term memory.

- **Long-term Memory.** The long-term memory holds a set of different types of memories, such as declarative, procedural, or visual ones. In contrast to the sensory and working memory, the long-term memory has infinite storage capacity. For remembering, therefore, not only the encoding and processing of information, but also the way how it is accessed and retrieved is crucial (Bransford 1979).

### 2.2.2. Cognitive Load Theory

*Cognitive load theory* was developed in the late 1980s by the Australian educational psychologist John Sweller (1946 –) in the context of his work on problem solving (cf. Sweller (1988)). The theory suggests that learning can only be effective if the individual (learner) is not overtaxed, meaning that the actual

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\(^5\)Transduction refers to the process of converting sensory stimuli into some kind of information that the brain is capable of processing.

\(^6\)The structuring and organization of information depends on its characteristics and might be done through chunking or based on its chronology.
2.2. Cognitivist Theories of Learning

Sensory Memory

Working Memory

Long-term Memory

Encoding

Retrieval

Attention

Forgotten

Forgotten

Figure 2.5.: The three component model of information processing theory (Driscol 2005, p. 69)

workload or cognitive load does not exceed the learner’s cognitive capacity (working memory). In other words, the working memory is limited in terms of its processing capacity and therefore cannot contain an infinite number of elements simultaneously (cf. Section 2.2.1).

The effectiveness of how information is processed is the primary concern of cognitive load theory (Sweller 1988). In this regard, the theory distinguishes between three types of cognitive load: intrinsic cognitive load, extraneous cognitive load, and germane cognitive load (Sweller et al., 1998).

− **Intrinsic cognitive load** is the inherent difficulty level of a specific task or element being learned (e.g., calculating the sum of 2 numbers versus solving a differential equation). According to Paas et al. (2003, p. 1), “[d]ifferent materials differ in their levels of element interactivity and thus intrinsic cognitive load, and they cannot be altered by instructional manipulations; only a simpler learning task that omits some interacting elements can be chosen to reduce this type of load.” The instructional design of complex subjects therefore might require breaking down tasks into smaller subtasks to be then discussed in the overall context again (Kirschner et al., 2006).

− **Extraneous cognitive load** refers to the cognitive processes that are triggered by the complexity of instruction materials (Van Merriënboer & Ayres, 2005). In contrast to the intrinsic dimension, however, this type of load is directly attributed to the instructional designer and therefore can be controlled to avoid overloading the learner (Chandler & Sweller, 1991). Extraneous cognitive load may be caused by, for instance, the improper selection of problem-solving techniques or an inappropriate ratio of visual and auditory design of instructional materials (Van Merriënboer & Ayres, 2005).

− **Germane cognitive load** is directly related to learning and describes the

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7 In cognitive psychology, cognitive load refers to the actual workload being used in the working memory.
processes associated with the effective construction of schemata and their storage in the long-term memory (Kirschner, 2002). Therefore, it is suggested to promote germane load while reducing extraneous load (Sweller et al., 1998). Van Merriënboer & Ayres (2005, p. 7), for instance, describe that the “[...] variability of problem situations encourages learners to construct cognitive schemas, because it increases the probability that similar features can be identified, and that relevant features can be distinguished from irrelevant ones.” This supports learners in the construction of schemata and their ability to transfer them to new situations and problems respectively.

According to cognitive load theorists, the different types of cognitive load are additive (Paas et al., 2003) and need to be kept within the bounds of one’s cognitive capabilities. While the intrinsic cognitive load is inherent to the task or element being learned, it is the extraneous and the germane cognitive load that need to be appropriately adapted to the learning situation at hand. Ginns (2006) suggests that in particular when intrinsic and/or germane cognitive loads are high, the extraneous cognitive load of instructional material should be reduced. The design of instructional materials therefore essentially affects the distribution of cognitive load. “[It] can reduce extraneous cognitive load and redirect learners’ attention to cognitive processes that are directly relevant to the construction of schemas” (Sweller et al., 1998, p. 265).

2.2.3. Situated Cognition

Situated cognition theory was first proposed by John Seely Brown, Allan Collins, and Paul Duguid in their seminal work on situated cognition and the culture of learning (cf. Brown et al. (1989)). They argued that many teaching practices and didactical methods at that time considered knowledge as integral, self-contained entity which consequently led to the separation of theory and practice. Accordingly, knowledge primary was treated without practical relevance neglecting the importance of the situation and context. Situated cognition theory, however, suggests knowing and doing to be inseparable in that knowledge needs to be considered as situated in activity with respect to its social, cultural, and physical contexts (Greeno et al., 1993). It therefore “[...] does not deal primarily with the relationship between entities as distinct and separate, instead, it considers the system – context, persons, culture, language, intersubjectivity – as a whole coexisting and jointly defining the construction of meanings” (Roth, 2007, p. 710). For instance, the outcome of learning a language by solely studying vocabulary is significantly worse when compared to ordinary communication in real life situations (Miller & Gildea, 1987). Talking to a native speaker will give the learner a sense of how words are used appropriately in everyday social interactions taking into account the respective cultural identity.
2.2. Cognitivist Theories of Learning

For the purpose of systematically describing the various meanings of the situative nature of cognition, Clancey (1997) developed a framework proposing three different perspectives (cf. Table 2.2). Commonly used to describe complex systems, he suggests a “functional (a choreographed activity, conceived as a social process), structural (a dynamically configured mechanism), and behavioral (a transactional process of transforming and interpreting materials in the world)” view (Clancey 1997, p. 23).

Table 2.2.: The three perspectives on the situatedness of cognition (Clancey 1997, p. 23)

<table>
<thead>
<tr>
<th>Perspective</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Functional form analysis</strong></td>
<td></td>
</tr>
<tr>
<td>Social</td>
<td>Organized by interpersonal perception and action; conceptually about social relations (norms, roles, motivations, choreographies, participation frameworks)</td>
</tr>
<tr>
<td><strong>Structural mechanism analysis</strong></td>
<td></td>
</tr>
<tr>
<td>Interactive</td>
<td>Dynamically coupled state-sensory-effector relations; reactive co-organization</td>
</tr>
<tr>
<td>Ready-at-hand</td>
<td>Physically coupled, non-objectified connection (&quot;seen through&quot;, without description)</td>
</tr>
<tr>
<td><strong>Behavioral content analysis</strong></td>
<td></td>
</tr>
<tr>
<td>Grounded</td>
<td>Located in some everyday physical activity, an interactive spatio-temporal setting</td>
</tr>
</tbody>
</table>

The functional or social perspective on situated cognition refers to how one conceives his or her participation in the society, taking into account cultural traditions, norms, roles, values, and so forth. This conception determines choreographies of actions allowing to perform more complex activities, such as writing a book or drawing a painting. Therefore, an activity is not only a simple action or movement, but rather constitutes a complex choreography involving a sense of place and a social identity (Clancey 1997). Thus, *doing* always needs to be considered from a social perspective, regardless of one acting alone or in a social setting.

The second perspective concerns structural mechanisms with respect to the
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physical coordination of perception, conception, and action. Clancey (1997) distinguishes between two aspects, namely interactive and ready-at-hand. The first aspect (interactive) concerns how others perceive and conceive one’s actions and material objects, such as a book or painting. It is important to recognize that the dynamic coupling of perception and conception mostly is subconscious and involuntary. In other words, both human perception, controlled by our sensory system, and the attribution of meaning typically occur at the same time, the latter being influenced by prior experience. The second aspect is that of ready-at-hand and describes the built-in procedures associated with tools and material objects. A hammer, for instance, is associated and used with a specific purpose in mind until it fails to successfully serve this particular function. At this point, reflective processes typically are necessary to reconsider the meaning of the tool and what it means to us. In this regard, “[c]urrent work in situated cognition can emphasize the role of reflection, abstraction of meanings, and how as humans we are able to engage in metacognitive thought where language and thinking are central” (Roth, 2007, p. 715).

The third and last perspective is the behavioral content that relates cognition to spatio-temporal settings. In contrast to the functional and structural dimension which concern the meaning of action and the internal mechanism respectively, the behavioral perspective considers local feedback and time-sensitive nature of action in place (Clancey, 1997). Accordingly, cognition is considered a continuous process of reshaping and readjusting behavior based on continual reflection and feedback.

2.3. Constructivist Perspectives on Learning

Constructivism refers to a set of theories concerned with both how people learn and the general nature of knowledge (Harasim, 2012). In contrast to previous learning theories which primarily follow objectivistic approaches to learning, constructivism emphasizes the individual construction of knowledge based on prior experiences (Ertmer & Newby, 1993). In this sense, constructivism requires to “[...] reconcile the new with our prior understanding: does the new fit with our previous understanding and if not, do we discard it, integrate it with our existing views or change our existing beliefs? This process is one of asking questions, exploring, engaging in dialog with others and reassessing what we know” (Harasim, 2012, p. 60). The constructivist school of thought therefore holds that knowledge only manifests itself through the individual construction of ideas and concepts (Mankel, 2008). According to Fosnot (2001, p. 54), “[c]onstructivism is a philosophy and a cognitive, developmental psychology that explains learning as a case of interpreting and inferring about the world. Meaning is understood to be the result of humans setting up relationships, reflecting on their actions, and modeling and constructing explanations.”

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2.3. Constructivist Perspectives on Learning

In this section, the two main schools of thought are discussed including the cognitive and social perspective of constructivism (cf. Section 2.3.1). Self-regulated learning as one important aspect is discussed in this regard as well (cf. Section 2.3.2). The metacognitive dimension finally is presented in this context, in particular referring to the aspects related to self-regulation (cf. Section 2.3.3).

2.3.1. Cognitive and Social Aspects

Since the beginnings of constructivism, two main schools of thought have emerged based on the work of Jean Piaget and Lev S. Vygotsky. Both theorists were focusing on human development, but put different emphases related to one’s individual cognitive performance and the social context respectively. As Piaget’s work was mainly based on individual learners and their biological developmental stages, Vygotsky claimed that the social context is of primary concern to learning. A wide range of different views and approaches have been developed since then (Ernest, 2010). According to Duffy & Cunningham (1996, p. 171), however, there is a common understanding of the fundamental principles of constructivism which refer to “[...] learning [as] an active process of constructing rather than acquiring knowledge [...]” and “[...] instruction [as] a process of supporting that construction rather than communicating knowledge [...]”.

Cognitive Constructivism

The Swiss clinical psychologist Jean Piaget (1896 – 1980) is considered the founder of cognitive constructivism, a theory of learning that focuses on the individual learner in terms of developmental stages. In his work, he studied the different stages of human development and, according to Harasim (2012, p. 61), “posited that humans learn through the construction of progressively complex logical structures, from infancy through adulthood.” Piaget claimed that all humans go through the same developmental stages at about the same age (cf. Piaget, 1964). He proposed a four stage sequence of cognitive development including the sensory-motor, the pre-operational, the concrete operational, and the formal operational stage (cf. Figure 2.6).

− The sensory-motor stage is the initial stage of an infant and lasts until approximately two years of age. During this time, the infant learns through the coordination of experiences (e.g., hearing, feeling, etc.) with the physical world (i.e., motor activities such as grasping and sucking). Physical objects, however, do not remain in memory once removed from the perceptual field. Piaget further detailed the sensory-motor stage and proposed six sub-stages, ranging from simple reflexes (birth – 6 weeks)
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<table>
<thead>
<tr>
<th>Stage</th>
<th>Pre-operational Stage</th>
<th>Formal Operational Stage</th>
<th>Concrete Operational Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensory-motor</td>
<td>Reflex-based</td>
<td>Abstract thinking</td>
<td>Problem solving</td>
</tr>
<tr>
<td>Stage</td>
<td>Know through senses</td>
<td>Theoretical reasoning</td>
<td>More than one viewpoint</td>
</tr>
<tr>
<td>0 - 2 years</td>
<td>2 - 7 years</td>
<td>7 - 11 years</td>
<td>12 years +</td>
</tr>
</tbody>
</table>

Figure 2.6.: Four stages of cognitive development (Harasim, 2012, p. 63)

and different levels of circular reactions (6 weeks – 18 months) to the internalization of schemas (18 – 24 months).

- The pre-operational stage is the second stage at which Piaget claims children reach a qualitatively new level of development. It begins at around the age of two as children learn to speak and lasts until approximately the age of seven. During this stage, children begin to engage in collective monologues, meaning that they talk but do not interact with each other. Their thinking is still egocentric which makes it difficult for them to understand the viewpoint of others. Piaget subdivides the pre-operational stage in two sub-stages, including the symbolic function and the intuitive thought stage. The symbolic function stage is concerned with the ability to remember and represent objects without physically having the respective object within sight. The intuitive thought stage is concerned with the curiosity of children and their need to know everything.

- The concrete operational stage begins at around the age of seven and takes about four years. During this stage, children start solving actual problems by logical reasoning. Abstract problems and (verbally expressed) hypothetical concepts, however, cause difficulties as children mainly operate on physical objects. Children also begin to be less egocentric, meaning that they begin to think about the viewpoints of others and what they think.

- The formal operational stage is the fourth and final stage of cognitive development which begins at around the age of twelve. From now on, children surpass mere concrete operations and reach the formal or hypothetico-deductive level. Consequently, children begin to reason not only on physical objects but also on (verbally expressed) hypotheses and abstract problems.

Social Constructivism

The Russian psychologist Lev S. Vygotsky (1896 – 1934) is famously associated with constructivism, in particular with respect to his work on cognitive development commonly referred to as cultural-historical psychology (cf. Vygotsky).
2.3. Constructivist Perspectives on Learning

In contrast to Piaget, his focus was not on the individual learner in terms of developmental stages, but rather on the underlying processes and their relationship with the learner’s social activities within the cultural context (Crawford, 1996; Harasim, 2012). “Learning”, as Vygotsky (1980) argued, “is a necessary and universal aspect of the process of developing culturally organized, specifically human, psychological functions.” In this regard, Vygotsky’s view on learning significantly differs from that of Piaget as he places learning before development (Harasim, 2012).

In the course of his work, Vygotsky introduced the zone of proximal development in which he proposed that learning occurs when a learner is situated between his or her actual development level and future potential (cf. Figure 2.7). At this point, the learner does not act on its own, but collaborates with more knowledgeable others (e.g., adults or capable peers) for the purpose of completing tasks or solving specific problems. According to the constructivist school of thought, this does not involve instructors guiding learners to predefined goals, instead, more knowledgeable others provide specific concepts and tools supporting the learner in eventually completing similar tasks or problems on its own. For instance, a child may not yet be able to solve simple equations (e.g., the addition of two numbers) by itself as its actual development level does not include the required mathematical concepts and tools. In the course of interaction with a more knowledgeable other (e.g., teacher), however, the child may develop the required competences to solve similar equations on its own in the future.

![Figure 2.7.: Zone of proximal development](Vygotsky, 1980)

2.3.2. The Self in Learning

Constructivism views learning as an active process in which new knowledge is constructed by the learning individual (cf. Duffy & Cunningham, 1996; Hadwin & Oshige, 2011; Mayes & De Freitas, 2004). The traditional role model which considers instructors as hierarchically superior to learners thereby has been replaced by a more constructivist approach supporting the construction of
knowledge among peers. Consequently, learning not only relies on the knowledge of the instructor, but also depends on what the learner already knows or what the learner can already do (Mayes & De Freitas, 2004). The degree to which learners are responsible for building their own knowledge therefore increases (Hadwin & Oshige, 2011), which allows to consider the construct of self-regulated learning as important aspect in this regard (Mayes & De Freitas, 2004).

Self-regulated learning was first proposed by educational and developmental psychologists in the mid 1980s and continuing into the 1990s as construct referring to the various ways individuals monitor, control, and regulate their own learning (Beishuizen & Steffens, 2011; Pintrich et al., 2000). According to Schunk & Zimmerman (1997), the development of capabilities required for self-regulated learning involves four levels, namely observation, emulation, self-control, and self-regulation. The first level, observation, is based on Bandura’s (1986) social cognitive theory, which suggests that models are the primary concern of learning (cf. Section 2.1.2). For instance, by observing an instructor one could learn the basic methods and tools for doing research, such as writing and presenting a scientific paper. At this stage, however, the learner has not acquired any experiences on its own. Once the learner feels confident enough, he or she starts imitating (emulating) the observed behavior. Constructive feedback might be received from the actual model during this stage, conceivably causing adaptations or adjustments in subsequent executions. The third level of self-control is concerned with executing the observed behavior in a routine manner. The learner begins to act independently of the model, which eventually leads to becoming a self-regulated learner. This stage indicates that one is capable of adapting and adjusting his or her skill set according to contextual conditions.

Since self-regulated learning was first proposed, various different models have been developed, mainly conceptualizing self-regulated learning as recurring cycle of three to four stages (Azevedo et al., 2012; Beishuizen & Steffens, 2011; Puustinen & Pulkkinen, 2001). Winne & Hadwin (1998), for instance, proposed a four-stage model distinguishing between task definition, goal setting and planning, enacting study tactics and strategies, and metacognitive adaption for future learnings. In the first stage, information on conditions related to the task is processed by the learner. In this regard, not only task-specific conditions (e.g., time constraints), but also cognitive as well as motivational conditions are of relevance. Cognitive conditions are concerned with information stored in the long-term memory, such as how one has performed on prior tasks already, whereas motivational conditions relate to the perceived competence or particular interest associated with a specific task. In the course of the second stage, the learner aims to develop a plan for coordinating and enacting study tactics. This, for instance, includes selecting specific learning strategies and plans as well as setting standards for their enactment. The third stage is concerned with the actual application of selected study tactics and aims for the construction
or re-organization of subject matter knowledge. If necessary, learning strategies and plans eventually are adapted, which might trigger changes in beliefs, conditional knowledge, or standards for judging qualities of study tactics.

A similar model of self-regulated learning has been proposed by Zimmerman (1998a) in the context of his work on the development of personal skill in academic settings (cf. Figure 2.8). In contrast to the model developed by Winne & Hadwin (1998), the first stage is not concerned with the specific conditions of a task to be performed, but rather is related to self-evaluating and monitoring a learner’s effectiveness with respect to his or her current learning goals, strategies, and plans. Once a learner has identified his or her deficiencies, respective learning goals, strategies, and plans are defined or readjusted in the second stage. Readjustments may become necessary when the learner recognizes that prior goals are too ambitious or particular learning strategies and plans are not adequate to the task at hand. In the third stage, the learner executes specific learning strategies and plans in structured contexts and monitors the effectiveness of implementation. Feedback and guidance might be necessary for novice learners as the required competences and skills are not yet developed accordingly. The strategic monitoring finally focuses on one’s study outcome for the purpose of adapting learning goals, strategies, and plans. The routinization of the strategy, the specificity of learning goals, as well as one’s strategy attributions are essential to the quality of the implemented adaptations.

Figure 2.8.: Cyclic model of self-regulated learning (Zimmerman, 1998a, p. 83)

In addition to the model of self-regulated learning as presented above, Zimmerman (1998b, 2000) proposed a second model focusing on properties from Bandura’s social cognitive theory. Represented as a cycle including the stages forethought, performance or volitional control, and self-reflection, the model provides a stronger focus on the processes which are relevant at each of the three stages (Beishuizen & Steffens, 2011). The forethought stage refers to two kinds of processes which are related to the analysis of the task and self-motivation
beliefs. While task analysis include processes such as goal setting and strategic planning, self-motivation beliefs refer to aspects such as self-efficacy, outcome expectations, intrinsic motivation or valuing and process versus outcome goal orientation (Beishuizen & Steffens, 2011; Puustinen & Pulkkinen, 2001). The second stage is based on the results from the first stage (i.e., the chosen strategy) and in particular is concerned with processes related to self-control (i.e., self-instruction, imagery or mental picture forming, or task strategies) and self-observation (i.e., self-recording and self-experimentation). The last stage is closely related to aspects of self-observation, but focuses on aspects of self-judgment and self-reaction. Self-judgment refers to the evaluation of one’s performance in the learning process and respective attributions with regards to the outcomes (Puustinen & Pulkkinen, 2001). Self-reaction, on the contrary, relates to perceptions with respect to one’s level of satisfaction as well as changes necessary for future learning.

Considering the underlying process of self-regulated learning, a general pattern reveals including three main phases (Puustinen & Pulkkinen, 2001). All models require some kind of preparation phase in the beginning, which is then followed by the performance or execution phase. Finally, an appraisal phase allows for adaptations with respect to applied learning strategies and plans for the purpose of increasing one’s effectiveness. For instance, the model proposed by Winne & Hadwin first requires the processing of conditions related to a specific task, followed by some kind of goal setting and planning procedure (cf. Winne & Hadwin (1998); Winne & Perry (2000)). These stages are subject to the preparatory phase as they are essential to the actual execution of learning strategies and plans. In the model suggested by Zimmerman, processes associated with the forethought stage (i.e., task analysis and self-motivation) are considered to be the equivalents (cf. Zimmerman (1998a,b, 2000, 2001)). The application of specific learning strategies and plans as well as processes related to self-control and self-observation are viewed as related to the performance phase. Finally, processes related to the adaptation of one’s metacognition and self-reflection are considered to be part of the appraisal phase.

Although there is no distinct definition in the literature, numerous contributions allow to conclude on the major components and concepts relevant to self-regulated learning. Back in 2001, Puustinen & Pulkkinen (2001) have identified two different kinds of approaches for defining self-regulated learning. Based on the models relevant at that time, they argued for distinguishing between goal-oriented and metacognitively weighted definitions. Goal-oriented definitions emphasize “[…] the constructive or self-generated nature of self-regulated learning [as well as that] monitoring, regulating, and controlling one’s own learning includes cognitive but also motivational, emotional, and social factors” (Puustinen & Pulkkinen, 2001 p. 280). In contrast, metacognitively weighted definitions emphasize “[…] the constructive or self-generated nature of self-regulated learning [as well as that] monitoring, regulating, and controlling one’s own learning includes cognitive but also motivational, emotional, and social factors” (Puustinen & Pulkkinen, 2001 p. 280). In contrast, metacognitively weighted definitions emphasize “[…] the constructive or self-generated nature of self-regulated learning [as well as that] monitoring, regulating, and controlling one’s own learning includes cognitive but also motivational, emotional, and social factors” (Puustinen & Pulkkinen, 2001 p. 280).
models aim at “[...] adapting the use of cognitive tactics and strategies to tasks” (Puustinen & Pulkkinen 2001, p. 280). Later, Beishuizen & Steffens (2011) in their work on a conceptual framework for research on self-regulated learning stated that a number of different concepts have been used to describe the responsibilities of learners to monitor and control their learning activities, including self-directed learning, self-organized learning, personalized learning, self-regulated personalized learning, as well as metacognition. Järvenoja et al. (2015) provide a similar conceptualization as they consider regulation activities as important for the learner to control, direct, or adjust activities and thoughts in the learning process. Referring to Boekaerts (2011), they detail regulation activities by means of their aim for controlling metacognitive, cognitive, motivational, and emotional processes which are contextually bound and become activated in learning situations.

2.3.3. A Metacognitive Perspective

Among the different components and concepts referred to in the literature, metacognition appears to be one prominent aspect relevant to self-regulated learning (cf. Azevedo 2009; Azevedo et al. 2012; Beishuizen & Steffens 2011; Dinsmore et al. 2008; Hadwin et al. 2011; Hadwin & Oshige 2011; Järvenoja et al. 2015; Kaplan 2008; Puustinen & Pulkkinen 2001; Veenman et al. 2006). Beishuizen & Steffens (2011), for instance, state that “[...] one of the concepts most akin to that of self-regulated learning is the concept of metacognition.” This, however, indicates that metacognition must not be seen as subordinated to self-regulated learning or vice versa. Instead, “[...] metacognition and self-regulation are parallel and intertwining constructs that are clearly distinct yet mutually entailed both developmentally and in their functions in human thought and behavior” (Fox & Riconscente 2008).

Metacognition was first introduced by the American developmental psychologist John H. Flavell (1928 –) in the late 1970s and used into 1980s by developmental and cognitive psychologists (Pintrich et al. 2000). Often referred to as cognition about cognition or thinking about thinking, metacognition involves complex processes related to the monitoring and control of thought, and thus is often described as “[...] a higher-order, executive process that monitors and coordinates other cognitive processes engaged during learning, such as recall, rehearsal, or problem solving” (Tobias et al. 2009, p. 108). Veenman et al. (2006, p. 5) in their work on conceptual and methodological considerations of metacognition and learning, however, indicate that this perception can be regarded as Comte’s paradox, describing that “[o]ne cannot split one’s self in two, of whom one thinks whilst the other observes him thinking.” They argue that metacognition is linked to cognition as it is “[h]ard to have adequate metacognitive knowledge of one’s competencies in a domain without substantial (cognitive) domain-specific knowledge [...]”
Chapter 2. Learning Theories: A Short Introduction

Although it seems that more theoretical work needs to be done with respect to a universal conceptualization of metacognition, Nelson (1996) proposed a first step towards such a unified theory (Veenman et al., 2006). In his model, learning takes place at two different levels, that is the object level and the meta level (cf. Figure 2.9). The meta level holds a model of the object level, which is used for constant monitoring the learning process. The model, however, is constantly updated as the learner exerts executive control over his or her learning process. This conception of metacognition has become widely acknowledge and often is associated with distinguishing between knowledge about one’s cognitive processes and monitoring and regulating these processes (cf. Hacker (1998)).

![Figure 2.9: Model of metacognition](Nelson, 1996)

In the context of self-regulated learning, Pintrich et al. (2000) acknowledge the general agreement, however, argue for distinguishing three components relevant to the conceptualization of metacognition. In particular, they propose to further detail monitoring and regulating processes into aspects concerned with metacognitive judgments and monitoring as well as self-regulation and control. Consequently, besides metacognitive knowledge, aspects concerned with metacognitive judgments and monitoring and self-regulation and control represent the three components of metacognition.

Metacognitive knowledge, as it is described by Pintrich et al. (2000, p. 45), includes the students’ “[…] declarative, procedural, and conditional knowledge about cognition, cognitive strategies, and task variables that influence cognition.” This component in particular recognizes the importance of knowledge stored in the long-term memory and is considered as separate to the dynamic components of metacognition, such as processes related to judging and monitoring.

- **Knowledge of cognition and cognitive strategies** is related to general aspects of cognition and learning strategies. This not only includes knowing the different strategies available for learning, but also concerns knowing how to actually apply these strategies in different contexts (when and why).
2.3. Constructivist Perspectives on Learning

- **Knowledge of tasks and contexts** are considered the traditional constructs related to metacognition. Both, task and strategy variables are considered important to metacognition in the sense that learners know to assess the consequences of task and strategy variations. This, for instance, supports individual learners in becoming aware that repetitive rehearsal (strategy variable) would increase chances of remembering facts.

- **Knowledge of self** is concerned with being aware of one’s own weaknesses and strengths in terms of both intraindividual and interindividual aspects. *Pintrich et al.* (2000) indicates that this part of metacognitive knowledge is not related to metacognitive self-knowledge, but rather concerns one’s own motivational aspects.

The second component focuses on metacognitive judgments and monitoring. In contrast to metacognitive knowledge, this component is considered more dynamic as judgment and monitoring processes are based on one’s performance with respect to specific tasks. Four general metacognitive processes are proposed by *Pintrich et al.* (2000), namely (1) task difficulty or ease of learning judgments, (2) learning and comprehension monitoring or judgments of learning, (3) feeling of knowing, and (4) confidence judgments.

- **Task difficulty or ease of learning judgments** allows individual learners to assess the actual difficulty level of a task at hand. This, however, not only includes knowledge of the task, but also requires knowledge of self related to knowledge of past performances on the same or similar tasks.

- **Learning and comprehension monitoring or judgments of learning** are concerned with a number of activities, such as becoming aware that some task (e.g., reading a text) is too difficult or that specific learning goals are too ambitious with respect to the current learning level (e.g., understanding a topic). Judgments of learning, on the contrary, involve learners’ capabilities to decide whether they have successfully accomplished a task and, for instance, are feel prepared to take a test.

- **Feeling of knowing**, or also often referred to as tip-of-the-tongue phenomenon, describes situations in which a learner is not able to recall specific facts, but is aware of knowing it.

- **Confidence judgments** represent the last category of metacognitive judgments and monitoring and relate to one’s confidence of doing things in the correct way. For instance, *Baker* (1989) studied these kind of judgments based on students’ self-assessments in text comprehension and error detection performance.

The third and last component is concerned with self-regulation and control involving activities based on which one’s cognition is developed and adapted.
Similar to metacognitive judgments and monitoring, this component is associated with developmental processes and, thus, considered as dynamic rather than static. Four general processes related to self-regulation and control are proposed by Pintrich et al. (2000), namely (1) planning activities, (2) strategy selection and use, (3) allocation of resources, and (4) volitional control.

- The **planning of activities** is essential to self-regulation as it is concerned with setting goals for learning, time management, and performance monitoring. In particular, this is crucial for one’s monitoring processes and therefore cognitive development as goals act as basis of comparison (Pintrich et al., 2000).

- **Strategy selection and use** is considered important to self-regulated learning and control as actual learning strategies are selected and applied to the task at hand. The application and use of learning strategies thereby might be deemed more cognitive, while the decision when to select which strategy is related to self-regulation and control.

- Processes related to the **allocation of resources**, such as time, overall effort, and pace of learning, include reflective activities on the overall use or resources. One might adapt or change his or her learning strategies based on the overall effort put into a specific task.

- **Volitional control** refers to emotional and motivational traits of learners and their ability to control their learning environment. These controls are activated once a learner gets engaged in a task and have the potential to significantly influence one’s cognition, learning, and performance (Pintrich et al., 2000). Controlling one’s environment, for instance, allows for creating a space adequate to the task at hand (Corno, 1993; Kuhl, 1985, 1992). A student, therefore, might be able to enhance his or her performance in studying vocabularies when being situated in a quiet space away from distractions.

### 2.4. Summary

In this chapter, the main paradigms of learning with respect to their theoretical foundations were discussed including the behaviorist (cf. Section 2.1), the cognitivist (cf. Section 2.2), and the constructivist (cf. Section 2.3) perspective. The behaviorist perspective as the first theoretical approach to learning—prior discussions were rooted in philosophy and religious thought—was discussed in the light of classical and operant conditioning (cf. Section 2.1.1) as well as the social learning theory (cf. Section 2.1.2) respectively. At that time, the notion of learning was reduced to observable behavior and therefore to simple conditioning. Conditioning in this context describes learning as a process in
2.4. Summary

which a given environmental stimulus becomes increasingly effective in causing a specific response. The mind was viewed as “black box” and considered as not being relevant for research. Marking the transition from the behaviorist to a cognitivist perspective, Bandura’s theory on social learning addresses the shortcomings of existing approaches to explain the acquisition of novel behavior. Social and cognitive factors were considered relevant viewing the mind as crucial component in the transition of environmental stimuli (inputs) to specific responses or behaviors (outputs).

Due to advances in fields such as linguistics, neurology, psychology, education, and computer science, cognitive learning theories (cf. Section 2.2) soon became the major school of thought and experimental paradigm. In particular the invention of the computer had a significant influence on cognitivist theory, leading to metaphors such as mind as computer or human information processing. Information processing theory (cf. Section 2.2.1) was one of the basic theories developed in this context building the foundation for the development of various different approaches. Despite the heterogeneity of the proposed approaches, however, the main principles and components remained the same, including the sensory memory, the working memory, and the long-term memory. Later, the working memory – it was considered the limiting factor in learning – was focused by the cognitive load theory (cf. Section 2.2.2). Cognitive load theory suggests that learning can only be effective if the individual (learner) is not overtaxed, meaning that the actual workload or cognitive load does not exceed the learner’s cognitive capacity (working memory). Three types of cognitive load were identified, namely the intrinsic, the extraneous, and the germane cognitive load. Since they are considered as being additive, it is the instructional designer’s responsibility to appropriately distribute and balance the loads based on the learners’ cognitive capacities. In most theoretical approaches to learning, knowledge is considered as being integral and self-contained, leading to the separation of theory and practice. Against this background, the situated cognition theory (cf. Section 2.2.3) was developed taking into account the situation and context so that knowledge is considered as begin situated in activity with respect to its social, cultural, and physical contexts.

With the rise of constructivist learning theories, the notion that knowledge is constructed individually based on prior experiences gained in importance (cf. Section 2.3). Two main schools of thought have emerged in this context, focusing on either the cognitive or social aspects of learning (cf. Section 2.3.1). Both theories focus on human development, but show different emphases on either one’s individual cognitive performance or the social context. In any case, however, constructivism views learning as an active process in which new knowledge is constructed by the learning individual. Therefore, learning not only relies on the knowledge of the instructor, but also depends on what the learner already knows or what the learner can already do. The degree to which learners are responsible for building their knowledge increases and, therefore,
suggests self-regulated learning as important aspect or capability (cf. Section 2.3.2). Various different models on self-regulated learning have been proposed since then, mainly conceptualizing it as recurring cycle of three to four stages, including self-evaluation and monitoring, goal setting and strategic planning, strategic implementation and monitoring, as well as strategic outcome monitoring. Once learners become responsible for their learning processes, metacognitive capabilities become important for the purpose of continuous development (cf. Section 2.3.3). Three components are considered relevant to the conceptualization of metacognition, including metacognitive knowledge, metacognitive judgments and monitoring, as well as self-regulation and control.

2.4.1. Relevance of Findings

This chapter provide an overview of current developments and conceptualizations of learning. The findings in particular illustrate the theoretical basis on learning which is relevant for further investigations related to learning designs where both the cognitive and social dimension are considered equally important.

RQ 1. What to consider in constructivist learning designs?

The historical development of learning with respect to the various conceptualizations was discussed in this section, in particular considering the cognitive and social dimension. While cognitive and social constructivism constitute two main schools of thought, both view learning as an active process in which new knowledge is constructed by the individual. The degree to which learners are responsible for acquiring knowledge therefore increases, which turns self-regulated learning and metacognitive capabilities into important aspect in the learning process.

2.4.2. Outlook

In the next chapter, the findings are further detailed with respect to situative self-regulated learning. In particular the shift from individually oriented to collaborative and situative perspectives are reviewed and discussed in this context (cf. Section 3.1). The findings are used as foundation for constructing an integrative approach to self-regulated learning with due regard to situative aspects (cf. Section 3.3).
3. A Situative Perspective on Self-regulated Learning

In addition to the importance of self-regulated learning and metacognitive capabilities, learning has become increasingly interactive and collaborative. Available technologies further amplify this fact which, in total, make individually oriented perspective on self-regulated learning insufficient. Against this background, not only collaborative learning theories but also conceptualizations of the situation and contextual factors are considered relevant to cognitive change and learning processes.

In this chapter, the situative perspective on learning is presented by reference to the historical development from individually oriented to collaborative and situative perspectives respectively (cf. Section 3.1). Theoretical approaches are discussed in this context as well and show the current state of the art in the literature on this particular topic (cf. Section 3.2). Based on these findings, an integrative approach is proposed based on the dimensions concerned with individuals’ cognitive capacities, the openness of communication and level of group cohesion, and underlying structures and processes related to the design and organization of courses (cf. Section 3.3).

3.1. Towards a Situative Perspective on Learning

Throughout the course of history, learning has been conceptualized in various different ways, not only including the major learning theories (behaviorism, cognitivism, and constructivism) but also with respect to the unit of analysis used to study cognition. Not until the early 1800s, the unit of analysis was extended from the individual level up to the cultural understanding of the society (Stahl, 2012). The mind no longer was considered as naturally given, but rather as constructed in the course of time. Various different conceptualizations and theories have been developed since then, including both individually oriented and collaborative perspectives. Recently, however, not only the wider social context but social interaction as such has been recognized as crucial to learning processes and therefore for constructing meaning and knowledge. In particular with respect to the collaborative perspective, social interactions are now considered relevant to cognitive change in the individual. Communicative and situative approaches address this issue by considering human interaction as essential to learning processes. The situation and contextual factors are
Chapter 3. A Situative Perspective on Self-regulated Learning

recognized as well.

In this section, the historical development of individual and social theories is discussed, in particular, with respect to current approaches and perspectives considering social interaction as important to learning (cf. Section 3.1.1). Collaborative learning as one potential outcome of social interaction is presented subsequently (cf. Section 3.1.2), followed by the situative perspective which explicitly considers the situation and contextual factors as relevant to learning processes (cf. Section 3.1.3).

3.1.1. Beyond the Individual Dimension

At the beginning of the 19th century, the understanding of theory has undergone a significant shift with respect to the unit of analysis used to study cognition. Until that point in time, cognition was considered an inherent and solely individual property of human beings. Theories developed by philosophers such as René Descartes\(^1\) (1596 – 1650), John Locke\(^2\) (1632 – 1704), David Hume\(^3\) (1711 – 1776), and Immanuel Kant\(^4\) (1724 – 1804) are regarded as the most influential contributions during this time. In 1807, however, the German philosopher Georg W. F. Hegel (1770 – 1831) claimed that for analyzing cognition it is necessary to extend the unit of analysis from the individual level up to the cultural understanding of the society (Stahl, 2012). The mind no longer was considered as naturally given, but rather as constructed in the course of time. Karl Marx (1818 – 1883), Ludwig J. Wittgenstein (1889 – 1951), and Martin Heidegger (1889 – 1976) continued on this approach and formed the basis for a post-Hegelian and post-Kantian philosophy (cf. Figure 3.1).

Since then, learning has been conceptualized in various ways. Racionero & Valls\(^{2013}\) could identified three different conceptions – objectivist, constructivist, and communicative – essential to the understanding of learning throughout the course of history. First and foremost, learning was based on the assumption that there exists a reality independent of the learners’ perceptions. Learners therefore were considered passive subjects required to assimilate information and knowledge transmitted by more knowledgeable others (e.g., teachers). Pro-

\(^1\)Descartes argued that thought, including consciousness, experience, feelings, etc., cannot be separated from the individual, which is famously known as “cogito, ergo sum” or “I think, therefore I am”.

\(^2\)John Locke was an opponent of innatism and therefore believed humans are born without any pre-existing mental structures. He argued that knowledge only comes from experience or sense perception.

\(^3\)David Hume was an opponent of innatism and believed that knowledge only comes from objects of experience and the relations of ideas, the latter characterizing knowledge as the result of conceptual thoughts and logical operations.

\(^4\)Kant did not fully agree with the rationalist school of thought as he believed mental structures and thus knowledge evolves through the interaction between the mind and the external world.
A paradigm shift in the conception of learning begun in the 1980s as researchers started to recognize that the objectivist conception is limited in the sense that the construction of knowledge depends on the individual and therefore cannot be objectivized. Racionero & Valls (2013, p. 550) notes that “[t]he idea behind constructivism is that people construct social reality, and this construction is different because the meanings that each person gives to this construction are different.” This implies that learning significantly depends on the quantity and quality of prior knowledge which is available for learning and corresponding knowledge construction processes. Two main schools of thought have emerged since the beginnings of constructivism. One focuses on the individual’s cognitive performance, whilst the other is particularly concerned with the social context prevalent during knowledge construction (cf. Section 2.3.1). Despite the different orientations, however, the fundamentals of the constructivist thought remain the same, referring to “[…] learning [as] an active process of constructing rather than acquiring knowledge […]” and “[…] instruction [as] a process of supporting that construction rather than communicating knowledge […]” (Duffy & Cunningham, 1996, p. 171).

According to Racionero & Valls (2013, p. 550), “[t]he constructivist conception of teaching and learning recognizes the contribution of the student in the teaching–learning process, but they are seen as individual processes that do not take sufficiently the pedagogical and sociological aspects into account.” Learn-
Chapter 3. A Situative Perspective on Self-regulated Learning

ing therefore remains mainly an individual effort which does not sufficiently consider the fact that knowledge construction and the actual attribution of meaning depends on human interaction. The communicative conception addresses this issue as it considers human interaction as essential for constructing meaning (cf. Table 3.1). Racionero & Valls (2013, p. 551) argue that “[...] learning from the [communicative conception] is the product of a process of collective construction of meaning through interaction.” Important to the concept is that one learns through engaging in egalitarian dialog[5] in which knowledge and meaning is constructed in the course of interactions among teachers, family members, and so forth.

Table 3.1.: Towards a communicative conception of learning (Racionero & Valls, 2013, p. 551f.)

<table>
<thead>
<tr>
<th>Conception</th>
<th>Constructivist</th>
<th>Communicative</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Base</strong></td>
<td>Reality is a social construction that depends on the meanings that individuals attribute to it.</td>
<td></td>
</tr>
<tr>
<td><strong>Learning</strong></td>
<td>Significative</td>
<td></td>
</tr>
<tr>
<td></td>
<td>One learns through relating new knowledge that is incorporated in the cognitive structure on the basis of prior knowledge.</td>
<td></td>
</tr>
<tr>
<td><strong>Education</strong></td>
<td>Dialog</td>
<td></td>
</tr>
<tr>
<td><strong>of Teachers</strong></td>
<td>One learns through interactions between equals, teachers, family members, friends, etc. who produce egalitarian dialogue.</td>
<td></td>
</tr>
<tr>
<td><strong>of Teachers, Family Members, and Community</strong></td>
<td>Knowledge of the learning processes of individuals and groups through the interactive construction of meanings.</td>
<td></td>
</tr>
</tbody>
</table>

[5] An egalitarian dialog is a dialog among equals in which statements and contributions are considered from the viewpoint of their quality and validity, instead of being assessed based on the status and position of individuals. (Flecha, 2000).
3.1. Towards a Situative Perspective on Learning

3.1.2. A Collaborative Perspective

The concept of social learning is not new. In fact, its origins can be traced back to [Miller & Dollard (1941), Rotter (1954), and Bandura’s social learning theory (cf. Section 2.1.2) developed in the 1970s (Lankshear & Knobel, 2011). At that early period, social learning mainly built on observation of human behavior, such as the concept of modeling described by Bandura. It therefore was often referred to as observational learning, imitation, or vicarious learning (Lankshear & Knobel, 2011). Research on social learning since then has been influenced by a variety of different fields, such as behavioral and cognitive psychology as well as social cognition. Among the vast number of contributions, most notably developments from Brown et al. and Lave & Wenger have had significant influence on the field. In their seminal paper on the situated cognition and the culture of learning, Brown et al. (1989) identified issues regarding the general assumption of didactic methods with respect to the separation of knowing and doing. According to Lankshear & Knobel (2011, p. 211), it is argued “[…] that by separating learning from ‘authentic’ activity grounded in physical and social contexts and situations, formal education largely defeats its goal of promoting ‘usable, robust knowledge’.”

In consequence of the diverse backgrounds, various different definitions of social learning emerged in the literature. Steyaert et al. (2007, p. 540) refer to social learning as an “[…] iterative process of knowledge co-production (i.e., of ‘knowing’) among stakeholders brought into interaction. Knowledge here is understood as an individual’s point of view on entities constituting the world.” Another definition has been proposed by Schusler et al. (2003, p. 311) who describe social learning as “[…] learning that occurs when people engage one another, sharing diverse perspectives and experiences to develop a common framework of understanding and basis for joint action.” Despite existing similarities among proposed definitions, varying conceptions of social learning can be identified with respect to the conceptualization as well as associated conditions and methods (Reed et al., 2010). An attempt to unify the different conceptions has been proposed by Reed et al. (2010). They argue that social learning not only needs to involve some kind of cognitive change in the individual, but also is required to be considered in the wider social context facilitated through social interaction. This leads to defining social learning as a “[…] change in understanding that goes beyond the individual to become situated within wider social units or communities of practice through social interactions between actors within social networks” (Reed et al., 2010, p. 6).

Being situated within wider social units or communities of practices requires the presence of new relational capacities concerned with ways of behaving and collaboration. Pahl-Wostl et al. (2008, p. 1) argue that these relational capacities not only relate to collaborative learning in the narrower sense, but also to emphatic qualities in terms of understanding the roles of others. The effectiveness of social learning therefore directly depends on the quality of collaboration.
By implication, collaboration cannot emerge or exist if there is no interaction among social agents (Kreijns et al., 2003).

According to Dillenbourg (1999, p. 1), collaborative learning is a “[…] situation in which two or more people learn or attempt to learn something together.” In his definition, Dillenbourg emphasizes three distinct elements referring to the collaborative situation (e.g., group size), what is intended to be learned, and the relevance of interaction among individuals, the latter also called collaboration. In comparison to traditional approaches, collaborative learning focuses on groups of students where interaction is considered essential for knowledge acquisition. The instructor in this context is seen more as a facilitator rather than a more knowledgeable other superior to the learners (cf. Figure 3.2).

Collaborative learning not only involves learners working to achieve a common goal, but in particular emphasizes that each contribution is respected in the overall context. In this regard, cooperation differs from collaboration as it considers each contribution decontextualized from the whole (cf. Dillenbourg 1999; Harasim 2012; McInerney & Roberts 2004). In collaboration, therefore, not only the result is collaborative, but also the process itself (Harasim 2012). Although there is no general agreement on a single definition of collaboration, in particular with respect to cooperation, Kirschner (2001) has identified several characteristics which both concepts have in common. First and foremost, he emphasizes that learning takes place in an active mode, where the instructor or teacher is more a facilitator rather than a “sage on the stage”. Learning therefore is not an individual effort, but is done in small groups under the guidance of a facilitator providing scaffolds for knowledge construction. As a consequence, learners need to take over responsibility for their own learning outcomes. Other characteristics are concerned with, for instance, the fact that collaborative learning supports the development of social skills and enhances one’s capability to reflect on his or her own thought processes.

Despite the fact that individuals need to take over responsibility for their own learning outcomes, group learning involves knowledge construction processes that most likely cannot be attributed to a single individual or sequence of contributions from individual intellects (cf. Mansour 2009; Stahl 2005, 2012; Vasilion et al. 2014). In the literature, group cognition processes are de-
3.1. Towards a Situative Perspective on Learning

scribed as being exposed to a variety of different influencing factors (cf. Figure 3.3. Stahl 2010) addresses these factors in his paper on group cognition in computer-supported collaborative learning environments. Central to group learning processes is that sequential team interaction combines the resources and experiences of each individual. Meanings which have been constructed collaboratively in these processes are then encapsulated in the form of team knowledge artifacts which make up the team outcomes. In this regard, the task provides the respective contextual conditions, also with respect to the interaction context as well as the culture of discourse. Technology and media is considered relevant as potentially supporting groups in their collaborative learning processes.

The constraints illustrated with respect to group learning processes show the importance of the technological perspective. In this regard, the development and widespread adoption of the Internet provoked substantial changes not only with respect to learning technology, but also related to learning itself. Two major waves of technological revolution were the main drivers behind this progress (Cox 2013). First, personal computers became available and affordable for use in formal and informal settings, leading to the emergence of more complex educational software. The Internet started this development as access to educational software and learning resources has become easier and more cost-effective since then. This technological progress, however, did not only support individual learners, but also opened up opportunities allowing to support collaborative processes. The second wave has been driven by technological developments as well, but more importantly, is associated with a shift related to the responsibilities of the learner in the learning process. According to Cox (2013, p. 5), “[t]his second wave of technological developments [...] has changed the balance between the control of e-learning from the teacher to the teacher with the learner, from the teacher to the learner, and from formal to informal uses.”

In particular with due regard to the technological progress, online collaborative learning theory has been developed (Harasim 2012). As a constructivist approach to learning, it encourages the collaboration among students under the
Chapter 3. A Situative Perspective on Self-regulated Learning

guidance of a facilitator which represents the link to the respective knowledge community. Online collaborative learning theory therefore considers collaborative discourse as essential to knowledge building and differentiates between three intellectual phases concerned with generating and organizing ideas as well as consolidating distributed knowledge for the purpose of constructing shared understandings (cf. Figure 3.4). The three intellectual phases are described in the following:

1. **Idea Generating.** The first intellectual phase of online collaborative learning is concerned with processes facilitating the generation, verbalization, and sharing of ideas. Each individual is encouraged to put his or her own perspectives on particular topics forward for discussion.

2. **Idea Organizing.** The second intellectual phase builds on the ideas constructed in the first phase and constitutes the basis for conceptual change. According to Harasim (2012, p. 93), ideas begin to converge during this phase as learners “[…] confront new or different ideas, clarify and cluster these new ideas according to their relationship and similarities to one another, selecting the strongest and weeding out weaker positions.” As a result, ideas become organized in the sense that multiple perspectives are recognized and analyzed with respect to potential relationships.

3. **Intellectual Convergence.** The last intellectual phase eventually leads to a shared understanding among the learners in terms of both agreeing and disagreeing. The structuring of ideas, as Harasim (2012, p. 93) states, “[…] reaches a level of intellectual synthesis, understanding and consensus, whereby participants in the discussion agree to disagree, and/or co-produce a conclusion.” Theories, positions, hypotheses, strategies, and so forth are potential outcomes and might either trigger further discussions (i.e., the process starts again with generating new ideas) or social applications. Harasim (2012), however, indicates that the process must not be interpreted as circular by nature, but rather as a spiral model where converged ideas are used as feedback for further discussions.

In online collaborative learning, the role of the instructor is seen to be crucial to the learning process. Instructors not only are considered as responsible for simply guiding learners through their learning processes, but act as representatives of their knowledge communities (cf. Figure 3.5). According to Harasim (2012, p. 94), instructors “[…] engage the learners in the language and activities associated with building the discipline, inducting the learners into the language and processes of the knowledge community. [Instructors] are representatives of their knowledge communities, and such introduce the learners to the appropriate language as well as its application within the particular discipline.” In other words, instructors are responsible for both facilitating the collaborative learning process as well as providing students with appropriate information relevant in the context of a particular knowledge community. The
3.1. Towards a Situative Perspective on Learning

As reflected in the model’s intellectual phases (cf. Figures 3.4 and 3.5), online collaborative learning considers knowledge-building discourse as crucial to learning [Harasim, 2012]. In contrast to tools based on mere knowledge-transmission, discourse in online collaborative learning environments is considered more flexible with respect to supporting various different communication modalities and interaction patterns. As a consequence, not only one-to-many communication, but also many-to-many and one-to-one collaboration needs to...
Chapter 3. A Situative Perspective on Self-regulated Learning

be supported. Online collaborative learning environments therefore are characterized by five attributes, allowing text-based discourse over the Internet without being restricted regarding place and time (Harasim 2012).

− **Place-independent Discourse.** The development of the computer as well as the emergence of the Internet are considered the enablers of place-independent communication and collaboration. In learning and teaching, this technological revolution provoked a major change (cf. Cox 2013; Harasim 2012), providing the basis for an integrated approach between formal and informal educational settings.

− **Time-independent Discourse.** Besides its place-independent nature, online collaborative learning environments also support both synchronous and asynchronous communication and collaboration. Consequently, learners are able to continuously participate in online discussions.

− **Many-to-many Discourse.** In contrast to one-to-many communication, online collaborative learning environments facilitate collaboration in the sense that learners can engage in group or many-to-many discourse for the purpose of knowledge-building. According to Harasim (2012, p. 104), this supports “[…] creativity by enabling participants to draw on ideas from many perspectives and diverse sources [as well as] the ability to respond to and interact with a range of ideas [in order to] refine and improve understanding and knowledge.”

− **Text-based Discourse.** In online collaborative learning environments, text-based discourse is considered of crucial importance as it makes accessible one’s views on particular topics. “This”, as Harasim (2012, p. 105) states, “creates an accurate and verbatim transcript that learners and educators can access for replying to comments, reviewing the discussion, making multiple passes through the transcript and for retrospective analysis or assessment.” Although online collaborative learning environments mainly focus on text-based discourse, multimedia content, such as audio and video, may be incorporated into online course activities as well.

− **Internet-mediated Discourse.** The Internet not only allows learners to collaborate with others independent of place and time, but also represents a massive repository of information to be linked with one’s messages in the course of collaboration. Beyond that, the constant development of tools and technologies, such as cloud computing or the Semantic Web, provide the basis for new application scenarios potentially useful for online discourse and knowledge-building.

Despite the potentials addressed by means of the attributes discussed above, collaborative online learning environments introduce new challenges to the quality of learning and knowledge-building. Allowing place- and time-inde-
3.1. Towards a Situative Perspective on Learning

Dependent discourse, indeed, offers great flexibility to learners, but at the same time might lead to issues induced by cultural differences or varying expectations with respect to response times, the quality of contributions, and so forth. For instance, learners which work on particular tasks in a collaborative setting might experience different levels of formalities and informalities when concerned with the form of address. In this regard, different expectations might be prevalent since some cultures may be more casual, whilst others would prefer a more formal way of interaction.

3.1.3. A Situative Perspective

Looking at the historical development and conceptualization of learning, the situation and contextual conditions were not considered relevant in research and the development of respective theories for a long time. Brown et al. (1989) in their seminal paper on situated cognition and the culture of learning were the first to question the general assumption on which didactic methods were based during this time. According to Lankshear & Knobel (2011, p. 211), they argue that “[...] by separating learning from ‘authentic’ activity grounded in physical and social contexts and situations, formal education largely defeats its goal of promoting ‘usable, robust knowledge’.” In this context, situated learning was first proposed by the social anthropologist Jean Lave and learning theorist Étienne C. Wenger (cf. Lave (1991); Lave & Wenger (1991)). Situated learning is based on the idea that learning needs to be considered in the context of the activity and culture in which it occurs. Social interaction therefore becomes a crucial component to one’s conceptual understanding and ability for reflection and articulation (cf. Figure 3.6). According to the three-step model proposed by Brown et al. (1989), individuals start learning in the context of an authentic activity under the guidance of a more knowledgeable other (e.g., teacher). Once learners gain more confidence in performing particular tasks, “[...] they move into a more autonomous phase of collaborative learning, where they begin to participate consciously in the culture” (Brown et al., 1989, p. 39). Collaborative activities eventually lead to reflective actions and the ability to articulate conceptual knowledge. Students can then “[...] use their fledgling conceptual knowledge in activity, seeing that activity in a new light, which in turn leads to the further development of the conceptual knowledge” (Brown et al. 1989, p. 39).

![Figure 3.6.: From situated activity to general applicability](Brown et al. 1989, p. 40)
Chapter 3. A Situative Perspective on Self-regulated Learning

Since the notion of situated cognition was first published in 1989 by Brown et al., several different directions have emerged (cf. Cobb & Bowers, 1999; Greeno, 1998; Kirshner & Whitson, 1998; Salomon & Perkins, 1998). A first school of thought has focused on the effect of social mediation on individual learning processes. In particular, studies concerned concepts such as scaffolding, cooperative learning, and scripted collaboration as relevant (Allal, 2001). Although that social mediation was considered important to the learning process, the individual and its cognitive capacities remained the primary influencing factor. This particular perception changed when research started to investigate and consider cultural artifacts, such as tools, signs, symbol systems, and so forth, as being relevant to learning (Allal, 2001). According to Allal (2001, p. 409), the scope of social mediation has been extended since then “[. . .] by taking into consideration not only the effects of the artifacts on individual cognition but also the effects with the artifacts in use for both individual and collective (or distributed) cognition.”

Compared with prior conceptions of learning, the situative perspective on learning shows differences with respect to corresponding learning processes, the form of knowledge and its transmission, the developed understanding, as well as the outcome of learning (cf. Table 3.2). Most importantly, this concerns the relevance of an authentic context in which individuals are subject to some kind of transformation with respect to their identity in the context of a particular knowledge community. Interaction and collaboration among peers is considered crucial to learning. Although this is in line with current research on situated learning (cf. Goel et al., 2010; Hotho et al., 2014; Zhu & Bargiela-Chiappini, 2013), the conceptualizations of prior approaches need to be considered more carefully. This in particular concerns the form of knowledge and its transmission, associated learning processes, as well as how understanding is developed in the course of learning. From an constructivist point of view, the transmission of knowledge does not follow authoritative principles, instead it is based on a more constructive way of collaboration where the instructor or teacher is considered as facilitator. In this sense, learning is not a passive activity, but seen as process where the individual is responsible for actively constructing his or her conceptual structures and therefore knowledge.

<table>
<thead>
<tr>
<th>Conceptualization</th>
<th>Established</th>
<th>Situated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning</td>
<td>Cognitive/Passive/Selective</td>
<td>Interactive/Participative/Pervasive</td>
</tr>
<tr>
<td>Form of knowledge</td>
<td>Canonical/Codified/Theoretical, Distilled in texts and manuals</td>
<td>Tacit/Embedded/Practical embedded in community and identity</td>
</tr>
</tbody>
</table>

(Continued)
3.1. Towards a Situative Perspective on Learning

Table 3.2.: (Continued)

<table>
<thead>
<tr>
<th>Conceptualization</th>
<th>Established</th>
<th>Situated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understanding</td>
<td>Abstract/Universal</td>
<td>Embodied/Context-sensitive</td>
</tr>
<tr>
<td>Outcome of learning</td>
<td>Acquisition of information or skills</td>
<td>Trans(formation) of identity</td>
</tr>
<tr>
<td>Transmission</td>
<td>Vertical: Instruction by authorities</td>
<td>Horizontal: Collaboration with peers</td>
</tr>
</tbody>
</table>

Although the situative perspective on learning especially focuses on contextual conditions prevalent during learning, it remains aligned with the fundamental principles of constructivist thought, in particular with respect to the notion of social constructivism (cf. Goel et al. (2010); Woo & Reeves (2007)). In this sense, each learner is responsible for his or her knowledge construction (i.e. learning progress) which makes the situative perspective not only crucial to learning, but also to self-regulatory processes (cf. Section 2.3.2). Current research in the field of educational psychology further highlights the importance of the situative perspective, Turner & Nolen (2015, p. 167), in the introductory article to their special issue on the relevance of the situated perspective, note that educational psychology would profit from the opportunity to understand the situative perspective [...] and call for further research in this direction.

The situative perspective addresses the issue that learning is increasingly interactive and collaborative today. Available technologies further amplify this fact which, in total, make individually oriented perspectives on self-regulated learning insufficient in terms of their capabilities to consider the relevant components and factors (Bang, 2015; Järvenoja et al., 2015). The situative approach recognizes this insufficiency by considering both individual- and group-level processes as being relevant to learning. This is enabled by providing an integrative approach to learning that understands the individual and social aspects as equally important and interdependent. Both, the socio-cognitive and the

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6Research in the context of educational psychology is concerned with studying human learning from both a cognitive and behavioral perspective.
7The socio-cognitive perspective considers learning as individual effort that is influenced but not driven by social aspects, such as other individuals or the culture. According to Järvenoja et al. (2015), most models on self-regulated learning follow this notion and consider the individual’s cognitive capacity as crucial to respective processes.
socio-cultural perspective therefore are considered relevant to learning and respective processes. Jarvenoja et al. (2015, p. 206) argue that “[...] individual and social regulation processes are understood to promote each other, exist in parallel, and function equally without either being subordinate to the other.”

A situative perspective on a particular topic, for instance, is one that considers individual beliefs and behaviors as being the results of social and cultural interactions in the context of a system (Turner & Nolen, 2015).

“Regulation activities that aim to control metacognitive, cognitive, motivational, and emotional processes to ensure goal-directed learning”, Jarvenoja et al. (2015, p. 205) state, “are context bound and become activated in learning situations.” According to the situative perspective, learning takes place in a social environment where contextual factors are crucial to learning processes (Jarvenoja et al., 2015). Decision making with respect to, for instance, the selection of learning strategies might be affected. In other words, contextual factors such as the description of tasks, other individuals, the instructional and pedagogical design of content and learning materials, and available technology influence the way how individuals regulate their learning processes in specific situations. Although often used synonymously, it is important to note that there are different conceptualizations associated with the terms context and situation. While a situation consists of a spatio-temporal arrangement of objects and agents, a context defines a more general construct that not only depends on socio-cultural properties (e.g., the language) but also on the properties of a particular setting, such as a seminar (Rohlling et al., 2003). Frohberg et al. (2009) in their work on mobile learning projects identified four different types of contexts alongside the pedagogic ambition and the relevance of the environment for learning context & the level of complexity (cf. Figure 3.7).

The first context which neither depends on the learning environment nor requires specific pedagogic ambitions is the independent context. Both contexts, the context of being and the context of learning, do not require one another and therefore are considered independent. The formalized context is more restrictive with respect to the physical surroundings. Meeting in a classroom, for instance, may help synchronize a number of learners to be in the same learning context. Although the formalized context has an organizational function, the physical surroundings do not bring along any cognitive advantage for learning processes. In case the physical surroundings are relevant to learning (physical context), requirements on the pedagogic design and the learning environment increase. For instance, a mobile museum guide may assist visitors through presenting information of the objects (e.g., paintings) in front of which they are standing. Finally, the socializing context is concerned with interpersonal relationships including a variety of different aspects, such as the current and

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8In contrast to the socio-cognitive perspective, the socio-cultural perspective focuses on the interaction between individuals and therefore the social and cultural aspects of learning. According to Jarvenoja et al. (2015), “[...] learning is not understood as a process solely in the mind of a learner, but as something that is social in nature [and] then internalized to become an individual process.”
3.1. Towards a Situative Perspective on Learning

Figure 3.7.: Classification of context types

past information or emotions. According to Frohberg et al. (2009, p. 314), systems supporting this type of context “[would need to] support an informal community of learners to exchange and reflect everyday situations and act as mutual peer coaches.” Although this type of context is hardly considered, Frohberg et al. (2009) recognize the relevance and potential of social media where learners provide and get provided the relevant context information.

In terms of instructional design, the situative perspective on learning involves specific conditions and requirements on how learning materials and instructions should be designed. Vincini (2003) argue that not only realistic problems, but also the content, the role of the instructor, as well as the environment are crucial to learning. These factors of influence are described in the following:

- **Realistic problems.** Instructions which represent problems close to reality support learners in thinking and acting like experts in the field.

- **Activities.** Learning typically is based on activities rather than on information which is structured and organized by the instructor.

- **Role of the instructor.** The role of the instructor focuses on coaching learners and providing scaffolds in the course of using information and creating knowledge.

- **Learning environment.** Situative learning environments need to support social discourse, evaluation, and reflective thinking. Activities to be processed typically are collaborative and group-based.
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3.2. Theoretical Approaches to Situatedness

Theoretical approaches to situated cognition and learning have emerged since the late 1980s in the context of research in education. In their famous article on situated cognition and the culture of learning, Brown et al. (1989, p. 32) claim that “[…] activity in which knowledge is developed and deployed […] is not separable from or ancillary to learning and cognition. Nor is it neutral. Rather it is an integral part of what is learned. Situations might be said to co-produce knowledge through activity. Learning and cognition, it is now possible to argue, are fundamentally situated.”

Various different theories have been developed considering the situation and contextual factors as relevant to learning. Stahl (2010) in this context provides an overview of relevant theories, including actor-network theory, activity theory, situated learning, distributed cognition, situated cognition, social informatics, and conversation analysis (cf. Figure 3.1). In the following, in particular activity theory, situated learning, situated cognition, and distributed cognition are presented and discussed as being relevant with respect to the objectives of this work. As explained in the following, actor-network theory, social informatics, and conversation analysis are not considered.

− **Actor-network theory.** Actor-network theory has been developed in the context of science studies and particularly focuses on objects and their relevance in social networks (cf. Callon (1984); Latour (1987); Law (1987)). Important to the theory, however, is not why such networks exist but rather the infrastructure of actor-networks and underlying causalities with respect to their emergence and decay.

− **Social informatics.** According to Kling (2007, p. 1), social informatics is “[…] the interdisciplinary study of the design, uses and consequences of information technologies that takes into account their interaction with institutional and cultural contexts.” The theory’s main focus therefore is concerned with information and communication technology (i.e., tools) and its application considering cultural and institutional contexts.

− **Conversation analysis.** Developed by the sociologist Harvey Sacks in the late 1960s and early 1970s, conversation analysis as an approach to the study of social interaction is considered an established method in sociology, anthropology, linguistics, speech-communication, and psychology (cf. Sacks (1995); Sacks et al. (1974)). Methods associated with conversation analysis focus on analyzing more formal and task-oriented interactions in the context of, for instance, offices or educational settings.

Nardi (1996) also considers activity theory, situated learning, situated cognition and distributed cognition as being relevant in this context.
3.2. Theoretical Approaches to Situatedness

3.2.1. Activity Theory

Activity theory is a general theory that covers a variety of different social science theories and research in the context of the cultural-historical psychology developed by Vygotsky in the 1980s. Scientists and scholars associated with activity theory focus on understanding human activities in the wider context including socially situated phenomena. This means that activities are considered from the social perspective (environment, culture, role of the artifacts, motivations, etc.) and therefore go beyond the individually oriented notion of just one actor or user (Engeström et al., 1999). Mayes & De Freitas (2004) consider activity theory as one important strand of new thinking as it integrates aspects of both the constructivist and situative view. In particular with respect to learning, activity theory has the potential to inform the design of learning environments (Jonassen, 2000).

The focus of activity theory is not the individual, but the activity system in which the individual is situated, such as the community, rules of interaction, and artifacts. An activity basically consists of a group of individuals which pursue a particular objective. Each individual typically is part of a community which acts according to a specific set of rules determining acceptable forms of interactions. Since activity systems are subject to constant change, the participants of the community, the objective, and tools are always changing as well. Tools in particular are important since they make activity possible in the first place. According to Mayes & De Freitas (2004, p. 18), “[t]ools can be both physical (networks, books, software) and cognitive (concepts, language, memory).”

Six elements are considered important in the activity theory (cf. Engeström (1987), Kaptelinin & Nardi (2006)), including the object, the subject (internalization), the community (externalization), tools or tool mediation, division of labor, and rules (cf. Figure 3.8). In the following, the separate elements are described in more detail:

− Object. The objective of the activity system which refers to the objectiveness of the reality in terms of both natural sciences and social/cultural properties.

− Subject or internalization. The cognitive capabilities or mental processes of individuals engaged in activities are referred to as subject or internalization.

− Community or externalization. The social context in which individuals are situated.

− Tools or tool mediation. Artifacts, such as concepts, tools and signs, which are used by individuals in the context of an activity system. A
variety of different factors, such as the culture, exist that influence the tools to be used.

- **Division of labor.** The division of labor structures activity in that work is assigned to the individuals in the system.

- **Rules.** Guidelines for interaction, conventions, and rules that exist in the system and determine acceptable forms of interactions.

![Activity system](Engeström 1987)

### 3.2.2. Situated Learning Theory

Situated learning theory was first proposed by the social anthropologist Jean Lave and the educational theorist and practitioner Étienee C. Wenger in their seminal paper on situated learning considering legitimate peripheral participation (cf. Lave (1991); Lave & Wenger (1991)). The theory argues that learning does not imply the transmission of abstract and decontextualized knowledge, but rather is considered as being situated with particular reference to the context and social processes where knowledge is co-constructed. Social interaction therefore is crucial to learning and involves being part of a community of practice where certain believes, values, and behaviors are present to be acquired. Similar to the zone of proximal development, Lave & Wenger (1991) describe learning as a process where new members of a community of practice move from the periphery to the center of the community. In the course of this process, members acquire the believes, values, and behaviors relevant to the community. In terms of Vygotsky’s social constructivism, being at the center of the community would be equal to the actual development level, that is what the learner can do without any further guidance.
3.2. Theoretical Approaches to Situatedness

3.2.3. Situated Cognition

Situated cognition theory was first proposed by John Seely Brown, Alan Collins, and Paul Duguid in their seminal work on situated cognition and the culture of learning (Brown et al., 1989). They argued that many teaching practices and didactical methods at that time considered knowledge as integral, self-contained entity which consequently led to the separation of theory and practice. Situated cognition theory, however, suggests knowing and doing to be inseparable in that knowledge needs to be considered as situated in activity with respect to its social, cultural, and physical contexts (Greeno et al., 1993). It considers the system, which is determined by the context, culture, language, and intersubjectivity among individuals, as a whole and one crucial element to the construction of knowledge.

Defined by the three perspectives with respect to the functional, structural, and behavioral qualities of situated cognition, the theory considers both spatio-temporal and contextual properties important to learning. According to the conceptualizations proposed by Rohlfing et al. (2003), situated cognition theory combines both the notion of situation and context, the latter not being focused on spatio-temporal but socio-cultural properties (e.g., social, cultural, and physical).

3.2.4. Distributed Cognition

Distributed cognition is an approach to cognitive science and was first proposed by Hutchins, a cognitive psychologist and anthropologist, in the mid 1990s (Hutchins, 1995). Based on his observations in the context of us navy ships he concluded that knowledge rather resides in the world (i.e., objects, individuals, artifacts, and tools in the environment) than in the mind’s of individuals. According to Zhang & Norman (1994) and Hollan et al. (2000), distributed cognition is based on three key components concerned with interactions among individuals and the environment, the embodiment of information, and cultural/ecological contributions. In the following, the separate components are described in more detail:

- **Socially distributed cognition.** It is important to note that in distributed cognition cognitive processes not only are socially distributed among members of a group, but also include phenomena that emerge through interactions among people or the structural properties of the surrounding environment. Important to the social distributed cognition is, on the one hand, how cognitive processes of individuals are implemented in groups, and on the other hand, how cognitive properties both differ and are affected between the priorities of an individual and group perspective (Hollan et al. 2000).
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− Embodied cognition. According to Hollan et al. (2000, p. 177), “[i]t is not an incidental matter that we have bodies locking us causally into relations with our immediate environment.” Minds therefore are not considered as being isolated from the environment, but as strongly connected to external object and artifacts. The organization of mind – both in development and operation – therefore is seen as emergent property affected not only by social interactions but also by the synergy of internal and external resources.

− Cultural and cognition. Culture and ecological conditions are considered an important factor of cognition. Culture arises from interactions among social agents and manifests in mental, material, and social structures. The historical development of mental, material, and social structures, however, may in turn affect and shape cognitive processes, in particular processes that are distributed over agents, artifacts, and environments (Hollan et al., 2000).

3.3. An Integrative Approach

In the previous sections, different theoretical approaches to learning as well as the development from individually oriented to collaborative and situative perspectives were discussed. While these approaches and perspectives share a common baseline, each of them individually focuses on particular aspects related to learning and associated processes. In order to structure and organize the different aspects for the purpose of constructing an integrative perspective on self-regulated learning under the consideration of situative conditions, the community of inquiry model is used as guiding framework. As relevant and most advanced model in the context of learning (Jézéquel, 2010), it not only considers the cognitive and social component as being relevant to learning, but also the teaching component as crucial factor with regards to providing respective structures and processes.

The basic concept of community of inquiry dates back to the work of Charles S. Peirce (1839 – 1914), an American scientist and philosopher who is considered the founder of pragmatism. In the context of his critiques on Cartesianism, Peirce (1868, p. 141) argued that “[w]e individually cannot reasonably hope to attain the ultimate philosophy which we pursue; we can only seek it, therefore, for the community of philosophers.” The notion of community was central to Peirce as he claimed that discourse is crucial for testing and grounding new ideas and hypotheses.

The concept of community of inquiry has been adopted and transferred to various different disciplines since its development. Lipman et al. (1980) extended the concept with respect to educational settings, arguing that classrooms ex-
hibit similar characteristics and therefore are a type of community of inquiry as well. In contrast to the educational principles prevalent during the time of development, however, Lipman (2003) argued in favor of a more reflective paradigm, dismissing the view that education is the mere transmission of unambiguous knowledge through authoritative teachers. With the development of the computer and the rise of communication technology, Lipman’s ideas were expanded further to online learning by Garrison et al. (1999) in their seminal paper on the critical inquiry in text-based environments. Focusing on computer-mediated communication, the goal was to develop a “[…] conceptual framework that would provide order, heuristic understanding and a methodology for studying the potential and effectiveness of computer conferencing” (Garrison et al., 2010a, p. 6). In this context, a community is characterized as “[…] a group of individuals who collaboratively engage in purposeful critical discourse and reflection to construct personal meaning and confirm mutual understanding” (Garrison, 2011, p. 2).

3.3.1. Three Dimensions of Presence

The community of inquiry model is composed of three independent dimensions or so-called presences (cf. Figure 3.9), which in sum account for creating a deep and meaningful (collaborative constructivist) educational experience (Garrison, 2011). “A presence”, as Garrison (2011, p. 23f.) describes, “is a sense of being or identity created through interpersonal communication […]” and focuses on either the cognitive, social, or teaching dimension. In the following, the three dimensions are described in more detail:

The cognitive presence is the core dimension in the community of inquiry model and is defined as “[…] the extent to which the participants in any particular configuration of a community of inquiry are able to construct meaning through sustained communication” (Garrison et al., 1999, p. 89). Based on Dewey’s (1986) social-constructivist view on learning, the cognitive presence is operationalized by the practical inquiry model which defines an inquiry learning cycle comprised of four different phases (Garrison et al., 2001). Each phase leads to a specific state in the learning process, ranging from the initialization of the learning process itself to problem solving (cf. Figure 3.10).

1. Triggering Event. At the beginning, the learning process is initialized by an event in the form of a specific issue or problem. In formal education this typically is done by the instructor or teacher. The students involved in the community of inquiry are becoming aware of the problem (perception) and prepared to start the exploration phase.

10John Dewey (1859 – 1952) was an American philosopher, psychologist, and educational reformer who is considered the founder of functional psychology. He also is famously associated with pragmatism.
Chapter 3. A Situative Perspective on Self-regulated Learning

Figure 3.9.: The community of inquiry model (Garrison et al., 1999, p. 88)

2. **Exploration.** The second phase is concerned with exploring the specific issue or problem at hand. In contrast to the first phase, however, exploration activities are performed by the students individually.

3. **Integration.** The integration phase starts once students have gathered and organized an appropriate body of information. Information is then synthesized, aggregated, and filtered for the purpose of generating new ideas (conception) or solutions in the context of the specific issue or problem.

4. **Resolution.** Finally, the issue or problem at hand is resolved, which, in formal education, typically is concerned with hypothesis testing. In many cases the resolution of the issue or problem initializes a new learning cycle associated with a novel triggering event.

In contrast to other approaches for analyzing cognition, such as Bloom’s taxonomy of educational objectives (Bloom, 1956) or the SOLO taxonomy (Biggs & Collis, 1982), the practical inquiry model considers both individual and socially distributed cognition (Schröder, 2004). This particular property is reflected by the separation of concerns relating to the individual and social part of the inquiry learning cycle. While the exploration and integration phase involves the individual learner, the triggering event and the resolution phase is situ-
3.3. An Integrative Approach

Figure 3.10.: The practical inquiry model (Garrison et al., 2001, p. 22)

ated in the social context. “[K]nowledge-building”, as Schrire (2004, p. 483) describes in the context of the practical inquiry model, “is considered to be both an individual and a group learning process involving collaboration among learners.”

The social presence is the second dimension in the community of inquiry model and is described by Garrison (2007, p. 63) as “[... the ability to project one’s self and establish personal and purposeful relationships”. In the literature, however, there is no agreed upon definition of social presence, instead there is a multitude of different explanatory approaches proposed by various researchers and practitioners (Lowenthal, 2009; Swan & Shih, 2005). Tu & McIsaac (2002a, p. 140), for instance, suggest that social presence is determined by the “degree of feeling, perception, and reaction of being connected by [computer-mediated communication technology]”, whereas Picciano (2002, p. 22) focus on “[...] a student’s sense of being in and belonging in a course and the ability to interact with other students and an instructor [online].” More recent conceptualizations suggest social presence as being a group-based phenomenon which involves an affective, an interactive, and a cohesive component (Richardson & Swan, 2003). More specifically, Garrison & Vaughan (2008) link social presence to the openness of communication and level of group cohesion and assess it as crucial for interpersonal communication.

Based on previous studies, Tu et al. (2012) propose social presence to be composed of three different dimensions, including the social context, online commu-
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...nication, and interactivity. In the following, the three dimensions are discussed in more detail:

- **Social context.** The social context is considered important in that it recognizes the importance of task orientation, privacy as well as social relationships and processes ([Tu et al., 2012](#)). [Walther (1997)](#) suggest that social processes, settings, and purposes are relevant to the social context and therefore influence social presence. Besides social processes, privacy is an important factor contributing to social presence as well. [Tu et al. (2012)](#) indicate that if learners feel exposed to a large group or even the public this would end up in a decreased perception of social presence.

- **Online communication.** Online communication refers to the basic conditions with respect to the language and applications used in online communication. Providing sufficient introductory materials and trainings therefore is crucial to the success of collaborative learning.

- **Interactivity.** The perception of social presence is influence by the interactivity of online communication applications. According to [Tu et al. (2012) p. 135](#), “[it] includes the activities in which [computer-mediated communication] users engage and the communication styles they use.” Asynchronous styles of communication, for instance, might negatively impact social presence since interaction is delayed and therefore perceived as not being immediate.

Given the three dimensions, [Tu et al. (2012)](#) identified various different factors as being relevant to the perception of social presence. They could identify these factors based on the results of their quantitative and qualitative studies on the relationship of social presence and interaction in online classes. Table 3.3 gives an overview of the different factors with respect to each of the dimensions.
### Table 3.3.: Dimensions and variables of social presence (Tu & McIsaac, 2002b, p. 141)

<table>
<thead>
<tr>
<th>Social Context</th>
<th>Online Communication</th>
<th>Interactivity</th>
<th>Privacy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Familiarity with recipients</td>
<td>Keyboarding and accuracy skills</td>
<td>Timely response</td>
<td>Formats of CMC</td>
</tr>
<tr>
<td>Assertive/acquiescent</td>
<td>Use of emoticons and paralanguage</td>
<td>Communication styles</td>
<td>Access and location</td>
</tr>
<tr>
<td>Information/formal relationship</td>
<td>Characteristics of real-time discussion</td>
<td>Length of messages</td>
<td>Patterns of CMC</td>
</tr>
<tr>
<td>Trust relationships</td>
<td>Characteristics of discussion boards</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social relationships (love and information)</td>
<td>Language skills (reading, writing)</td>
<td>Type of tasks (planning, creativity, social tasks)</td>
<td></td>
</tr>
<tr>
<td>Psychological attitude toward technology</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Access and location</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>User’s characteristics</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Teaching presence as the third and last dimension in the community of inquiry model is concerned with the underlying structures and processes related to the design and organization of courses. According to Anderson et al. (2001) it accounts for “[t]he design, facilitation, and direction of cognitive and social processes for the purpose of realizing personally meaningful and educationally worthwhile learning outcomes.” In particular, research on capabilities concerned with the teaching presence include three different types (Anderson et al., 2001; Arbaugh, 2010; Daspit & D’Souza, 2012; Garrison & Arbaugh, 2007):

- **Course design and organization.** The ability to design and organize courses is considered important to teaching presence. It includes defining and setting the curriculum, selecting appropriate methods and tools, as well as establishing respective conditions including the location and time.

- **Facilitation of discourse.** Setting the climate for social interaction is considered crucial to teaching presence. It includes the facilitation of discourse so as to engage students in interactive activities.

- **Organization of learning processes.** The teaching presence also includes abilities with respect to guiding and supporting learning processes. It concerns “[…] the ability to direct instruction, provide scholarly leadership, and offer subject-matter expertise” (Daspit & D’Souza, 2012, p. 668).

The community of inquiry model not only considers three separate presences crucial to educational experiences, but also suggests overlappings as being relevant (cf. Figure 3.9). These overlappings are defined at the intersections between the presences. For instance, the overlapping between the social and cognitive presence highlights the importance of facilitating social discourse. Relationships among the different presence, however, are not further described by the model (Garrison et al., 2010b; Shea & Bidjerano, 2008). On this account, could identify potential interdependencies based on data gather from more than 5000 online learners. Most importantly, they showed that “[…] variance in student judgments of their own cognitive presence can be modeled from their ratings of instructor teaching presence mediated by their assessment of social presence in their online courses” (Shea & Bidjerano, 2012, p. 1722). In turn, these research results indicate that the quality of teaching and social presence could predict the level and respective qualities of the cognitive presence (cf. Figure 3.11). Daspit & D’Souza (2012) report similar findings and conclude that “[t]he teaching presence and social presence are shown to influence cognitive presence (e.g., learning), which reaffirms that the role of the instructor continues to be paramount to student learning in technology-enhanced environments.”
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3.3.2. Supporting Situative Learning

Self-regulated learning is considered an important factor with respect to the success of online education (Lehmann et al., 2014). It views learning as an active process in which knowledge is constructed by the individual, rather than being transmitted from a more knowledgeable other to the student. The degree to which learners are responsible for building their own knowledge therefore increases making the construct of self-regulated learning an relevant factor in this context. Consequently, metacognitive capabilities are considered essential to learning processes as well (Akyol & Garrison, 2011). The solely focus on self-regulated learning and metacognition, however, is insufficient due to the fact that learning today is increasingly interactive and collaborative. Available technologies further amplify this fact and make individually oriented perspectives on self-regulated learning not ideal. The situative perspective brings in further details with regards to the importance of the situation and contextual factors.

In the following, self-regulated learning is discussed with reference to the community of inquiry model as conceptual framework. Each presence thereby is presented and discussed with respect to the relevance of metacognitive capabilities, condition and effects introduced by collaborative aspects, as well as the influence of the situation and contextual factor.

**Teaching Presence**

Although there is no particular sequence inherent to the different presences, the teaching presence is considered an important factor of influence with respect to
the perception of social and cognitive presence (cf. Figure 3.11). This means that the quality of teaching presence – in combination with social presence – could predict the level and respective qualities of cognitive presence. Responsibilities and activities associated with the teaching presence are not dedicated to a specific role (e.g., teacher or instructor), but are equally shared among all learners in the group (Akyol & Garrison, 2011). These responsibilities and activities may include, but are not limited to, building and re-purposing learning materials, administrating the learning group, or designing individual or group learning processes. Akyol & Garrison (2011, p. 186) argue that “[each learner] in a community of inquiry is expected to assume teaching presence responsibilities and those responsibilities include contributing knowledge, monitoring the inquiry process and actively regulating the progress of inquiry. It is through the teaching presence construct that [learners] become metacognitively aware and assume the regulatory responsibilities for successfully completing the inquiry process.”

With respect to online collaborative learning theory, responsibilities and activities associated with teaching presence are not discussed explicitly but are inherent to the three intellectual phases. The phase concerned with generating ideas, for instance, assumes learners to share experiences and contribute knowledge to the learning group (cf. Figure 3.4). Most notably, however, metacognitive capabilities are reflected in the transitions between intellectual phases. These transitions require learners to constantly monitor and actively regulate the inquiry process for the purpose of knowledge building and eventually social application. During brainstorming (i.e., idea generating), for instance, the learning group is concerned with collecting experiences and inputs from the individual learners. Due to collaborative learning processes and the shared nature of responsibilities and activities, learners are in charge to decide whether to move on to the next phase, that is idea organizing. The same holds when further input is required in order to solve the task at hand. This requires learners to actively regulate the inquiry process in that the learning group re-enters the phase of idea generating. Although the process appears to be circular, Harasim (2012, p. 94) argues the converse saying that “[it is] one of continual growth or advance based on a feedback spiral.”

The situative perspective as particularly concerned with increasing levels of interactivity and collaboration is reflected in the overlapping of teaching and social presence. Here, activities related to providing direct instruction and the facilitation of discourse are considered relevant. Akyol & Garrison (2011) indicate that the facilitation of social discourse potentially affects and enhances metacognitive capabilities of students. In addition, the discussion on the importance and the relevance of the situation and contextual factors may contribute to a better understanding of teaching presence. In terms of instructional design, for instance with respect to building and re-purposing learning materials or defining tasks and activities, the situative perspective details the teaching presence. According to Vincini (2003), activities and tasks which are close to
3.3. An Integrative Approach

the preceived reality are crucial to learning.

Social Presence

For a long time, research on the community of inquiry model with respect to self-regulated learning and metacognition was restricted to the individual, which means that co-regulative activities were not considered explicitly. Only recently, the importance of collaboration and co-regulation was recognized in this context. [Garrison & Akyol (2015, p. 87) identified these shortcomings and call for “[recognizing] the collaborative constructivist nature of the community of inquiry model and [adopting] a commensurate metacognitive construct that reflects the self and co-regulation dimensions.” First conceptual findings in this context were reported by [Volet et al. (2009)] in their work with respect to an integrative perspective on self- and social regulation in learning contexts.

Co-regulation is an important aspect of regulatory processes particularly relevant to communication-intensive learning environments ([Kaplan, 2014]) where collaboration is key to learning processes. In this context, not only the result is collaborative, but also the process itself ([Harasim, 2012]). Online collaborative learning theory is one potential approach to guide the engagement with participants in the context of the community of inquiry model. Specifically, the theory suggests to structure the collaborative learning process along three intellectual phases. First (i.e., idea generating), in brainstorming sessions the different experiences and inputs are gathered from the individuals which facilitates the generation, verbalization, and sharing of ideas. Based on these results, ideas and inputs begin to emerge in the course of the second phase (i.e., idea organizing) building the basis for conceptual change. As ideas and inputs become organized, multiple perspectives are recognized and analyzed with respect to potential relationships. Finally (i.e., intellectual convergence), the structuring of ideas leads to a shared understanding among the learners. With respect to associated learning processes, the teaching presence is considered key for providing a setting where collaboration and engagement among learners is facilitated. For instance, if the design of learning processes particularly reinforces individual work (e.g., through creating a competitive environment), collaborative activities, as described in the online collaborative learning theory, will not emerge.

The situative perspective further highlights the importance of facilitating collaboration and the engagement among learners, in particular since it addresses the issue that learning has become increasingly interactive and collaborative. The main contribution of the situative perspective, however, is not related to social presence as such, but rather unfolds in the overlappings to the other presences, in particular with respect to the teaching presence.
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Cognitive Presence

The cognitive presence is considered the core dimension in the community of inquiry model and is operationalized by the practical inquiry model. The practical inquiry model consists of four phases, each describing a separate step in the learning cycle (cf. Figure 3.10). From a self-regulated learning point of view, understanding the inquiry process is particularly helpful with respect to metacognitive processes (Akyol & Garrison, 2011). For instance, being aware that the second phase (i.e., exploration) is concerned with the individual and/or collaborative exploration of information, learners can be more conscious with respect to the selection and application of appropriate learning strategies. The same holds for the other phases in the practical inquiry model.

With regards to the collaborative aspect, in particular the second (i.e., exploration) and the fourth (i.e., resolution) phase provide the respective setting and appropriate conditions for learning processes. According to Akyol & Garrison (2011, p. 186), for instance, refer to the exploration phase “[as a] process where learners individually and collaboratively explore information and ideas that might provide insight into the particular problem.” After having integrated the information in the course of the third phase, learners then collaboratively confirm solutions relevant to the problem at hand. Compared with the online collaborative learning theory, similarities can be identified with respect to the collaborative aspect, most notably related to the first (i.e., idea generating) and third (i.e., intellectual convergence) phase. The individual perspective, however, is neglected and only presented explicitly in the practical inquiry model.

The situative perspective with regards to the cognitive presence is not relevant directly, but is important at the overlappings to both the teaching and social presence (cf. Figure 3.11). In particular, this concerns situational and contextual factors related to the selection of content, the regulation of learning, and the support of social discourse. The situative perspective therefore provides a structured view on the critical success factors relevant to the educational experience in learning processes.

3.4. Summary

In this chapter, the situative perspective on self-regulated learning was discussed by means of the development from individually oriented to collaborative (cf. Section 3.2) approaches, in particular with respect to the situative perspective (cf. Section 3.1). At the beginning of the 19th century, the understanding of theory has undergone a significant shift regarding the study of cognition (cf. Section 3.1.1). The unit of analysis was extended from the individual level up to the cultural understanding of the society. Since then, learning has been
3.4. Summary

conceptualized in various ways, most notably related to the two main schools of thought focusing on either the individual or the social context. Despite the different orientations, however, the fundamentals of the constructivist thought remain the same, referring to learning as an active process of knowledge construction. Although the social context has been considered by constructivist approaches ever since, learning remained an individual effort of constructing knowledge which insufficiently takes into account the pedagogical and sociological setting. Communicative or situative approaches address this issue as they consider human interaction essential for constructing meaning. Collaborative learning (cf. Section 3.1.2) in that sense follows this notion since it recognizes that group learning involves knowledge construction processes that most likely cannot be attributed to a single individual or sequence of contributions from individual intellects. Different conceptualizations of group cognition and respective processes – also regarding the relevance of technology – have been proposed since then. Addressing today’s availability of technology, online collaborative learning theory constitutes one main theory in this context. The theory considers collaborative discourse as essential to knowledge building and differentiates between three phases which eventually lead to intellectual convergence and social application of knowledge. The facilitator (e.g., lecturer) represents the link to the knowledge community and therefore is responsible for both facilitating the collaborative learning process as well as providing students with appropriate information.

In line with the constructivist approach, in particular with respect to the notion of social constructivism, the situative perspective addresses the fact the learning is increasingly interactive and collaborative today (cf. Section 3.1.3). Technology further amplifies this fact which, in total, make individually oriented perspectives on self-regulated learning insufficient in terms of their capabilities to consider relevant components and factors. The situative approach recognizes this insufficiency by considering both individual- and group-level processes with respect to the situation and contextual factors. The different conceptualizations of situation and context allow focusing on either the spatio-temporal arrangement of objects and agents or socio-cultural properties as well as properties of particular settings.

Considering the different developments, the community of inquiry model is one potential approach and conceptual framework for constructing an integrative perspective on self-regulated learning under the consideration of situative conditions (cf. Section 3.3). It is composed of three different dimensions involving aspects concerned with individuals’ cognitive capabilities (cognitive presence), the openness of communication and level of group cohesion (social presence), and underlying structures and processes related to the design and organization of courses (teaching presence). While each of these presences reflects a distinct dimension of a successful educational experience, overlappings and relationships exist between these dimensions. In constructing an integrative perspective, the three dimensions were assessed and discussed in the context
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of the findings with respect to metacognition (i.e., self-regulated learning), collaborative learning (i.e., online collaborative learning theory), and the situative perspective.

3.4.1. Relevance of Findings

The findings presented in this chapter, in particular with reference to the proposed integrative approach, are fundamental to the conceptualization of socio-cognitive learning designs as well as learning context. The learning context is considered as linking element among socio and cognitive aspects.

RQ 1. What to consider in constructivist learning designs?
The constructivist design perspective as introduced in the previous chapter was extended by the collaborative aspect using online collaborative learning theory. The importance of cognition considering the social dimension was discussed and put into perspective relating to the context as relevant to learning processes.

RQ 2. How to conceptualize learning context?
The situative perspective was introduced as guiding concept between the priorities of social and cognitive perspectives and as means to conceptualize learning context. Considering current research, learning context was argued as separate but, with respect to social and cognitive aspects, governing dimension in the learning process. In particular, aspects concerned with the course design and organization, the facilitation of discourse, and the organization of learning processes are considered relevant.

3.4.2. Outlook

In the following chapters, the findings are used as foundation for the conceptualization, implementation, and evaluation of a tool supporting self-regulated learning under the consideration of situative conditions. Before that, however, the state of the art of e-learning platforms is discussed and presented by reference to the history of development (cf. Chapter 4). Based on both the theoretical findings and the state of the art technology review, the tool is conceptually defined and described in the course of Chapter 5 by means of high-level goals (cf. Section 5.1) as well as the development process and design guidelines (cf. Section 5.2). Both, functional and non-functional requirements are identified and described subsequently (cf. Section 5.3).
4. E-Learning

Due to technological advances, information technology has been considered a relevant constituent in the educational research agenda as early as since the late 1970s (Cox, 2008). The growing availability of personal computers to be used in both formal and information settings, the emergence of the Internet, and the development of generic educational software were the main drivers behind this educational revolution. Since then, different technologies have been tested in the context of the educational domain and adopted to its requirements, ranging from desktop computer and portable devices (e.g., smart phones and tablets) to social media platforms, such as Facebook and Twitter (Cox, 2013). Figure 4.1 gives an overview of the technological developments in the context of the educational domain and shows the timeline between the early 1970s to now.

As already indicated in the timeline of technological developments (cf. Figure 4.1), educational software has become increasingly interactive and embedded. Both, individual and collaborative knowledge generation has been enabled not only due to the technological progress (e.g., mobile technologies), but also through the development of social software environments (e.g., Facebook). In this context, Harasim (2012) propose a more detailed comparison among the different types of e-learning, including online courseware, online distance learning, and online collaborative learning. Most notably, individualized learning, online delivery, and tutor support were replaced by instructed-led online collaborative discourse.
From a cognitive science perspective, e-learning needs to follow several design principles in order to support effective multimedia learning using electronic devices, such as desktop computers, tablets, or smart phones. These principles mainly have been established by Richard E. Mayer, John Sweller, and Roxana Moreno in the context of their work on a theory for e-learning (cf. Clark et al. (2011); Mayer (2009); Mayer & Moreno (2003)). In the course of identifying and designing these principles, their main goal was to minimize extraneous cognitive load, while trying to manage intrinsic and germane load so that learners are best supported. The following 11 principles were empirically established and are associated with e-learning theory:

- **Multimedia Principle.** Learning is facilitated when the relevant content is shown by means of appropriate representations. The main properties of a triangle, for instance, might be easier to grasp and understand when represented graphically instead of being described with words.

- **Modality Principle.** Learning is more effective when content not only is represented as text on the screen, but accompanied by audio narrations also. Some exceptions exist, for instance, when the learner is already familiar with the content or is not a native speaker of the language used in the narrations.

- **Coherence Principle.** Irrelevant or unrelated content, such as videos, graphics, music, and images, should be omitted in order to minimize distractions and therefore cognitive load.
4.1. Towards a New Generation

- **Segmenting Principle.** Learning is more effective when content is segmented into smaller pieces. Long texts, for instance, might be segmented into shorter text passages.

- **Contiguity Principle.** Related information should be presented together. A label, for instance, should be placed close to the figure to which it belongs.

- **Signaling Principle.** Learning is supported when important content is highlighted and is made distinguishable from other parts. The use of arrows or circles, annotations, or pausing in a speech are common methods in order to signal particular importance.

- **Learner Control Principle.** It is of advantage when learners can control the rate at which they learn. In the case of videos, it is important to provide respective functionality, such as play, pause, and fast forward, to the learners so that they can individually adjust the pace in which content is presented to their retentiveness.

- **Personalization Principle.** Learning is more effective when content is presented with a particular focus on aspects related to the social presence. Computer-controlled learning agents (e.g., conversational scripts are presented to the learner in an automated manner) therefore might decrease the effectiveness in learning the content.

- **Pre-training Principle.** Learning is more effective when key concepts and terms are presented prior the actual content (e.g., processes, concepts, etc.). [Mayer et al. (2002)] suggest that learners should build component models (e.g., being able to name and describe the major state changes of each component in a system) before presenting how a system works in terms of its causal effects.

- **Redundancy Principle.** Avoid redundancy by explaining visuals, such as graphics and figures, by either audio narration or on-screen texts.

- **Expertise Principle.** Learners with high prior knowledge may not be supported by the instructional methods used for a specific lessons.

### 4.1. Towards a New Generation

Information technology has been considered a relevant constituent in the educational research agenda as early as since the late 1970s. In particular due to the technological progress, technology-enhanced learning have become increasingly important and effective in both formal and informal settings. Since the
beginning, however, technology-enhanced learning platforms passed through different generations which, according to Laanpere et al. (2013), not only concerned technological aspects, but also the way how learners were using them. In their work on next-generation technology-enhanced learning support, Laanpere et al. (2013) proposed to categorize technology-enhanced tools into three generations by means of four dimensions, including software architecture, pedagogical foundation, content management, and dominant affordances (cf. Table 4.2).

− Software architecture. Due to the technological progress, the software architecture of technology-enhanced learning tools has been changing significantly. Today, based on mobile communication standards, cloud architectures and mobile clients are state of the art and widely available.

− Pedagogical foundation. In terms of the pedagogical foundation, technology-enhanced tools have moved towards a social constructivist perspective. This, in particular, has gone along with the emergence of the Web 2.0, referring to an increased level of interactivity and collaboration.

− Content management. Due to the widespread availability of the Internet, content management has moved towards web-based representations. Instead of being integrated and separated from software in the first and second generation, content now is openly available and embeddable via standards, such as HTML.

− Dominant affordances. In comparison to former affordances, such as presentations, assignments, and discussions, recent technology-enhanced learning tools focus on principles related to reflection, sharing and remixing of content, as well as tagging. This concerns working with content from both an individual and a collaborative perspective.

Table 4.2.: A three-generation perspective on e-learning (Laanpere et al., 2013, p. 94)

<table>
<thead>
<tr>
<th>Dimension</th>
<th>1st Gen.</th>
<th>2nd Gen.</th>
<th>3rd Gen.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software architecture</td>
<td>Desktop software</td>
<td>Single-server monolithic system</td>
<td>Cloud architecture, mobile clients</td>
</tr>
<tr>
<td>Pedagogical foundation</td>
<td>Stimulus-response reinforcement</td>
<td>Pedagogical neutrality</td>
<td>Social constructivism, connectivism</td>
</tr>
</tbody>
</table>

(Continued)

1HTML, short for Hypertext Transfer Markup Language
4.1. Towards a New Generation

Table 4.2.: (Continued)

<table>
<thead>
<tr>
<th>Dimension</th>
<th>1st Gen.</th>
<th>2nd Gen.</th>
<th>3rd Gen.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Content management</td>
<td>Content was</td>
<td>Separated from</td>
<td>Open,</td>
</tr>
<tr>
<td></td>
<td>integrated</td>
<td>software,</td>
<td>web-based,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>re-usable</td>
<td>embeddable</td>
</tr>
<tr>
<td>Dominant affordances</td>
<td>Presentation,</td>
<td>Presentation,</td>
<td>Reflection,</td>
</tr>
<tr>
<td></td>
<td>drill, test</td>
<td>assignments,</td>
<td>sharing, tagging</td>
</tr>
<tr>
<td></td>
<td></td>
<td>discussions</td>
<td></td>
</tr>
</tbody>
</table>

Similar to the three-generation perspective on e-learning proposed by Laanpere et al. (2013), Adams & Morgan (2007) in their work on supporting management soft-skills development introduce key characteristics and design principles of first and second generation e-learning (cf. Table 4.3). They argue that first generation e-learning tends to be “[...] technology-driven and based on an instructor-in-control, compliance learning model” (Adams & Morgan, 2007, p. 164). The second generation e-learning, on the other hand, is based on a learner-in-control model which primarily is focused on practical and performance-oriented learning.

Table 4.3.: A two-generation perspective on e-learning (Adams & Morgan, 2007, p. 162)

<table>
<thead>
<tr>
<th>First Generation</th>
<th>Second Generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology-driven</td>
<td>Pedagogy-driven</td>
</tr>
<tr>
<td>Linear-sequential logic of component parts (i.e., organized)</td>
<td>Holographic-fractal, self-organizing</td>
</tr>
<tr>
<td>Instructor-in-control</td>
<td>Learner-in-control</td>
</tr>
<tr>
<td>Evaluation based on content memorization, repetitive practice and “passing the test”</td>
<td>Evaluation based on self-assessment, reflective practice and successful application</td>
</tr>
<tr>
<td>Engagement – primarily visual, “eye catching”</td>
<td>Engaging through provocation/hooks/ideas</td>
</tr>
<tr>
<td>Separates theory and practice</td>
<td>Integrates theory/practice/work/learning in real-time</td>
</tr>
</tbody>
</table>

(Continued)
Despite the focus on different aspects, both generation models indicate that e-learning now is considered to be more open and participative. In particular due to the development of the Internet and cloud-based architectures, the availability of respective platforms has been increased in the last few years, allowing both stationary and mobile access as well as more participative approaches to learning. E-learning therefore is not only driven by technological developments, but also with respect to pedagogical principles, such as social constructivism, reflective practices, and so forth.

4.2. Mobile Learning

In particular due to the emergence and pervasion of mobile devices, mobile learning has become increasingly popular not only to practitioners but also to research (cf. Korucu & Alkan (2011); Traxler & Kukulska-Hulme (2015)). According to Ally (2009) in his book on transforming the delivery of education and training, mobile learning is defined through the use of wireless technologies which allow access to information and learning artifacts from anywhere and at any time. He also argues that through mobile learning learners would have control of when and from which location they want to learn. In literature, however, there is no single definition on mobile learning, instead further research is required to understand and define the field of mobile learning (Crompton, 2013). In the context of this work, the definition proposed by Crompton (2013, p. 83) is considered sufficient, referring to mobile learning as “learning across multiple contexts, through social and content interactions, using personal electronic devices.” In this regard, context encompasses mobile learning as being “[...] formal, self-directed, and spontaneous learning, as well as [being] context-aware and context-neutral” (Crompton, 2013, p. 82).

In comparison to e-learning, mobile learning offers various differences which have been identified and proposed by Korucu & Alkan (2011). Besides technological differences, such as network capacities and bandwidths, mobile learning in particular fosters spontaneous interactions as well as situated and informal learning. Both, constructivist and collaborative approaches are supported to be implemented. In terms of collaboration, student-to-student as well as
4.3. Summary

In this chapter, technological developments were reviewed in particular with respect to its impact on e-learning. Ranging from real-time interactive computers in the 1970s to the widespread access to wireless technologies and social software environments in the 2000s, technology was one of the main drivers in this regard. During this time, different types of learning emerged, eventually leading to online collaborative learning environments where social interaction is considered important to respective learning processes. The relevance of the cognitive perspective was discussed with respect to the design principles of e-learning tools including, for instance, the coherence of learning artifacts or features allowing the personalization of the learning environment. Based on two generation models, current drivers behind recent developments were introduced, in particular referring to more open and participative approaches with regards to constructivist and collaborative perspectives (cf. Section 4.1). Mobile learning, eventually, was introduced as a relevant concept allowing the access to information and learning artifacts from anywhere and at any time (cf. Section 4.2). Learning in this context, therefore, can be re-conceptualized as “learning across multiple contexts, through social and content interactions, using personal electronic devices” (Crompton 2013, p. 82).

4.3.1. Relevance of Findings

The findings presented in this chapter provide an overview of current e-learning tools with respect to technological developments. In this regard, the following aspects need to be considered during development:

− Autonomy. Today, learning tools need to be available to learners all the time. An web-based architecture therefore is required, allowing time- and place-independent access to information and learning artifacts. External devices (e.g., mobile devices) need to be integrated so as to reduce boundaries and increase accessibility.

− Interactivity. Since e-learning is increasingly collaborative and participative, the underlying technology needs to be sufficiently stable and robust. Adequate response times need to be guaranteed for the purpose of good usability.
Chapter 4.  E-Learning

– Reusability. Due to the collaborative nature, the reusability of learning artifacts is considered crucial in the course of learning processes. Capabilities supporting self-reflective processes as well as sharing and tagging of learning artifacts need to be supported.

4.3.2.  Outlook

The findings presented in this chapter guide the development process with respect to both the AEOLION framework (cf. Chapter 6) and the web-based learning tool Ueber Learn (cf. Chapter 7). In particular related to the autonomy and interactivity of learners as well as the reusability of learning artifacts, respective requirements are identified and defined.
Part II.

Situative Learning Support
**Introduction**

Based on the theoretical findings presented in part Part I of this work, Part II focuses on the conceptualization of a tool supporting self-regulated learning through situative learning support (cf. Chapter 3.2). Development goals and requirements are identified and defined which in further consequence are considered as foundation for development activities associated with both the middleware framework AEOLION (cf. Chapter 6) and the web-based learning tool Ueber Learn (cf. Chapter 7). Figure 4.2 shows the overall context of this second part including the dependencies among the abovementioned chapters. The dotted lines show the relevance of findings from Part I in particular referring to the situative perspective on self-regulated learning (cf. Chapter 3), the constructivist perspective (cf. Section 2.3), and technology-enhanced learning (cf. Chapter 4).

![Figure 4.2.: Overall context of situative learning support](image)

Based on the findings related to constructivist approaches as well as the situative perspective on self-regulated learning, Chapter 5 specifies and defines the tool to be developed based on specific requirements considering both functional and non-functional aspects. Development goals in this context are introduced as high-level communication goals which in further consequence are used to identify and define evaluation criteria for assessing the actual benefit for users. Respective requirements on the development process and design guidelines are specified which, in further consequence, guide the implementation processes of both the middleware framework AEOLION and the web-based learning tool Ueber Learn.
5. Tool Conceptualization

In this chapter, research results presented in Part I are used to derive requirements for a tool supporting situative self-regulated learning. For this purpose, in particular theoretical findings concerned with both the constructivist perspective on learning (cf. Section 2.3) and situative aspects in the context of self-regulation (cf. Section 3) are considered. In Section 5.1, development goals are identified to be used as evaluation criteria for assessing the actual benefit for users and are put into perspective based on the development process and respective design guidelines (cf. Section 5.2). Requirements are derived subsequently, including both functional and non-functional aspects of the tool to be developed (cf. Section 5.3).

5.1. Identification of Goals

Since technology allows for the development of complex web applications, respective processes concerned with the elicitation and analysis of requirements need to be in place. Requirements engineering processes in this regard not only need to consider functional and non-functional requirements, but also have to take into account high-level communication goals (Bolchini & Paolini, 2004). Subsequently, these goals may be used to identify and define evaluation criteria for assessing the actual benefit for users (Bolchini & Paolini, 2004).

In accordance with the goal-driven requirements engineering approach, respective goals are identified based on the results of the literature review presented in Part I. The goals adhere to the three intellectual phases defined in the online collaborative learning theory – idea generating, idea organizing, intellectual convergence – and are conceptualized within the situative perspective considering the cognitive, social, and teaching dimension.

**Generation of ideas (G1)** The first intellectual phase in the online collaborative learning theory is concerned with processes facilitating the generation, verbalization, and sharing of experiences and ideas (i.e., brainstorming). Each learner is encouraged to contribute his or her own ideas on a specific subject or question, which in total makes for a highly collaborative process. Learners, (Harasim, 2012, p. 93) notes, “[...] engage in democratic participation and thereby contribute toward building a large and diverse set of ideas and perspectives.”
Chapter 5. Tool Conceptualization

− **Cognitive Dimension.** Brainstorming is considered mainly a cognitive process (cf. Paulus & Brown (2007); Puntambekar (2006)). “[I]nvolves”, Paulus & Brown (2007, p. 252) states, “both the retrieval of existing knowledge from [long-term memory] and the combination of various aspects of existing knowledge into novel ideas.” Since memory is associative, ideas are processed top to bottom, that is from the most common categories of a given topic to the less common one’s.

− **Social Dimension.** Although processes related to the first intellectual phase are considered mainly cognitive, listening to and engaging with ideas of others potentially offers stimulating effects. According to Paulus & Brown (2007, p. 253), “[ideas] from another group member might spark a good idea from an individual’s less accessible area of knowledge.”

− **Teaching Dimension.** From the perspective of learning structures and processes respectively, the generation of ideas is influenced by contextual factors in that the working environment or the openness of communication is linked to the level of innovation (Paulus & Brown, 2007). In particular at the interface to both the social and cognitive dimension, measures associated with the teaching presence would effect the engagement with participants and content respectively.

Although embedded in the social context, the generation of ideas mainly relates to cognitive processes with regards to the retrieval and combination of existing knowledge (e.g., experiences and ideas). Contextual factors are considered relevant as well and further empower learning processes, for instance with respect to organizational concerns (e.g., pedagogical course design) or the facilitation of discourse.

**Organization of ideas (G2)** The second intellectual phase in the online collaborative learning theory is concerned with processes with respect to the organization of information collected in the preceding phase. Relationships and similarities among ideas are identified in order to eliminate the weaker from the stronger one’s. Ideas therefore converge and become organized in the sense that multiple perspectives get aligned and arranged.

− **Social Dimension.** Creating a shared understanding among learners requires to move from assimilation to construction, that is individuals create new understandings based on collaborative processes with others (Puntambekar (2006)). This is considered as social process in which individual learners adopt various strategies to align divergent ideas or to resolve differences in perception.

− **Teaching Dimension.** The teaching dimension in this phase particularly is considered important as it not only supports learners to structure their
learning processes (e.g., through regulating interactions) but also as it contributes to an engaging setting (e.g., respectful ways of behaving, openness, etc.). Stein et al. (2007, p. 133), for instance, argue that “[... ] learner-moderated chats lead to the space in which cognitive presence develops.”

− **Cognitive Dimension.** Due to the collaborative focus, the cognition in this phase is subordinated to both the social and teaching dimension. Its relevance increases again once a learner provides new inputs (cf. generation of ideas) or the group of learners start to create a shared understanding (cf. intellectual convergence),

The social dimension is considered crucial during this phase. It makes for the alignment of divergent ideas in order to create new understandings among the involved learners. The teaching dimension supports respective processes, in particular with respect to structuring learning processes and contributing to an engaging setting.

**Intellectual convergence (G3)** The third intellectual phase in the online collaborative learning theory is concerned with processes which eventually lead to a shared understanding among learners in terms of both agreeing and disagreeing. According to Harasim (2012, p. 93), “[idea] structuring [...] reaches a level of intellectual synthesis, understanding and consensus [...].” This may be represented as an artifact, such as a solution to a problem, a written report of an assignment or experiment, a publication, or any similar output which is collaboratively created by the learning group.

− **Social Dimension.** Moving from individual perspectives (e.g., experiences, ideas, etc.) to collaborative knowledge building and therefore a shared understanding requires social interactions among the involved learners. According to Puntambekar (2006, p. 332), “[this is] a social process among [learners] who adopt various strategies for resolving differences including asserting dominance, acquiescing, or some form of reciprocal sense making.”

− **Teaching Dimension.** Similar to the previous phase, the teaching dimension in particular supports learners to structure their learning processes as well as contributes to an engaging setting. In addition, however, respective measures are aligned to support the transition from collaborative processes to individual reflection.

− **Cognitive Dimension.** The cognitive dimension as being influenced by both the social and teaching perspective primarily becomes relevant once a shared understanding has been reached among the involved learners (Puntambekar 2006). Reflective processes may be triggered which sub-
Chapter 5. Tool Conceptualization

...sequently lead to conceptual change and an increase of knowledge on the individual level.

The social dimension is considered crucial in the third phase of the online collaborative learning theory. It provides the basis for aligning individual perspectives in order to create a shared understanding among the involved learners. Together with measures associated with the teaching dimension (e.g., scaffolds, guidelines, etc.), it reinforces the cognitive performance of the individual.

5.2. Development Process & Design Guidelines

The development of a web-based learning tool requires respective processes which structure and guide development activities. Schwabe et al. (2012) have identified three different approaches related to the development process of computer-supported collaborative learning environments. The selection of an appropriate process in this regard depends on the usage scenario of the tool and requires to determine if it is used primarily for research or as learning support in real-life scenarios \(^1\), the latter not being relevant in the context of this work.

Learning systems (e.g., specific learning tools or environments) developed for research purposes aim to provide researchers (e.g., computer scientists, educational theorist, psychologists, etc.) with a platform suitable for testing new ideas, graphical interfaces, interaction concepts, and so forth. Both, development and testing processes are tightly coupled, allowing to continuously collect feedback from end users throughout development. A lightweight development process therefore is essential to reduce additional effort with respect to administration and documentation. In this context, Schwabe et al. (2012) differentiates such systems by means of their maturity levels, meaning that the actual requirements depend on whether a system is evaluated only with respect to specific conceptual novelties (proof-of-concept) or as an overall system and the intended value (proof-of-value). While the former allows researchers to exclusively focus on the development and testing of particular features, the latter requires additional effort to ensure that the system under development provides sufficient quality of service, for instance, with respect to stability and functionality. As an example, a proof-of-value system might require the development of features allowing the management of users and their permissions. Requirements on the long-term performance might also be considered more crucial in proof-of-value systems.

\(^1\) According to Schwabe et al. (2012), real-life scenarios imply that the application is deployed in a production environment and used by multiple institutions on a business-critical basis. Non-functional requirements (e.g., stability, security, long-term performance, and maintainability) therefore are considered more important and need to be reflected in the development process accordingly.
Based on the goals and requirements described in Section 5.1 and 5.3, the integration of respective features for the purpose of supporting self-regulated learning does not allow focusing on the evaluation of features isolated from the overall context. Accordingly, the learning tool in terms of functional and non-functional requirements is beyond the scope of a proof-of-concept system. A proof-of-value system is required, involving not only the development of dedicated features but also the provision of support functions, such as an appropriate user and permission management.

From a technological perspective, the tool design is guided by three main principles including (i) the client-server model, (ii) reactive design, and (iii) open application programming interfaces. The first is concerned with the client-server model (cf. Figure 5.1), a software architecture which allows supporting a variety of different scenarios in terms of learning situations ranging from formal to informal settings (cf. Dagger et al. (2007); González-Martínez et al. (2015); Malzahn et al. (2012)). On the server side, a back-end server hosts the data services deployed in the context of the learning tool. Using HTTP as a transmission protocol, clients are able to retrieve data by sending respective HTTP requests to the server. This architecture allows for being independent of the specific technology used at the client side. In addition to the back-end server, a front-end server provides the specific web application developed for supporting self-regulated learning. The front-end server, however, is not responsible for handling data, but only provides the necessary components and layouts for the visualization of data and processing of user inputs. Accessing the tool via the web therefore always involves both the front-end and back-end server, the latter responsible for providing the web application with data.

Figure 5.1.: General architecture of the web-based learning tool

The second principles deals with how the tool is built in terms of handling and processing incoming requests. In this context, the reactive manifesto has been published on September 16, 2014 based on the need of a coherent approach to software architectures that are flexible, loosely-coupled, and scalable. According to Vernon (2015, p. 5), “[t]he manifesto addresses the problem with existing enterprise and web applications that are generally single-threaded, [in that it] is meant to help bridge the gap between current, typical single-threaded thinking, introducing those to the need to scale using a reactive, event-driven

\[\text{For detailed information on the reactive manifesto see } \text{http://www.reactivemanifesto.org (accessed on August 8, 2016.)}\]
Chapter 5. Tool Conceptualization

approach to software development." The term reactive can be detailed by the following properties (cf. Vernon (2015):

- **React to the users and other components.** Systems and their components only react to requests from users or other components.

- **React to failure.** Systems and their components are able to react to and recover from failure.

- **React to load.** Systems and their components are able to react to varying work loads which allow for high elasticity and throughput.

- **React to messages.** Systems and their components are message-driven, meaning that asynchronous message-passing is the principle design philosophy.

The manifesto specifies four design principles which large systems should considered (cf. Figure 5.2). These principles are concerned with describing systems as being **responsive**, **resilient**, **elastic**, and **message-driven**. In this context, building responsive applications is the ultimate goal which relies on applications being both scalable and resilient. Message-driven architectures provide the basis for scalable and resilient, and therefore responsive applications.

- **Responsive.** The system is capable of being responsive irrespective of the current system load. This ensures a consistent quality of service and usability for the end user. According to Vernon (2015, p. 6), “[t]his includes real-time user interfaces that allow for overlapping edits by multiple users simultaneously.” From an implementation perspective, responsiveness can be achieved by observable models using event streams.

- **Resilient.** Systems are resilient when they are able to automatically recover from failure. This typically involves measures such as replication, containment, isolation, and delegation. Recovery procedures are delegated to other components responsible for ensuring availability.

- **Elastic.** Systems are able to handle varying workloads by automatically increasing or decreasing the amount of allocated resources, such as memory or computation time. This requires systems to be designed in such a way that they can shard or replicate components for the purpose of distributing input.

- **Message-driven.** Asynchronous message-passing allows system components to be loosely coupled ensuring isolation and location transparency, even in the case of an error. Monitoring and manipulating message queues enables load management, elasticity, and flow control.
5.3. Requirements Analysis

Development goals (cf. Section 5.1) have been identified and put into perspective based on the development process and design guidelines (cf. Section 5.2). In order to conceptualize a web-based learning tool supporting situative self-regulated learning, however, specific requirements need to be derived covering the relevant features of the tool (cf. Bolchini & Paolini (2004)). In this section, the respective requirements are illustrated including both functional and non-functional aspects.

The conceptual design of the learning tool (cf. Figure 5.3) primarily is based on the concept of workspaces which follow the room metaphor proposed by Greenberg & Roseman (2003). It allows learners to gather together in a shared but separated space which contains a number of artifacts used for various learning purposes (e.g., resources, interaction spaces, etc.). According to Haake et al. (2004), not only learning materials (e.g., documents, resources, etc.) but also tools supporting the interaction of learners (e.g., chats) or the awareness (e.g., notification mechanisms) would be considered as such artifacts. Both, tool-specific interactions as well as interactions on Facebook are provided as bidirectional communication channels. An email-based notification system offers additional support in terms of user awareness. Finally, respective management functionalities (resource and document manager) allow administrating documents and resources beyond their scope, i.e. the workspace.
5.3.1. Functional Specification

In this section, the functional requirements of the learning tool are discussed. The primary focus here is on functional requirements which are specific to the functionality required by the case of application. Additional requirements, such as those essential to the implementation of a proof-of-value system, are not discussed explicitly, but are included in the individual specifications. For presentation purposes, the requirements are bundled into 9 sets of features which include resource management [R], document management [D], typecasting of content [T], interaction management [I], constant update of interaction threads [C], interaction of Facebook [FB], sharing of information [S], workspace management [W], and e-Mail notification [M].

Each requirement bundle is introduced based on its general purpose and further detailed by means of its specific features that need to be supported in the case of application. Each requirement additionally is reasoned by further research and considered from the three main dimensions, namely the cognitive, teaching, and social dimension. The relevance with regards to the online collaborative learning theory, that is the three intellectual phases, finally is discussed for the purpose of justification.

**Resource management [R]** The learning tool should provide features which allow the management of static resources, such as PDF documents, ZIP files, MS Word documents, and so forth.
R1. *List/Access existing resource(s).* Users should be able to list and access static resources at a designated page provided by the learning tool. Resources are listed only if the respective user holds the required access privileges.

R2. *Upload a new resource.* Users should be able to upload new resources at any time when using the learning tool.

R3. *Update the name of a resource.* Users should be able to update the name of the resource at any time when using the learning tool. The name of a resource can only be updated if the respective user holds the required access privileges.

R4. *Replace existing resource.* Users should be able to replace existing resources with a new resource. Existing resource can only be replaced if the respective user holds the required access privileges.

Content and respective management functionalities are considered a crucial aspect of learning tools and platforms (cf. Dagger et al. [2007]; Ismail [2001]). In particular when delivered as a web application, content can be created and authored in a collaborative manner irrespective of time and place. According to Ismail [2001], in particular capturing and structuring knowledge, incorporating third-party content and the utilization is key to respective processes. In the context of the learning tool, however resource management capabilities are considered more static since editing and authoring functionalities are limited to updating resources’ meta data or replacing resources as a whole respectively. The relevance in terms of the different perspectives can be illustrated as follows:

- **Cognitive dimension.** In particular with respect to the cognitive dimension, resource management capabilities support learners to share ideas in the collaborative context, i.e. in the learning group.

- **Teaching dimension.** The teaching dimension is not directly concerned as associated features primarily address general management capabilities, such as uploading resources and manipulating meta data. Pedagogical measures, like the integration of resources into specific working contexts, become visible when organized by means of workspaces (cf. [W]).

- **Social dimension.** The social dimension at this point in time is not addressed directly, but in further consequence uses resources as the general basis of social interaction, e.g. discussion on specific topics.

\(^{3}\)More flexibility in terms of editing and authoring functionalities are provided by documents which are introduced in the course of the requirement concerned with the management of documents (cf. R2)
Chapter 5. Tool Conceptualization

In terms of the three intellectual phases defined in the online collaborative learning theory, resource management capabilities in particular are related to the first phase concerned with the generation of ideas. During this phase, learners are supported in articulating and sharing ideas on specific subject using resources as potential form of representation. Documented ideas in the following serve as a basis for processes concerned with the organization of ideas.

Document management [D] The learning tool should provide features which allow the management of interactive documents. In contrast to static resources, interactive documents allow providing a more powerful set of features with respect to learning support functions.

D1. List/Access existing document(s). Users should be able to list and access interactive documents at a designated page provided by the learning tool. Documents are listed only if the respective user holds the required access privileges.

D2. Create a new document. Users should be able to create new interactive documents at any time when using the learning tool.

D3. Update the title of a document. Users should be able to update the title of a document at any time when using the learning tool. The title of a document can only be updated if the respective user holds the required access privileges.

D4. Update the content of a document. Users should be able to update the content of a document at any time when using the learning tool. The content of a document can only be updated if the respective user holds the required access privileges.

As already addressed in the context of resource management capabilities, document management is considered a relevant aspect of learning tools and platforms as well (cf. Dagger et al. (2007); Ismail (2001); Mendoza et al. (2014)). In contrast to resource management, however, editing and authoring capabilities, such as structuring and annotating content, are more advanced when used in the context of documents. The proposed set of features in particular meets the requirements proposed by Ismail (2001) addressing content development processes where more than one learner is involved. The relevance in terms of the different perspectives, particularly in distinction to resource management capabilities, can be illustrated as follows:

− Cognitive dimension. Similar to resource management, document management capabilities support learners to share ideas in the collaborative context, i.e. in the learning group. Learners, however, are provided with
more advanced features (i.e., web-based editor) when it comes to authoring capabilities, such as structuring the content by means of pedagogical elements and so forth.

− Teaching dimension. The teaching dimension is reflected to the extent that documents can be structured individually using web-based authoring capabilities, such as putting together blocks of content using hierarchical structures and so forth. Further pedagogical measures, such as annotating blocks of content or integrating documents into specific working contexts, are addressed in the following (cf. R3 and R8).

− Social dimension. The social dimension is not directly concerned by document management capabilities. In further consequence, however, documents serve as a basis for social interaction, such as the discussion on specific topics.

Document management capabilities, in particular, are concerned with the first two phases of the online collaborative learning theory, that is idea generation and organization. During idea generation, learners are supported in articulating and sharing ideas on specific subjects using documents as potential form of representation. Documented ideas in the following serve as a basis for further organizational processes in order to eventually achieve intellectual convergence.

Typecasting of content [T] In order to make the structure of content explicitly visible to users, the learning tool should allow typecasting the content which is made available, for instance, through interactive documents. Typecasting refers to a way of enriching specific parts of a document with additional information, such as further information on the structure or type of content blocks. Lecture notes, for instance, may be annotated with typecasts distinguishing between the introductory part (e.g., motivational part), the main part (e.g., content), and further information (e.g., literature or examples).

T1. Typecast the content of a document. Users should be able to annotate documents by typecasting specific parts of the content. Documents can only be annotated if the respective user holds the required access privileges.

T2. Change presentation mode of a document based on typecasts. Users should be able to change the mode of presentation of a document based on specific typecasts. A document, for instance, may be presented as a whole or based on a selected set of typecasts (e.g., only explanations).

Providing adaptive support for learners while using interactive documents has been recognized as relevant to learning processes in the literature (cf. Furlinger).
Chapter 5. Tool Conceptualization

et al. (2004); Mwanza & Engeström (2005); Šimko et al. (2010)). According to Šimko et al. (2010, p. 368), it has become crucial “[…] to be able to support students in their way through the course, to locate, recognize, and understand information, which is the most relevant, considering the given time and progress of the student.” One potential approach in this context is to enrich documents by means of annotations (e.g., pedagogical elements, classifications, etc.), which further divide documents into types including, for instance, explanation, question, or exercise. The proposed set of features not only allows to enrich documents by means of specific typecasts, but also uses them to adapt the mode of presentation according to current learning needs. The relevance in terms of the different perspectives can be illustrated as follows:

− **Cognitive dimension.** The typecasting of content in particular serves the individual in terms of providing cognitive support in the learning process. Learners may not only rely on the inherent structure of documents, but may also experience support in terms of navigation and orientation.

− **Teaching dimension.** Used as pedagogical measure, more experienced learners may support others by enriching documents based on typecasts. This, for instance, allows tagging specific content blocks of a document as examples.

− **Social dimension.** The social dimension is not directly concerned by this set of features, but may benefit from enriched documents in that collaboratively working with content is supported.

The typecasting of content, in particular, is concerned during idea generation and organization. During the first phase, it primarily supports the structuring of documents, that is providing additional information on the content of documents apart from the inherent structure, such as the hierarchical arrangement of sections (i.e., level of headings). During the second phase, the primary purpose of use shifts towards collaborative support in the course of organizing the different ideas. It becomes more of a social tool supporting collaborative processes which eventually lead to intellectual convergence.

**Interaction management [I]** The learning tool should provide features which allow managing interactions among selected users. Interactions therefore should provide designated areas where users can asynchronously interact with each other by publishing posts on their opinions to a specific topic or question.

II. **List/Access existing interaction(s).** Users should be able to list and access interactions at a designated page provided by the learning tool. Interactions are listed only if the respective user holds the required access privileges.
5.3. Requirements Analysis

I2. *Create a new interaction.* Users should be able to create new interactions at any time when using the learning tool.

I3. *Update the title of an interaction.* Users should be able to update the title of an interaction at any time when using the learning tool. The title of an interaction can only be updated if the respective user holds the required access privileges.

I4. *Manage the participants of an interaction.* Users should be able to manage the participants of an interaction, that is invite participants for discussion. The participants of an interaction can only be managed if the respective user holds the required access privileges.

I5. *Publish a post in an interaction.* Users should be able to publish a post in an interaction. A post can only be published in an interaction if the respective user holds the required access privileges.

I6. *Archive a post contained in an interaction.* Users should be able to archive a post contained in an interaction. A post can only be archived if the respective user holds the required access privileges.

Features supporting collaborative work and therefore social interaction is inherent to collaborative learning environments and need to be considered as an integral part (cf. Zhang et al. [2005a,b]). According to Zhang et al. [2005a], social interaction consists of three phases which involve aspects concerned with encounter, communication, and collaboration. In the first phase, the interacting learners get together in the form of groups, meaning that the right communication partners are selected and invited for participation. In the second phase, actual communication processes are performed with the aid of respective tools, such as instant messengers, chats, or forums. Finally, in the third phase, the interacting learners collaborate in the sense that, for instance, ideas are shared and discussed. The propose set of features primarily supports the first two phases, that is the encounter and communication phase. Collaborative activities are support as well but are specifically addressed by the requirement on sharing of information [S].

- *Cognitive dimension.* The cognitive dimension is not directly concerned since interaction management capabilities primarily focus on providing collaboration support. In the contrary, however, cognitive aspects may support and initiate social discourse.

- *Teaching dimension.* Interaction management capabilities do not inherently address the teaching dimension, but provide the right context to guide learning processes. This, for instance, may be accomplished through providing scaffolds in the form of content-related notes or suggestions.
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− Social dimension. The social dimension is directly addressed by interaction management capabilities which facilitate the engagement and collaborative processes among learners.

Interaction management capabilities are considered relevant throughout all phases of the online collaborative learning theory. During the generation of ideas, however, the proposed features are most useful since they allow articulating experiences and ideas. This primarily matches the first two phases of social interaction, that is encounter and communication. More advanced concepts required for collaborative activities, such as the sharing of ideas among different groups of learners, are not discussed here, but are addressed by the requirement on sharing of information [S].

Constant update of interaction threads [C] The learning tool should provide features which allow reducing users’ effort required for interacting with other users.

C1. Automatically reload an interaction thread. Users should be able to see new posts immediately without having to reload the entire interaction thread.

The effects of asynchronous and synchronous communication tools already have been studied extensively in the past (cf. Dennis et al. (2008); Schwarz & Asterhan (2011); Spencer & Hiltz (2003)). Only recently, research has started to investigate pedagogical outcomes when synchronous and asynchronous communication tools are applied in an integrative manner. Oztok et al. (2013), for instance, explore asynchronous and synchronous tool use in online courses, finding that the convergence of both modes of communication offers potential benefits to the learners, but must be considered carefully with respect to privacy concerns and quality of notes with regards to reading ease, academic content, and social processes. Since respective features, such as the management of participants, is already concerned by the requirement on interaction management [I], the constant update of interaction threads only needs to be considered as enhancement with respect to the level of synchronicity supported by the learning tool.

− Cognitive dimension. The cognitive dimension is not affected by the constant update of interaction threads.

− Teaching dimension. The teaching dimension is not affected by the constant update of interaction threads.

− Social dimension. The social dimension is addressed since the constant update of interaction threads improves the user awareness in the context of specific interactions. In particular, this is accomplished as interactions
5.3. Requirements Analysis

...do not need to be reloaded by the user (e.g., through refreshing the web page).

The constant update of interaction threads is considered relevant throughout all phases of the online collaborative learning theory in particular, however, during idea generation and organization. During these phases, social interaction is crucial since ideas are gather and begin to converge due to the identification of relationships and similarities.

Integration of Facebook [FB] The learning tool should provide possibilities for users to support their learning processes by integrating content from Facebook.

FB1. **Login using a user’s Facebook account.** Users should be able to authenticate by using their Facebook credentials.

FB2. **List Facebook groups.** Users should be able to list groups available on Facebook by using the learning tool. Groups are listed only if the respective user holds the required access privileges, both, granted by the learning tool and Facebook.

Facebook not only is one of the most popular social networking sites, but also supports the connection among individuals and the formation of groups by providing easy and intuitive features for interaction and sharing (Lin et al., 2013). In the education domain, it is considered a potential tool for supporting learning processes in terms of course management and communication. Tess (2013), for instance, note growing interest in the investigation of social media in the learning domain, in particular as it may function as a facilitator and enhancer of learning. The proposed set of features follows this notion and not only supports basic authentication via Facebook, but also the integration of content (i.e., postings in the course of threads) and its further use which is specifically addressed by the requirement on sharing of information [S].

- **Cognitive dimension.** The cognitive dimension is not affected by the integration of Facebook.

- **Teaching dimension.** The integration of Facebook does not inherently address the teaching dimension but, similar to interaction management capabilities, offers options to provide scaffolds in the form of, for instance, content-related notes.

- **Social dimension.** The social dimension is addressed by the integration of Facebook since it not only supports the connection among individuals, but particularly allows the formation of groups by providing respective collaboration features which are easy to use and intuitive.
Chapter 5. Tool Conceptualization

Similar to the management of interactions, the integration of Facebook particularly addresses the generation of ideas. Features provided using Facebook primarily match the first two phases of social interaction, that is encounter and communication (cf. Zhang et al. (2005b)). More advanced features required for collaborative activities, such as the sharing of ideas among different groups of learners, are not discussed here, but are addressed by the requirement on sharing of information [S].

Sharing of information [S]  The learning tool should provide features which allow sharing posts between interactions, both, available via the learning tool and Facebook.

S1. Republish an existing post in another interaction. Users should be able to republish an existing post in another interaction. A post can only be republished in another interaction if the respective user holds the required access privileges.

S2. Republish an existing post on Facebook. Users should be able to republish an existing post on Facebook. A post can only be republished on Facebook if the respective user holds the required access privileges.

S3. Republish an existing post on Facebook in another interaction. Users should be able to republish an existing post on Facebook in another interaction. A post on Facebook can only be republished in another interaction if the respective user holds the required access privileges.

Taking notes is considered helpful in learning processes, in particular when used in collaborative settings as means to making individual knowledge available to other learners or learning groups (cf. Marshall & Brush (2004)). For instance, Atrash et al. (2015b, p. 1262) note that “[...] taking notes [...] motivates the individual’s ability to learn which in turn enhances the collaborative learning process.” However, despite recognized benefits (Atrash et al. 2015a), such as increased attention or more encouraged discussions, current tools and platforms only provide limited support in terms of sharing notes (cf. Atrash et al. (2015a,b); Yang et al. (2004)). The propose set of features addresses these benefits and allows sharing of contributions (e.g., posts in an interaction or on Facebook) with selected learners or learning groups. Privacy, as important to maintain social presence (Tu, 2000), is ensured as the individual learners can define the target group, that is the participants of each interaction (cf. [I]).

– Cognitive dimension. Since note taking (e.g., writing a post) is already addressed by the requirement on interaction management [I], this set of features not directly is concerned with the cognitive dimension.

– Teaching dimension. The sharing of information does not inherently ad-
dress the teaching dimension, but offers options to guide interactions by sharing particular posts at a definite time.

— *Social dimension.* The social dimension is addressed as collaborative note taking (e.g., in the form of posts) is considered to encourage discussion among learners. Atrash et al. [2015b] note that the knowledge value of each note is accumulated when being shared.

With respect to the different phases of social interaction proposed by Zhang et al. [2005b], the sharing of notes (e.g., through posts) is considered particularly relevant for collaboration, that is after the phases encounter communication. In terms of the online collaborative learning theory, this mainly matches the second phase in the course of which ideas are organized in a collaborative manner.

**Workspace management [W]** The learning tool should provide features which allow managing workspaces including their configurations in terms of assigned resources, materials, and interactions.

W1. *List/Access existing workspace(s).* Users should be able to list and access workspaces at a designated page provided by the learning tool. Workspaces are listed only if the respective user holds the required access privileges.

W2. *Create a new workspace.* Users should be able to create new workspaces at any time when using the learning tool. New workspaces can only be created if the respective user holds the required access privileges.

W3. *Update the availability of a workspace.* Users should be able to update the availability of a workspace at any time using the learning tool. The availability of a workspace can only be updated if the respective user holds the required access privileges.

W4. *Manage the participants of a workspace.* Users should be able to update the access privileges of a workspace at any time using the learning tool. The access privileges of a workspace can only be updated if the respective user holds the required access privileges.

W5. *Associate an existing document with a workspace.* Users should be able to associate an existing document with a workspace. An existing document can only be associated with an existing workspace if the respective user holds the required access privileges.

W6. *Disassociate an existing document from a workspace.* Users should be able to disassociate an existing document from a workspace. An existing
document can only be disassociated from a workspace if the respective user holds the required access privileges.

W7. *Associate an existing resource with a workspace.* Users should be able to associate an existing resource with a workspace. An existing resource can only be associated with a workspace if the respective user holds the required access privileges.

W8. *Disassociate an existing resource from a workspace.* Users should be able to disassociate an existing resource from a workspace. An existing resource can only be disassociated from a workspace if the respective user holds the required access privileges.

W9. *Add a new interaction to a workspace.* Users should be able to add a new interaction to a workspace. An interaction can be only added to a workspace if the respective user holds the required access privileges.

W10. *List posts published in groups on Facebook.* Users should be able to access posts which have been published in groups on Facebook. Posts are listed only if the respective user holds the required access privileges on both the learning tool and Facebook.

W11. *Tag an existing post as content.* Users should be able to tag an existing post in order to mark its content as qualitatively valuable. A post can only be tagged if the respective user holds the required access privileges.

Project-based learning is a method in which learners engage in authentic, real-life problems for the purpose of knowledge building (cf. Rahimi et al. (2014); Tambouris et al. (2014)). According to Rahimi et al. (2014), project-based learning not only supports knowledge building and higher-level cognitive activities through engaging in complex problems, but also the development of social and metacognitive skills (e.g., decision making, selection of learning strategies, etc.) due to the design and implementation of projects. Since learners typically are involved in multiple projects at the same time, appropriate management capabilities need to be in place and provided by the learning tool. Separate spaces (i.e., workspace) therefore are required to ensure consistency within the individual projects, each of which provides an integrated set of features supporting both individual and collaborative activities in the context of the respective project (cf. Hou et al. (2007)). The proposed set of features addresses the requirements raised by the project-based learning approach and integrates features, such as interaction, document, and resource management (cf. [R], [D], [I], etc.).

− *Cognitive dimension.* The cognitive dimension is concerned by individual requirements, such as the management of resources and documents.
5.3. Requirements Analysis

− **Teaching dimension.** The management of workspaces, in particular, addresses the teaching dimension as it allows organizing individual or collaborative activities by means of separate spaces (i.e., workspaces).

− **Social dimension.** The social dimension is concerned by individual requirements, such as the management of interactions or the integration of Facebook.

From the perspective of the online collaborative learning theory, the management of workspaces encompass all three phases from idea generation to intellectual convergence. As a means for structuring and organizing individual and collaborative activities, it not only allows the formation of learning groups but also the individual setup in terms of features according to project needs.

**E-Mail notification [M]** The learning tool should proactively notify users about updates concerning interaction threads and workspaces. In doing so, users are kept up to date without having them to constantly check for new content provided by the learning tool.

M1. **Notify users about new posts.** Users should be notified about new posts which have been published in interactions. Notifications are sent only if the respective user is register as participant of the interaction.

M2. **Notify users about new workspaces.** Users should be notified about new workspaces. Notifications are sent only if the respective user is registered as team member of the workspace.

Group awareness is an important aspect to be considered in collaborative activities, such as in project-based learning. Notification systems, for instance, are one potential approach to increase group awareness as they typically enrich the “[…] display areas outside the primary application window(s) and help to keep people aware of events beyond their current task-oriented interactions” [Carroll et al. (2003) p. 606]. The proposed set of features address this issue by means of providing an additional communication channel (i.e., email) that keeps learners up to date with respect to specific changes.

− **Cognitive dimension.** The cognitive dimension is not affected by the notification mechanism.

− **Teaching dimension.** The cognitive dimension is not affected by the notification mechanism.

− **Social dimension.** The social dimension is addressed by the notification mechanism since it allows increasing social awareness. Learners receive notifications concerning changes (e.g., a new posting was published in the
context of a specific project) and can directly access the respective part in the learning tool.

The notification mechanism is considered relevant throughout all phases of the online collaborative learning theory in particular, however, during idea generation and organization. During these phases, social awareness is important towards intellectual convergence and may be increased by proactively notifying learners on changes, such as new posting in the context of specific projects.

5.3.2. Non-functional Specification

In this section, the non-functional requirements\(^4\) of the proposed learning tool are presented and include the extensibility, the ability to integrate, as well as the reusability of content. The primary focus here is on those non-functional requirements which are considered most relevant to the case of application in the context of proof-of-value system. Others, such as scalability and availability, are out of scope of this work and become critically relevant not until the tool is deployed in production environments.

**Extensibility [NF:E]** In order to allow the continuous development of the learning tool (i.e., short iteration cycles), extensibility as an inherent property is considered crucial. Extensibility in this context includes the following aspects:

- The learning tool should support the continuous development by providing a basic set of features (e.g., authentication, permission management, and so forth) which remains consistent across all functional groups.

- Existing artifacts (e.g., specific posts, interactions, content) should be available to be used in contexts and usage scenarios other than the one’s in which they have been created initially. This should allow using artifacts in newly developed features without limiting their prior deployment and application.

**Integration Ability [NF:I]** The learning tool should be responsible to different contexts and usage scenarios. The ability to integrate in this context differs from the extensibility of the learning tool, as it includes the following aspects:

\(^4\)Although there is no consistent definition on non-functional requirements in the literature, common characteristics among the different conceptions exist (cf. Chung & Do Prado Leite (2009)). In the context of this thesis, non-functional requirements are concerned with how the systems works in terms of, for instance, performance requirements, external interface requirements, design constraints, and software quality attributes.
5.3. Requirements Analysis

− The learning tool should support the adaptation to different contexts and usage scenarios by using a common service infrastructure. This, for instance, would allow using the learning tool not only in stationary settings (e.g., in front of a desktop computer), but also in a mobile manner (e.g., using a smart phone) or customized for specific operational scenarios (e.g., focused on the interaction among users or authoring of content).

− The learning tool should allow the integration of other tools and services in order to support users by providing a wide range of different features. It should allow users to individually setup their learning tool according to their specific needs.

Reusability of content [NF:R] The learning tool should provide appropriate mechanisms supporting the reusability of content across different contexts and usage scenarios. The reusability of content in this contexts includes the following aspects:

− The learning tool should provide a common service infrastructure supporting the reuse of learning artifacts by means of an interoperable interchange and representation format.

− The learning tool should allow embedding and extending existing learning artifacts in contexts and usage scenarios other than the one’s in which they have been created initially.

5.3.3. Relationship Structure

So far, requirements on the learning tool have been described independently of each other, that is each requirement was defined based on its individual functionality only. Existing dependencies among requirements, therefore, have not been illustrated which additionally impairs the traceability and thus the evaluation. In this section, therefore, the requirements are presented in a traceability matrix (cf. Table 5.1) in which requirements are illustrated with respect to respective preconditions (i.e., dependencies) as well as permission structure, the latter defining read [R] and/or write [W] permission requirements.
<table>
<thead>
<tr>
<th>ID</th>
<th>Name</th>
<th>Precond.</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>List/Access existing resource(s)</td>
<td>-</td>
<td>[R—W] required</td>
</tr>
<tr>
<td>R2</td>
<td>Upload a new resource</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R3</td>
<td>Update the name of a resource</td>
<td>R1 R2</td>
<td>[W] required</td>
</tr>
<tr>
<td>R4</td>
<td>Replace existing resource</td>
<td>R1 R2</td>
<td>[W] required</td>
</tr>
<tr>
<td>D1</td>
<td>List/Access existing document(s)</td>
<td>-</td>
<td>[R—W] required</td>
</tr>
<tr>
<td>D2</td>
<td>Create a new document</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D3</td>
<td>Update the title of a document</td>
<td>D1 D2</td>
<td>[W] required</td>
</tr>
<tr>
<td>D4</td>
<td>Update the content of a document</td>
<td>D1 D2</td>
<td>[W] required</td>
</tr>
<tr>
<td>T1</td>
<td>Typecast the content of a document</td>
<td>D1 D2 D4</td>
<td>[W] required</td>
</tr>
<tr>
<td>T2</td>
<td>Change presentation mode of a document</td>
<td></td>
<td>[R—W] required</td>
</tr>
<tr>
<td></td>
<td>based on typecasts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I1</td>
<td>List/Access existing interaction(s)</td>
<td>-</td>
<td>[R—W] required</td>
</tr>
<tr>
<td>I2</td>
<td>Create a new interaction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I3</td>
<td>Update the title of an interaction</td>
<td>I1 I2</td>
<td>[W] required</td>
</tr>
<tr>
<td>I4</td>
<td>Manage the participants of an interaction</td>
<td>I1 I2</td>
<td>[W] required</td>
</tr>
<tr>
<td>I5</td>
<td>Publish a post in an interaction</td>
<td>I1 I2</td>
<td>[R—W] on interaction required</td>
</tr>
<tr>
<td>ID</td>
<td>Name</td>
<td>Precond.</td>
<td>Comments</td>
</tr>
<tr>
<td>----</td>
<td>--------------------------------------------------</td>
<td>----------</td>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>I6</td>
<td>Archive a post contained in an interaction</td>
<td>I1 I2</td>
<td>[W] on post required, [R—W] on interaction</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>required</td>
</tr>
<tr>
<td>C1</td>
<td>Automatically reload interaction threads</td>
<td>I1 I2</td>
<td>[R—W] on interaction required</td>
</tr>
<tr>
<td>FB1</td>
<td>Login using a user’s Facebook account</td>
<td>FB1</td>
<td>active account on Facebook required</td>
</tr>
<tr>
<td>FB2</td>
<td>List Facebook groups</td>
<td></td>
<td>group membership required</td>
</tr>
<tr>
<td>S1</td>
<td>Republish an existing post in another interaction</td>
<td>I1 I2 I5</td>
<td>[W] on post required, [R—W] on interaction</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>required</td>
</tr>
<tr>
<td>S2</td>
<td>Republish an existing post on Facebook</td>
<td>FB1 FB2 I1 I2</td>
<td>[W] on post required, [R—W] on interaction</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>required</td>
</tr>
<tr>
<td>S3</td>
<td>Republish an existing post on Facebook in another interaction</td>
<td>FB1 FB2 I1 I2</td>
<td>group membership on Facebook required, [R—W] on interaction required</td>
</tr>
<tr>
<td>W1</td>
<td>List/Access existing workspace(s)</td>
<td>-</td>
<td>[R—W] required</td>
</tr>
<tr>
<td>W2</td>
<td>Create a new workspace</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>W3</td>
<td>Update the availability of a workspace</td>
<td>W1 W2</td>
<td>[W] required</td>
</tr>
<tr>
<td>W4</td>
<td>Manage the participants of a workspace</td>
<td>W1 W2</td>
<td>[W] required</td>
</tr>
<tr>
<td>W5</td>
<td>Associate an existing document with a workspace</td>
<td>W1 W2 D1 D2</td>
<td>[W] on workspace and document required</td>
</tr>
</tbody>
</table>

(Continued)
<table>
<thead>
<tr>
<th>ID</th>
<th>Name</th>
<th>Precond.</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>W6</td>
<td>Disassociate an existing document from a workspace</td>
<td>W1 W2</td>
<td>[W] on workspace and document required</td>
</tr>
<tr>
<td>W7</td>
<td>Associate an existing resource with a workspace</td>
<td>W1 W2</td>
<td>[W] on workspace and resource required</td>
</tr>
<tr>
<td>W8</td>
<td>Disassociate an exiting resource from a workspace</td>
<td>W1 W2</td>
<td>[W] on workspace and resource required</td>
</tr>
<tr>
<td>W9</td>
<td>Add a new interaction to a workspace</td>
<td>W1 W2</td>
<td>[R—W] on workspace required</td>
</tr>
<tr>
<td>W10</td>
<td>List posts published in groups on Facebook</td>
<td>W1 W2</td>
<td>[R—W] on workspace required</td>
</tr>
<tr>
<td>W11</td>
<td>Tag an existing post as content</td>
<td>W1 W2 I1 I2 I5 D1 D2 D4</td>
<td>[W] on workspace required, [R—W] on interaction required</td>
</tr>
<tr>
<td>M1</td>
<td>Notify users about new posts</td>
<td>I2 I5</td>
<td>[R—W] on interaction required</td>
</tr>
<tr>
<td>M2</td>
<td>Notify users about new workspaces</td>
<td>W2</td>
<td>[R—W] on workspace required</td>
</tr>
</tbody>
</table>
5.4. Summary

In this chapter, development goals were identified with regards to the theoretical findings (cf. Part I) and put into perspective based on the development process and respective design guidelines (cf. Section 5.2). On this basis, requirements including functional and non-functional aspects were identified and described by means of 9 requirement bundles (cf. Section 5.3).

- **Functional requirements.** Resource management, document management, typecasting of content, interaction management, constant update of interaction threads, integration of Facebook, sharing of information, workspace management, and e-mail notification

- **Non-functional requirements.** Extensibility, integration ability, and reusability of content

Since the proposed tool is to be evaluated as overall system (proof-of-value), the identified requirements only address the most crucial ones with respect to the learning processes to be supported. This means that additional programming effort is required to ensure that the tool under development provides sufficient quality of service with respect to, for instance, the management of users and permissions.

5.4.1. Relevance of Findings

The findings presented in this chapter conceptualize a tool for supporting situative self-regulated learning. Both, development goals and specific requirements were defined, which provide the basis for the technical analysis and empirical studies respectively.

**RQ 3. How to operationalize an integrated learning design?**

Based on the findings on the socio-cognitive design of learning processes considering the context, the basis conditions for the implementation of a tool supporting situative self-regulated learning were set in this chapter. While development goals and design guidelines provide the foundation on a goal-level, specific requirements including functional and non-functional aspects operationalize a respective tool in this context.

5.4.2. Outlook

In the following chapters (cf. Chapters 6 and 7), both functional and non-functional requirements are used as foundation for the development of the AE-
Chapter 5. Tool Conceptualization

OLION framework as well as the web-based learning application Ueber Learn. Constraints introduced with respect to the development process and design guidelines (cf. Section 5.2) provide respective parameters for the actual implementation process. In terms of the evaluation of the web-based learning tool (cf. Part 11), the requirements are used as input for the technical analysis, that is the review for completeness (cf. Chapter 8). The development goals eventually become relevant in the context of the empirical evaluation, in particular concerned with the validation of requirements and the assessment of the actual benefit for users (cf. Chapter 9).
6. Enabling Middleware Framework

Both, the design principles and the requirements introduced in Chapter 5 provide the basic foundations for the design and development of the AEOLION middleware framework in this chapter. AEOLION is an acronym which stands for Articulation Engineered Organizational Learning In Open Networks and refers to a set of technologies combined to support organizational learning processes in flexible and interoperable environments.

AEOLION is located on the server side and is responsible for hosting the data services deployed for the purpose of supporting situative learning (cf. Figure 6.1). The middleware framework handles and processes data requests received from the user interacting with any kind of front-end application (e.g., web-based learning tool). An appropriate architecture therefore needs to be in place which not only provides the required functionality, but stays responsive under varying work loads. The reactive manifesto introduced as part of the development process and design guidelines provides respective conditions. The manifesto describes specific design guidelines, however, does not give any indications for specific technologies which are capable of meeting these requirements.

![Diagram of AEOLION Framework](image)

Figure 6.1.: The middleware framework AEOLION in the context of the general architecture of the learning tool

In this chapter, AEOLION is presented with respect to its technological foundations (cf. Section 6.1) as well as its functional capabilities (cf. Sections 6.2 and 6.3). Section 6.2 in particular focuses on the middleware framework and its support for flexible application development, referring to the actor-based design approach, the service specification mechanism, and the unified endpoint architecture. Section 6.3 then introduces a specific service choreography aligned with the requirements identified and presented in Section 6.3.
Chapter 6. Enabling Middleware Framework

6.1. Technological Foundations

AEOLION is based on up-to-date technologies which currently are available for the development of tools following a responsive design approach\(^1\). At the core, the Actor model is used as main technology allowing for structuring the application alongside multiple actors which operate in an asynchronous way and communicate via message sending. The persistence layer is based on MongoDB, a NoSQL database technology offering a flexible mechanism with respect to the data structures at hand.

The Actor Model

The implementation of reactive applications is supported by a wide range of different components, libraries, frameworks, and so forth. The Actor model, however, is one of the main and widely used concepts for developing reactive applications. Although already developed in the 1970s by Hewitt \(1977\) and further refined in the 1980s by \(\text{Igra} 1985\), the Actor model retained relevant as a model of concurrent computation in distributed systems. According to Vernon \(2015\), “[t]he Actor model promotes actors as the first-class unit of computation and emphasizes communication between actors via message sending. Because message sending is asynchronous, actors operate in a highly concurrent manner, which naturally makes for problem solving in parallel. Each actor generally cares for a single application responsibility.” Reactive applications based on the Actor model therefore are concerned with the following responsibilities \(\text{Vernon} \ 2015\):

- What and which kind of incoming messages (i.e., commands or events) are accepted as input?
- What and which kind of outgoing messages (i.e., commands or events) are emitted as output?
- How does the state change as a reaction to incoming messages?
- What is the supervision strategy in place for supervised actors?

The first two concepts are concerned with how an actor is perceived from the outside world in terms of its ingoing and outgoing interface. The third concept describes the actual business logic and the internal effect on the actor’s state, the latter potentially influencing the reaction to prospective incoming messages. The last concept relates to the resilience of applications, in that it defines how the actor actually responds to failures.

\(^1\) A comprehensive list of dependencies is included in the Appendix (cf. Appendix A.2.1).
6.1. Technological Foundations

Today, a wide range of different libraries and frameworks support the development of distributed systems by providing implementations of the Actor model. To name but a few, the following list includes libraries and frameworks across various platforms and programming languages:

- Actor Framework (Java / Scala / .NET) (.NET)
- Akka (Java / Scala)
- Akka .NET (.NET)
- Cloud (C/C++, Erlang, Java, JavaScript, Perl, PHP, Python, Ruby)
- CAF C++ Actor Framework (C++)
- Actor-CPP (C++)
- ...

Among the different libraries and frameworks, the Akka toolkit is considered one powerful and prominent solution. Schöneberg et al. (2013), for instance, have developed a scalable, distributed and dynamic workflow system based on the Akka framework. Due to this approach, they were able to provide a highly scalable and flexible application architecture adapting to the changing requirements in terms of external data sources to be processed. Latoschik & Tramberend (2011, 2012) and Rehfeld et al. (2013) in their work on realtime interactive systems were also using the Actor model as means for developing a scalable and concurrent architecture.

Akka, in general, is a toolkit for building highly concurrent, resilient, and message-driven applications using the JVM. Based on the Actor model, Akka provides an abstraction layer that facilitates the development of distributed, fault-tolerant, and scalable applications. According to the official documentation, Akka implements a unique hybrid of the Actor model, fault tolerance concepts, location transparency, and persistence models.

- Actors. Actors provide you with simple and high-level abstractions for distribution and concurrency by implementing a highly effective and ef-

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2A more comprehensive list on libraries and frameworks supporting the development of distributed systems by providing implementations of the Actor model is available at https://en.wikipedia.org/wiki/Actor_model (accessed on December 12, 2016).

3http://actorfx.codeplex.com (accessed on December 12, 2016)

4http://akka.io (accessed on December 12, 2016)

5https://getakka.net/ (accessed on December 12, 2016)

6http://cloudif.org (accessed on December 12, 2016)

7http://actor-framework.org (accessed on December 12, 2016)

8https://code.google.com/archive/p/actor-cpp (accessed on December 12, 2016)

9Java Virtual Machine
Chapter 6. Enabling Middleware Framework

efficient message-driven programming model. Actors communicating via message-passing therefore operate in an asynchronous and non-blocking manner.

- **Fault Tolerance.** Fault tolerance as an inherent characteristic enables tools to continue operating in a proper manner in the event of a failure occurring in one of its components.

- **Location Transparency.** Since Akka actors use pure message-passing as a means of communication, actor systems and actors can span over multiple JVM distributed across the network.

- **Persistence.** The internal state of an actor can be persisted in order to be able to recover the respective state in the case of a failure.

The Akka toolkit is available for Java and Scala. In terms of programming with the actor model, however, Scala is considered more powerful and expressive. Charousset et al. (2013, p. 92) note that “Erlang and Scala are currently the most relevant languages for actor programming.” Vernon (2015) also identifies Scala as the more appropriate language for programming with the actor model provided by Akka.

NoSQL Databases

In recent years, NoSQL approaches have gained in importance over traditional systems since data handling today is more complex in terms of volume (terabyte to petabyte), variety (structured, unstructured, and hybrid), as well as velocity (high speed in growth). NoSQL approaches address these requirements by focusing on scalability, availability, and parallelism in the context of distributed computing. According to Padhy & Panigrahy (2015), there are four key characteristics that distinguish NoSQL databases from traditional RDBMS approaches. These characteristics are described in the following:

- **Based on distributed computing.** NoSQL approaches are designed considering the characteristics of distributed systems and a shared nothing architecture. This enables horizontal scalability and therefore supports handling large workloads.

- **Commodity Hardware.** Most NoSQL approaches are designed to run on commodity hardware instead of high end servers. This allows for keeping down costs when scaling horizontally.

For detailed information on Scala see [http://www.scala-lang.org](http://www.scala-lang.org) (accessed on August 9, 2016).

RDBMS, short for Relational Database Management System
6.1. Technological Foundations

- **ACID, BASE, and the CAP Theorem.** NoSQL approaches typically trade in ACID properties for BASE properties. Enabling systems to scale horizontally, however, comes along with tradeoffs related to the consistency of data.

- **Flexible schema.** In order to cope with changing requirements, NoSQL approaches provide a flexible schema for data structures which evolves according to the needs of the application. Schemas as used in traditional RDBMS approaches, in contrast, are more rigid in this regard.

Four major categories exist in terms of data models supported by NoSQL approaches (Padhy & Panigrahy, 2015). These categories are described in the following:

- **Key-value stores.** Key-value stores implement a simple data model which is based on key-value pairs (i.e., associative map or dictionary). Being especially efficient in managing distributed data, key-value stores do not support data structures which require relations or any other more complex structures.

- **Column-family stores.** Column-family stores typically are based on Google’s Bigtable where data is managed according to columns each of which is uniquely identified by a key. Providing powerful indexing and querying mechanisms, column-family stores do not support data structures which require relations or any other more complex structures.

- **Document stores.** Document stores are suitable for any type of data which can be represented in the form of documents. Each document thereby can contain complex data structures and is uniquely identifiable by a key. Keys in further consequence are also used for indexing and querying capabilities.

- **Graph databases.** Graph databases are based on graph theory and use graphs as their data model. Particularly suitable for the representation of highly interconnected data, graph databases are limited with respect to handling data other than graphs and relationships.

Since document-like data structures are at the core of the tool to be developed, document stores are considered the most suitable approach. **MongoDB** as one prominent solution is an open source database which provides a document-oriented storage mechanism based on JSON. In contrast to CouchDB which

---

12ACID, short for Atomicity, Consistency, Isolation, and Durability
13BASE, short for Basic Availability, Soft-state, and Eventual consistency
14For more detailed on MongoDB see https://www.mongodb.com (accessed on August 9, 2016).
15JSON, short for JavaScript Object Notation
16For more detailed information on CouchDB see http://couchdb.apache.org (accessed on
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emphasizes availability, MongoDB focuses on consistency and therefore is considered more relevant in the context of this work.

6.2. A Framework for Flexible Application Development

The non-functional requirements identified and presented in Section 5.3 are considered crucial for the development of the AEOLION framework. In the following, the requirements concerned with extensibility and adaptability are discussed with particular focus on the implementation and respective constraints. The reusability of learning artifacts at this point is not discussed, but becomes relevant in the context of the service choreography introduced for supporting sitative learning.

− **Extensibility.** In order to allow the continuous development of the learning tool, extensibility as an inherent property is considered crucial. Extensibility not only includes that existing artifacts are available in contexts other than the one’s in which they have been created initially, but also that the framework provides a basic set of features (e.g., permission management) which remains consistent across all functional groups.

− **Adaptability.** The adaptability ensures that the learning tool is adaptable to different contexts and usage scenarios by using a common service infrastructure. This in particular concerns the provision of respective interface which can be accessed by different devices, such as a desktop computer or a smart phone. The integration of third-party services or external platforms should be supported additionally.

6.2.1. Actor-based Tool Design

AEOLION follows an actor-based design approach, meaning that the core of the system is composed of a set of actors where each actor is responsible for a dedicated set of features. As a consequence, the functionality provided by the framework is broken down into functional groups which are encapsulated by separate actors.

The framework’s core is composed of 7 main actors, one being the root actor in particular responsible for coordinating the interplay among the involved actors during startup (cf. Figure 6.2). Besides the root actor, the framework’s core involves various managing actors, the dispatcher, as well as the rest handler. The managing actors, represented by the user manager, the session manager, the persistence manager, and the plugin manager, are responsible for the basic April 10, 2017).
set of features provided by the framework. In terms of the actor hierarchy, the root actor is at the core of the hierarchy serving as parent for the user manager, the session manager, the persistence manager, the plugin manager, the dispatcher, and the rest handler. Except for temporary working actors, no further actors are instantiated and used in the core.

Figure 6.2.: Actor hierarchy in AEOLION

**User Manager**

The user manager is instantiated in the context of the root actor and is responsible not only for managing users, but also allows organizing users by means of groups and roles.

- **Users.** Since no action is allowed to be executed without a designated user, respective management procedures are at the core of the learning tool and therefore crucial to any other component or plugin. The user manager not only manages the users, but also allows to organize them by means of groups and roles.
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- **Groups.** Groups are one simple way to organize a subset of users into a specific group, for instance, a learning group which is associated with a particular workspace.

- **Roles.** In addition to groups, roles also support the organization of users but, more importantly, serve as the basis for the implementation of a flexible permission management. Roles can be defined standalone but also can be structure hierarchically, meaning that the parent always holds all permissions granted to its children plus may have granted some specific privileges. This structure is defined independent from any specific artifacts, since the actual binding is done during runtime using the identifiers of the involved artifacts.

Listing 6.1 shows the class hierarchy of messages involved when, for instance, creating a new user. The `UserMessage` is the class which allows identifying messages as related to the user manager. All subclasses therefore are forwarded to the user manager. For instance, the `CreateUser` message allows any component or plugin to create a new user based on the arguments `userName`, `firstName`, `lastName`, and `email`.

Listing 6.1: Class hierarchy of messages for the users manager

```scala
abstract class UserMessage extends AeolionBaseMessage("users")

case class CreateUser(userName: String, firstName: String, lastName: String, email: String)(implicit val token: AeolionToken) extends UserMessage

// output truncated
```

**Session Manager**

The session manager is instantiated in the context of the root actor and manages anything related to user authentication. Accordingly, this is the first contact point for components or plugins when starting to interact with each other.

Listing 6.2 shows the class hierarchy of messages involved when, for instance, authenticating a user. The `SessionMessage` is the class which allows identifying messages as related to the session manager. All subclasses therefore are forwarded to the session manager. For instance, the `RequestToken` message allows any component or plugin to authenticate a user by means of its user name and password.

Listing 6.2: Class hierarchy of messages for the session manager

```scala
abstract class SessionMessage extends AeolionBaseMessage("session")
```
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```scala
case class RequestToken(userName: String, password: String) extends SessionMessage
```

Persistence Manager

The persistence manager is instantiated in the context of the root actor and is responsible for handling requests concerned with storing artifacts which have been create or manipulated by core components or plugins. Since the persistence manager is not dedicated to a specific storage technology, child actors which provide specific databases support (e.g., MongoDB) are initialized during startup.

Listing 6.3 shows the class hierarchy of messages involved when, for instance, saving a new artifact. The PersistenceMessage is the class which allows identifying messages as related to the persistence manager, but does not yet indicate any specific storage technology. The MongoDBMessage, a subclass of the PersistenceMessage, is used for identifying all subclasses as messages related to the MongoDB as storage technology. For instance, the Insert message allows any component or plugin to store a specific artifact into a given collection.

```
abstract class PersistenceMessage extends AeolionBaseMessage("persistence")

abstract class MongoDBMessage extends PersistenceMessage

case class Insert(collection: String, value: MongoDBObject, condition: Option[MongoDBObject] = None) extends MongoDBMessage
```

Plugin Manager

The plugin manager is instantiated in the context of the root actor and is responsible for managing plugins during runtime. Use for the purpose of extending the functionality of the framework, the plugin manager allows registering and mounting an arbitrary number of plugins. Each plugin thereby is described by means of its descriptor which provides basic information on the actor class to be instantiated as well as dependencies to other plugins. Once
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the plugin manager receives the message for loading a plugin, the following steps are processes:

1. **Instantiate actor.** First, the actor is created in the context of the actor system which, in the following, serves as point of reference for any requests.

2. **Creating plugin-specific roles.** In order to allow plugins to manage their data accordingly, plugin-specific roles are created during initialization. The respective references are then passed to the main actor.

3. **Initialization of the plugin.** Once the initialization process of the plugin is completed successfully, the plugin is notified so as to start its own initialization process. After completing the initialization, the plugin notifies the plugin manager by sending the *Initialized* message.

4. **Enabling plugin.** Finally, the plugin is enabled and made available to other plugins. From this point, the dispatcher forwards message directed to the plugin.

**Rest Handler**

The rest handler is instantiated in the context of the root actor and is responsible for managing the unified endpoint provided by AEOLION. Once initialized, components or plugins can register and make available specific endpoints by means of the rest handler (cf. Section 6.2.3).

The rest handler provides a unified endpoint which is composed of different parts (cf. Listing 6.4), starting with the transmission protocol (http or https) which is followed by the actual IP address as well as the port of the server hosting the learning tool including its respective data services. Separated by the constant `api`, the endpoint’s unique prefix follows right before the actual endpoint definition is appended (i.e., an endpoints specific paths and methods).

```
Listing 6.4: Basic structure of the unified HTTP-based service endpoint
1. https://<ip>:<port>/api/<prefix>/...
```

Besides managing available endpoints, the rest handler takes over responsibility for some basic checks and operations. The main features provided by the rest handler are discussed in the following:

- **Access validation.** Since the rest handler receives all requests directed to AEOLION, access validation mechanisms are in place to ensure whether
the request is associated with an active and validated session. This is done by a dedicated access token which needs to be attached to every incoming HTTP request. In case of an invalid or missing token, the request is not further processed (i.e., not forwarded to the responsible plugin actor) and canceled by sending a respective error message. Otherwise, the request is marked as valid and forwarded to the responsible plugin actor.

- Since external systems may request data from AEOLION also, the rest handler provides respective procedures and methods required for handling CORS requests. In particular this means that the HTTP method options is processed for all patterns by the rest handler on behalf of the services provided by the core system or plugins. This concerns the headers for specifying the list of methods and headers to be accepted by AEOLION.

- In the course of interacting with external systems, AEOLION uses JSON as the common format for the representation of artifacts. The respective headers specifying the content type of the response are automatically attached by the rest handler.

Dispatcher

The dispatcher is instantiated in the context of the root actor and holds all information required for dispatching messages among components and plugins. Any actor requesting data from another component or plugin therefore only needs to forward its request to the dispatcher. The dispatcher then takes over the routing of the request including the response address for returning the data. The response is sent back directly to the requester without involving the dispatcher again.

Figure 6.3 shows the dispatcher’s functional principles and illustrates the components involved when an actor requests data from another component or plugin. The following steps are passed through in the course of dropping a request and waiting for a response:

1. The requesting actor creates the request (i.e., message) and instantiates a temporary working actor, the request handler. This is done to ensure non-blocking behavior and provides the requesting actor with some basic functionality, such as timeout handling or response type checking.

---

17 CORS stands for cross-origin resource sharing and is a W3C specification that allows requesting resources that are provided from other domains.

18 Access-Control-Allow-Methods and Access-Control-Allow-Headers

19 JavaScript Object Notation
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2. The request handler takes over control and forwards the request to the dispatcher.

3. The dispatcher receives the request and forwards it to the responding actor. The routing is done by means of matching class types, such as \texttt{AeolionMessage}, \texttt{UserMessage}, \texttt{MongoDBMessage}, or any other message types which are specified by plugins (cf. Listing 6.5).

\begin{verbatim}
Listing 6.5: Routing mechanism of the dispatcher

def dispatch(message: AeolionMessage, ...): Unit = {
  message match {
    case m: CoreMessage => core.forward(m)
    case m: UserMessage => modules.usersManager.actor.forward(m)
    case m: SessionMessage => modules.sessionManager.actor.forward(m)
    case m: PersistenceMessage => modules.persistenceManager.actor.forward(m)
    case m: SamplePluginMessage => modules.pluginManager.actor.forward(m)
    case m: AeolionMessage => modules.pluginManager.actor.forward(m)
  }
}
\end{verbatim}

4. The responding actor processes the request and sends back the results to the requesting actor. Since the requesting actor was using a temporary working actor, the response is addressed to the request handler and not to the requesting actor directly. After some basic response type checking, the response is forwarded to the requesting actor which can then complete the request-response cycle.

Figure 6.3.: Mechanism for dispatching messages among components
6.2. A Framework for Flexible Application Development

Although requests may involve a variety of different actors, especially when not resolvable in a single request-response cycle as shown in Figure 6.3, using the dispatcher is straightforward from a programmer’s perspective. Listing 6.6 exemplarily shows how a specific user can be resolved by means of its identifier. The actual request `GetUser(10)` is passed to a new `Request` instance which also requires to define the expected response of type `$User`. The map-function unfolds the response and makes available the data representing the respective user. In the case of an unexpected behavior, the failure can be handled in the `onFailure` callback method.

Listing 6.6: Requesting data from other components or plugins

```scala
val request = for {
    user <- Request[$User](GetUser(10)).map(_.user)
} yield // process result
request.onFailure { case f => /* handle failure */ }
```

6.2.2. Service Specification and Choreography Design

So far, the core system only provides basic functionality by means of the actors described in the previous section. In order to extend the basic functionality by specific services (e.g., a service which supporting the organization of learning processes by means of workspaces or projects), the plugin manager allows to mount plugins which basically operate in an independent manner, but are integrated in so far as plugins are authorized to use functionality provided by the core and may interact with other plugins available during runtime.

Each plugin is defined based on its descriptor which specifies the main properties required for instantiation (cf. Listing 6.7). First, a unique identifier (`id`) is specified allowing the core system to manage multiple plugins simultaneously during runtime. Since the core system is responsible for integrating the plugin into its runtime environment, the corresponding actor (`actorClass`), which represents the actual service provider, is defined. Finally, dependencies to other service providers or plugins are defined (`dependencies`). This allows plugins to use and integrate specific features that go beyond the scope of the core system but are made available and provided by other plugins during runtime.

Listing 6.7: Definition of the basic properties of plugins

```scala
object SamplePluginDescriptor extends Descriptor {
  override val id = "sample-plugin"
  override val actorClass = "class.path.SampleActor"
  override val dependencies = Vector(OtherPluginDescriptor.id)
}
```

Besides the descriptor, each plugin provides its service by means of specific message (cf. Listing 6.8). For this purpose, a specific message type (`SamplePluginMessage`) is derived inheriting from the based message type `AeolionMessage`
which is provided by the core system. The attribute origin is not required at the plugin level, but supports the core system in handling messages which are exchanged during runtime. Using the specific message type, the actual messages are defined which represent the plugin’s interface. In the example, the sample-plugin not only allows to retrieve artifacts (GetArtifact or GetArtifacts) based on its identifiers, but also supports the creation of artifacts (CreateArtifact) providing an appropriate data object. The result type is specified as a separate message containing the retrieved artifact (ArtifactRetrieved).

Listing 6.8: Message-based service interface description

```java
abstract class SamplePluginMessage extends AeolionMessage {
    override val origin = PluginDescriptor.id
}

case class CreateArtifact(data: ArtifactData)(implicit val token: AeolionToken) extends SamplePluginMessage

case class GetArtifact(id: AeolionID)(implicit val token: AeolionToken) extends SamplePluginMessage

case class GetArtifacts(ids: Vector[AeolionID], all: Boolean = false)(implicit val token: AeolionToken) extends SamplePluginMessage

case class $ArtifactRetrieved(artifact: Artifact) extends SamplePluginMessage
```

Having defined the main properties and the message-based interface, the core system is able to trigger the initialization process which eventually allows the core to make available the plugin in its runtime environment. In the following, the initialization process is described by means of the involved messages (cf. Listing 6.9).

1. **Initialize.** The initialization process is triggered by the core system through sending the initialization message (Initialize). Since the plugin is treated as independent service provider, however, the core system does not take any responsibility during this process. This means that each plugin is required to setup and configure the provided infrastructure based on its specific needs. Each plugin, for instance, may define specific roles used for access control. During the initialization process, the core system knows about the plugin, but does not forward any messages directed to the plugin until it is marked as available.

2. **Initialized.** Once the plugin has been initialized (i.e., the required infrastructure is setup according to its specific needs), it notifies the core system about its status (Initialized). In case the plugin depends on other plugins provided by the runtime environment, this interim state is valid until the core system makes available the corresponding plugins.
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In case all dependencies are resolved already during the first phase, the plugin skips this interim state immediately.

3. Available. Once the initialization process has been completed successfully, the plugin notifies the core system about its status (Available). The core system eventually registers the plugin as successfully initialized and, as a consequence, marks it as available for other plugins.

Listing 6.9: Messages involved during the initialization of a plugin

```
final case class Initialize(...) extends PluginMessage
final case class Initialized(...) extends PluginMessage
final case class Available(...) extends PluginMessage
```

6.2.3. Extending the Unified Service Endpoint

Generally, plugins are accessible via messages which initially get processed by the corresponding actor (cf. Listings 6.7 and 6.8). This enables the core system and the plugins available in the runtime environment to interact with each other. External applications, however, are limited to be integrated, in particular, when implemented as autonomous systems using technologies other than the core system and respective plugins. For this purpose, the unified endpoint provided by the rest handler can be extended by plugin-specific HTTP requests. This is done by informing the core system using the message `ExposeEndpoint` (cf. Listing 6.10). The message thereby not only specifies the prefix to be used, but also contains the configuration settings and the actual information required for integration (i.e., the actor properties).

Listing 6.10: Exposing a HTTP-based service endpoint

```
case class ExposeEndpoint(id: AeolionPluginID, config: RestConfig, endpoint: Props) extends SamplePluginMessage
```

The endpoint including the specific request definitions is described using the domain-specific language provided by the libraries used for providing the HTTP service. Listing 6.11 illustrates some sample paths, including methods such as get, post, and delete.

Listing 6.11: HTTP-based service endpoint

```
override def receive: Receive = runRoute(artifactsRoute)

private val artifactsRoute = {
  pathEnd {
    get { /* GET .../artifacts */ } ~
    post { /* POST .../artifacts */ }
  }
}
```
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```java
pathPrefix(IntNumber) { 
    pathEnd { 
        get { /* GET .../artifacts/1 */ } ~ 
        delete { /* DELETE .../artifacts/1 */ } 
    } 
} 
```

Figure 6.4 illustrates how HTTP requests are handled by AEOLION in terms of dispatching the messages and querying the requested data. In the example, a HTTP request requesting user data is received by the HTTP server (1) and further processed by a dedicated request handler (2). This request handler is responsible for processing the actual request at the HTTP level and provides respective data as well as operations (request context) for sending back the response. In the next step, the request is forwarded to the REST handler (3) which takes care of some basic operations and checks, such as handling CORS requests, verifying the validity of the access token, or matching the structure of the URL used for dispatching. Based on the structure of the URL, the request including its context eventually is forwarded to its managing endpoint (4), that is the specific actor having the appropriate references required for processing. At this point, the request has reached its final destination with respect to the component capable of addressing the appropriate actors responsible for handling. In this example, the request concerns the user manager which is consulted by the user endpoint in order to obtain the requested data (i.e., the user). The HTTP request therefore is translated to the corresponding command (5) and forwarded to the internal request handler responsible for managing the interaction among the involved actors (6). In particular, this means that the request handler not only receives and forwards the request (6), but also provides the response or handles failures (7 and 8), such as time outs or issues concerned with unexpected responses. In any case, the managing endpoint returns either the request data or information on the failure occurred during processing (9). The response eventually is sent back by the HTTP server.

6.3. Supporting Situative Learning: A Service Choreography

Based on the goals and requirements identified in Sections 5.1 and 5.3, an appropriate plugin structure as well as respective plugin specifications are defined using AEOLION. Accordingly, each plugin is divided into two separate modules, one providing the message-based interface description, and the second providing a specific actor implementation in compliance with the corresponding interface. Following this approach, the given requirements are bundled into five functional groups, namely resources, documents, interactions, workspaces, and notifications.

- **Resources.** This functional group allows managing static resources, such
as PDF documents, ZIP files, MS Word documents, and so forth. Besides uploading new resources, existing resources can be listed, updated, and replaced. With respect to the requirements, this includes all features listed under resource management [FR:MgmR].

- Documents. This functional group allows managing interactive documents. In contrast to static resources, interactive documents allow providing a more powerful set of features with respect to learning support. Besides creating new interactive documents, existing documents can be listed and updated. In order to make the structure of content explicitly visible to users, documents additionally allow typecasting the content and its parts respectively. With respect to the requirements, this includes all features both listed under document management [FR:MgmD] and typecasting of content [FR:TypC].
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- **Interactions.** This functional group allows managing interactions among selected users. Besides creating new interactions, existing interactions can be listed and updated. As a way to organize and structure interactions among users, publishing or sharing posts are supported as well. With respect to the requirements, this includes all features listed under interaction management [FR:MgmI], constant update of interaction threads [FR:CoUI], and sharing of information [FR:Shrg]. Features associated with using Facebook in the context of the learning tool are not considered, since the integration only affects the web application but not AEOLION.

- **Workspaces.** This functional group allows managing workspaces including their configurations in terms of assigned resources, materials, and interactions. With respect to the requirements, this includes all features listed under workspace management [FR:MgmW].

- **Notifications.** This functional group allows notifying users about updates concerning interaction threads and workspaces. With respect to the requirements, this includes all features listed under e-mail notification [FR:EmNt].

Based on the functional groups, plugins are specified in terms of their features and functional dependencies (cf. Figure 6.5). The most fundamental plugins in this context are concerned with the management of resources and the notification mechanism. Both plugins are self-contained with respect to their functionality, which means that they do not require any other plugins to be available during runtime. All other plugins are considered more complex as they cannot be operated independently, that is they show dependencies to other plugins.

The documents plugin supports the management of images embedded in interactive documents by using the resources plugin. This is not considered crucial in the context of a single document, but becomes relevant once images need to be referenced in other contexts, for instance, as part of a contribution to an interaction.

Interactions are managed by the interactions plugin which directly depends on the documents plugin. The documents plugin allows representing the content of posts by means of a common structure. This not only ensures using existing content blocks (e.g., content blocks of a specific document) as part of particular posts, but also allows referencing the content of posts in other contexts, for instance, as part of a document. As an indirect dependency, the resources plugin is required to be available during runtime.

The workspaces plugin is considered the most complex plugin as it not only unifies the management of resources and documents, but facilitates the inter-
6.3. Supporting Situative Learning: A Service Choreography

action among users as well. It therefore shows dependencies to the resources, the documents, and the interactions plugin. In order to notify users about new workspaces or postings, the notifications plugin is referenced also.

![Diagram showing dependencies between Resources, Documents, Workspaces, Interactions, and Notifications](image)

Figure 6.5.: Dependencies of plugins for supporting situative learning

6.3.1. Reusability of Learning Artifacts

A common representation format is specified for the purpose of representing learning artifacts. This not only supports to share learning artifacts across plugins, but also allows to partially access learning artifacts in order to reuse them in different context and use scenarios. For instance, contributions to a specific interaction among a group of students might also be reused for the purpose of compiling lecture notes which reflect students’ opinions.

The structure of the representation format mainly builds on the composite pattern, allowing to treat a group of objects in the same way as a specific instance of an object. Specific content types such as a text element or an image, for instance, are treated the same way as a paragraph (e.g., a list of text elements). In the following, this structure is described with reference to the specific content types and collection elements:

- **Content.** The content type is considered the most generic element in the structure and subsumes the specific content elements available for the representation of learning artifacts. It furthermore ensures that every single content element (e.g., a text element or an image) is accessible by means of a unique identifier.

- **Text.** The text element is the most simple element and contains a value of type string.

- **Image.** The image element provides similar characteristics compared to the text element, however, needs to be interpreted differently in terms of its semantics. Specifically, the value of type string (**source**) does not represent a text, but rather specifies the image in terms of a hyperlink.

- **Collection.** The collection element is a composite of multiple content ele-
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ments. For instance, a specific collection (e.g., a paragraph or a heading) might contain a list of text elements which are arranged sequentially.

- **Heading.** The heading element is a specific collection composed of a list of content elements. The level of the heading is specified by the attribute `level`.

- **Paragraph.** The paragraph element is a specific collection composed of a list of content elements. It does not provide any additional attributes as it only serves as means for structuring the content (e.g., as means for the specification of some margins surrounding a paragraph).

- **List.** The list element is a specific collection composed of a list of content elements. In contrast to the collection type, list elements allow representing content as enumerated or itemized lists. This means that each content item is considered a separate entry in the list.

The data model described so far only supports specifying the structure of learning artifacts. The formatting, however, is not included in this specification, but is defined by means of separate elements referenced by the `Annotation` class.

- **Annotation.** The annotation type is considered the most generic element for representing annotations, such as formatting styles, hyperlinks, comments, or any kind of information indicating pedagogical structures. As a means for organizing annotations, a specific group is associated via the attribute `group`. In case the annotation is not valid in the overall context (i.e., the entire content element), a specific section may be defined using the `begin` and `end` attribute.

- **Formatting.** Annotations of this type describe specific styles which are applied to content elements for formatting purposes. For instance, a text element may be formatted according to some guidelines, that is a specific font size and color.

- **Reference.** The reference type allows to specify hyperlinks by means of the attribute `target`. Text elements may be annotated by this type referencing web resources, such as web sites or images.

- **Didactics.** This type is used for the purpose of structuring content by means of pedagogical tags. Lecture notes, for instance, may be augmented by specific tags allowing students to focus on certain parts, such as application examples, instructions, and so forth.

- **Comment.** In the context of annotations, comments are the most flexible type available to be used for augmenting content. Since the comment itself is of type `Content`, the structure which is available for the representation of learning artifacts can be used.
Figure 6.6.: Class hierarchy for the representation of learning artifacts
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Listing 6.12 shows an example of how a specific learning artifact may be described using the structure described above. Starting at line 3, the basic properties of the root element are defined, including a unique identifier, the actual owner (i.e., the user), the creation date, and the type. Depending on the type, the attribute `items` is included, referencing the content elements which are considered the children. The collection element is composed of an element of type `Heading` (line 10) which references a string of value `Heading 1`. The content element of type `Text` additionally shows the attribute `annotations` which may be used to define a specific formatting or attach some comments.

Listing 6.12: An example representation of a learning artifact

```json
{
  "data": {
    "id": 272163,
    "owner": 23,
    "created": 1480711068286,
    "_type": "Collection",
    "items": [
    // output truncated
      {
        "_type": "Heading",
        "level": 1,
        "items": [
          {
            "id": 272137,
            "owner": 23,
            "created": 1480711068023,
            "_type": "Text",
            "value": "Heading 1",
            "annotations": []
          }
        ]
      }
    // output truncated
  }
}
```

Using the example representation from above, specific visualization components may be used to render this format by means of specific technologies. Figure 6.7, for instance, shows the visualization of the example by using HTML as output format.

Listing 6.13 shows the corresponding data types from a programming perspective. For illustration purposes, the listing only shows the content type `text` which is described based on its value. The attribute `annotations` is used to reference annotations providing information on, for instance, specific styles or comments.

Listing 6.13: The data types defining learning artifacts (truncated)

The complete listing is included in the appendix (cf. Appendix A.4).
6.3. Supporting Situative Learning: A Service Choreography

Figure 6.7.: An example visualization of a learning artifact

trait ContentItem

class Content(
  val data: ContentData
)
  extends ContentItem with AeolionParticle with Ownership with CreationDate

ContentData(
  val annotations: Vector[AnnotationItem]
)
  extends ContentItem

class Text(
  val aid: AeolionID,
  val owner: AeolionID,
  val created: Long,
  override val data: TextData
)
  extends Content(data)

class TextData(
  val value: String,
  override val annotations: Vector[AnnotationItem]
)
  extends ContentData(annotations)
6.3.2. Workspace-based Learning Support

Workspaces are central to AEOLION and are available to be used for organizing both individual and collaborative learning processes. Since it references data and consolidates features from other plugins (cf. Figure 6.5) it is considered the most comprehensive plugin in the context of the use case for supporting situative learning. With respect to the primary attributes, each workspace is described based on its name, a short description, and a state (cf. Listing 6.14). The remaining attributes, such as interactions, notepads, and materials, are used to reference specific learning materials or interaction spaces associated with the workspace.

- **Name.** The name of a workspace can be assigned without any further restrictions, but should convey the primary goal in terms of content, learnings, and so forth. Duplicated names should be avoided so as to minimize misunderstandings and ambiguity.

- **Description.** In addition to the name, each workspace can be assigned a short description. This may be used to provide a more detailed description of the primary goal in terms of content, learning, and so forth.

- **State.** During workspace configuration and setup, a workspace may be locked for users not granted the required privileges. The workspace is unlocked as soon as it is configured and explicitly made available to team members.

Listing 6.14: The data types defining a workspace

```scala
class Workspace(
  val aid: AeolionID,
  val owner: AeolionID,
  val created: Long,
  val data: WorkspaceData
) extends AeolionParticle with Ownership with CreationDate

class WorkspaceData(
  val name: String,
  val desc: String,
  val state: Project.STATE.Value,
  val interactions: Vector[AeolionID],
  val notepads: Map[AeolionID, AeolionID],
  val materials: Vector[AeolionID]
)
```

In terms of access privileges, workspaces distinguish between two major permission levels, the manager and the team member. While managers are entitled

---

21 A more detailed description of the workspaces plugin in terms of its specification is included in the appendix (cf. Appendix A.3.1).

22 The creator of a workspace automatically is granted the manager role.
to setup workspaces in terms of their configurations. Team members only are allowed to access workspaces and participate in interactions.

Interactions

Interactions among students are supported by AEOLION and are accessible via workspaces. With respect to the primary attributes, each interaction is described based on its name and a state, the latter indicating whether the interaction is closed or open for discussion (cf. Listing 6.15). The attribute `posts` is used to reference the actual contributions to the interaction in terms of the author, the date of publication, and the content.

- **Name.** The name of an interaction can be assigned without any further restrictions, but should convey the primary goal in terms of topic or content to be discussed. Duplicated names should be avoided so as to minimize misunderstandings and ambiguity.

- **State.** The state of an interaction indicates whether it is open or closed for interaction, the former allowing student to publish new contributions.

Listing 6.15: The data types defining an interaction

```java
class Interaction {
  val aid: AeolionID,
  val owner: AeolionID,
  val created: Long,
  val data: InteractionData
}

class InteractionData {
  val name: String,
  val posts: Vector[AeolionID],
  val closed: Boolean
}
```

In terms of access privileges, interactions distinguish between two major permission levels, the manager and the participant. While managers are entitled to setup interactions in terms of their configurations, participants only are allowed to publish new contributions.

---

23 The configuration of workspaces includes the name and the state as well as members invited for participation.

24 The configuration of interactions includes the name and the status as well as participants invited for discussion.
Learning Materials

Learning processes in AEOLION are supported by the use of learning materials, more specifically, resources and documents. The two types of learning materials differ from each other in that they allow different modes of interaction. For instance, documents support more sophisticated mechanisms for structuring content, e.g., assigning pedagogical block types to specific content elements.

The use and management of resources is supported by AEOLION. Resources are managed independently, however, typically are provided in specific learning contexts (i.e., workspaces). With respect to the primary attributes, each resource is described based on its name, its hash value, and a state, the latter indicating whether it is locked or available for download. The data type is automatically generated in the course of uploading a specific resource (i.e., a file). In the case of replacing existing resources, corresponding revisions are created and kept available for future access.

- **Name.** The name of a resource can be assigned without any further restrictions, but should convey the actual content of the resource (e.g., contents of an archive or title of a scientific paper). Duplicated names should be avoided so as to minimize misunderstandings and ambiguity.

- **Hash.** The hash values is calculated based on the contents of the resource and is used for parity checks. Multiple uploads of the same resource therefore are avoided supporting the user with respect to the management and organization of resources.

- **State.** The state of a resource indicates whether it is locked or available for download. In the latter case, resources are not accessible by other plugins and, for instance, are not listed in workspaces having respective references.

```java
final class Resource(
  val aid: AeolionID,
  val owner: AeolionID,
  val created: Long,
  val data: ResourceData
) extends AeolionParticle with Ownership with CreationDate

class ResourceData(
  val name: Option[String],
  val hash: String,
  val dataType: Resource.DataType.Value,
  val revisions: Vector[Revision],
  val file: File,
  val state: Resource.STATE.Value
)
```

Listing 6.16: The data types defining a resource
In terms of access privileges, resources distinguish between two major permission levels, the manager and the reader. While managers are entitled to update resources\(^{25}\), readers are granted access privileges only.

In addition to resource, AEOLION also supports the use and management of interactive documents. Despite documents are managed independently, they typically are provided in specific learning contexts (i.e., workspaces). With respect to the primary attributes, each document is described based on its name, the actual content, and a state, the latter indicating whether it is locked or available for access. In the case of updating an existing document, corresponding versions are created and kept available for future access.

Listing 6.17: The data types defining a document

```scala
final class Document(
  val aid: AeolionID,
  val owner: AeolionID,
  val created: Long,
  val data: DocumentData
) extends AeolionParticle with Ownership with CreationDate

class DocumentData(
  val name: String,
  val content: Option[AeolionID],
  val versions: Vector[(Long, AeolionID)],
  val state: Document.STATE.Value
)
```

In terms of access privileges, documents distinguish between two major permission levels, the manager and the reader. While managers are entitled to update documents\(^{26}\), readers are granted access privileges only.

### 6.3.3. Linking Cognitive and Social Efforts

Learning processes are facilitate by AEOLION not only by features isolated from each other, such as supporting interactions among users and the management of documents or resources, but also through linking cognitive and social efforts in terms of learning materials and interactions. In particular this means that content initially provided as learning material (i.e., document) can be referenced and used in the context of interactions. Vice versa, content published in the course of interactions can be used for creating or augmenting documents.

Listing\(^{6.18}\) illustrated the linking of cognitive and social efforts based on postings published in the course of interactions. Basically, a posting is described

\(^{25}\) Update processes may include changing the name of a resource, its state, or associated file.

\(^{26}\) Update processes may include changing the name of document, its state, or associated content.
based on the corresponding interaction, a state, as well as its content. The content, however, is not specific to the interactions plugins, but uses the common format for representing learning artifacts (cf. Section 6.3.1). Consequently, content published in the course of interactions can be referenced and used in contexts other than the initial one.

Listing 6.18: The data types defining a post

```scala
class Post(
  val aid: AeolionID,
  val owner: AeolionID,
  val created: Long,
  val data: PostData
) extends AeolionParticle with Ownership with CreationDate

class PostData(
  val interaction: AeolionID,
  val content: AeolionID,
  val state: Post.STATES.Value
)
```

6.4. Summary

In this chapter, the middleware framework AEOLION was presented and described with respect to its architecture and design. The framework is the main component responsible for both handling and processing data requests received from the user interacting with any kind of front-end application (e.g., a web-based learning tool). It is implemented in Scala by using the Actor model as the main paradigm allowing for structuring the application alongside multiple actors which operate in an asynchronous way and communicate via message sending (cf. Section 6.1). The persistence layer is based on MongoDB, a NoSQL database technology offering a flexible mechanism with respect to the data structures at hand (cf. Section 6.1).

Following an actor-based design approach, AEOLION is composed of the root actor and 6 child actors which take responsibility for managing users and sessions, the persistence layer, handling plugins and corresponding REST-based endpoints, as well as the routing of messages (cf. Sections 6.2.1 and 6.2.2). A unified REST-based endpoint allows external applications (e.g., web-based learning tools or applications specifically aligned to the requirements of mobile devices) to interact with AEOLION (cf. Section 6.2.3).

Based on the requirements identified and presented in Section 5.3 as well as the functionality provided by AEOLION, a set of plugins including respective interface specifications were defined for the purpose of supporting situative learning (cf. Section 6.3). Five functional groups concerned with the management of resources, documents, interactions, and workspaces as well as with an appro-
appropriate notification mechanism were implemented and integrated by means of AEOLION. In order to ensure the reusability of learning artifacts, a common representation format was specified and used for the representation of learning artifacts across the different plugins (cf. Section 6.3.1). Documents, for instance, are structured using the same representational format than postings within the context of a specific interaction. This in particular allows using learning artifacts (e.g., documents, contributions to interactions, and so forth) in context other than the one in which it has been created. As central unit, the workspaces plugin consolidates features from all other plugins and therefore allows organizing both individual and collaborative learning processes (cf. Section 6.3.2). For instance, a specific workspace may contain a set of interactions, documents, and resources which are relevant in the context of a given subject or topic. Finally, based on the common representational format of learning artifacts, cognitive and social efforts can be linked in that created content can be used in contexts other than the original one (cf. Section 6.3.3). An interaction post, for instance, may be used in the context of a specific document which collects the most relevant contributions across a specific set of interactions (e.g., interactions concerned with a specific topic).

6.4.1. Relevance of Findings

The findings presented in this chapter illustrated the architecture and design of AEOLION including implementation details. Using the proposed framework, the identified requirements were structured by means of the plugin concept and implemented accordingly.

RQ 3. How to operationalize an integrated learning design?

An extensible core was developed with the purpose of flexible application development in the context of learning support. The requirements (cf. Section 5.3) proposed for supporting situative self-regulated learning were structured by means of the core concepts (e.g., plugin mechanism, etc.) and implemented accordingly.

6.4.2. Outlook

The middleware framework AEOLION including the service choreography designed and developed for the purpose of supporting situative learning builds the foundation for the implementation of the web-based learning application Ueber Learn (cf. Chapter 7). More specifically, the interfaces defined and made available by the framework need to be considered accordingly in order to ensure a proper integration of features and exchange of data. The AEOLION framework together with Ueber Learn subsequently are used as basis for both the technical as well as the empirical evaluation (cf. Chapters 8 and 9).

The AEOLION framework is responsible for providing features in the context of situative learning, however, does not provide any particular user interface to be used for learning. Instead, it offers a REST-based interface to be used for the development of learning applications which not only are aligned to the specific requirements but also support integrating different devices, such as desktop computers, smart phones, and tablets. Ueber Learn\(^1\), a name proposed to reflect the flexibility of learning processes, is considered such an application, focusing in particular on the requirements with respect to self-regulated learning.

In terms of its responsibility, Ueber Learn takes on providing the user interface including its general design and structure as well as the visualization of specific components, such as interactions and associated postings. In addition, Ueber Learn manages the communication with the AEOLION framework in terms of creating appropriate requests as well as processing responses including the obtained data objects. In the context of the general architecture (cf. Figure 7.1), Ueber Learn is located on the server side communicating with both the back-end server and involved clients (i.e., browser).

From a technological perspective, Ueber Learn is based on up-to-date web technologies offering great flexibility in terms of accessibility (e.g., responsive design for the purpose of supporting different devices) as well as design and usability\(^2\).

\(^1\)Ueber Learn is part of a tool set which provides support in the context of individual and organizational learning. Other tools, such as the workflow engine Ueber Flow, complement the tool set and provide support ranging from knowledge articulation to workflow execution.

\(^2\)A comprehensive listing of dependencies is included in the Appendix (cf. Appendix A.2.2).

- **Node.js.** Node.js is an open-source, cross-platform JavaScript runtime built on Chrome’s V8 JavaScript Engine. It offers an event-driven architecture supporting an asynchronous and non-blocking I/O model which makes it lightweight and efficient in the context of developing web applications.

- **JavaScript.** According to Flanagan (2006), “JavaScript is a powerful scripting language that can be embedded in HTML. It allows [...] to create dynamic interactive web-based applications that run completely within a web browser [without any need for] server-side programming [...].” Standardized in the ECMAScript language specification, it is one of the most widely used web technologies and is supported by all modern web browsers without any specific plugins and extensions. Beyond that, a wide range of frameworks and libraries are available to be used as open-source.

- **AngularJS.** AngularJS is a JavaScript-based open source web application framework which offers great flexibility with respect to the integration of other libraries. As part of the MEAN stack, AngularJS represents the front-end component for developing dynamic web sites and applications.

- **Sass (SCSS).** Sass, also referred to as Syntactically Awesome Style Sheets, is a CSS extension language supporting the design of web applications with more abstract and flexible mechanism, such as variables, nesting, mixins, and so forth.

Considering the implementation details of the AEOLION framework as well as user requirements in terms of usability, Ueber Learn is implemented following a rich web application design approach. This not only allows using up-to-date libraries, but in particular enables providing a high user experience since many characteristics of desktop application software are replicated. Specifically, this means that the application is able to act immediately on user input as well as to react to data changes on the server.
7.1. Integrative Arrangement of Features

Instead of providing features by means of separate and isolated containers, Ueber Learn follows an integrative approach where the different features are combined and integrated on the user interface so as to increase user experience. This, for instance, becomes evident when navigating within a workspace (cf. Figure 7.2). The learning materials view provides centralized access to a wide range of different features, including features provided by the documents or the resources plugin. As an example, the overview on the left-hand side of the screen shows a list of learning materials available in the context of the selected workspace. In this regard no visual distinction is made between documents and resources, instead, both types of learning materials are made accessible via the same list.

![Figure 7.2.: Integrative user interface layout](image)

7.2. Situation-specific Accessibility

Situation-specific accessibility in the context of this thesis is concerned with providing access to the learning tool irrespective of the surrounding conditions in which the user is situated. This flexibility is achieved by two different approaches, that is responsive user interface design and the integration of Facebook as social media and communication platform.

Responsive User Interface Design

The general architecture, in particular the separation of back-end and front-end services, allows selecting front-end technologies which fit the requirements

of the primary user group, such as students at a university. In a first step, Ueber Learn has been implemented using web technologies which provide high accessibility without particular hardware requirements on the client side. This means that users only are required to have an up-to-date browser installed on their device as well as a connection to the Internet.

In order to ensure accessibility across different devices, such as desktop browsers, tablets, or smart phones, Ueber Learn provides layouts that are able to adapt to the different conditions mainly concerned with different screen sizes. The arrangement of features as shown in Figure 7.2 therefore needs to adapt accordingly. Figure 7.3 illustrates this adaption and shows two different views, that is the general dashboard (cf. Figure 7.3a) and the private notes in the context of a specific workspace (cf. Figure 7.3b). In both cases, the main header including the home button, the current users, and the main menu remains the same in terms of the layout. The context descriptor as well as the contextual menu, however, are rearranged in order to fit the different screen sizes. Specifically, this means that the two sections are not arranged side by side but one below the other. The layout of the main content area adapts as well. As exemplary shown in the case of the general dashboard, that is the list of available workspaces, and the private notes view, the content is arranged according to the screen size. With respect to the list of workspaces, for instance, the names are wrapped so as to make sure that they are entirely visible.

![Figure 7.3: Responsive user interface layout](image)

(a) The general dashboard view  
(b) The private notes view

*Figure 7.3.: Responsive user interface layout*
7.2. Situation-specific Accessibility

Facebook Integration

In addition to the responsive user interface design, Ueber Learn integrates Facebook in that it supports the visualization of user groups on Facebook (cf. Figure 7.4) in the context of a specific workspace.

![User group on Facebook](image)

Figure 7.4.: User group on Facebook

From a technological perspective, Ueber Learn uses the Facebook JavaScript API in order to provide features such as the login using a user’s Facebook credentials or loading content from a user’s personal wall or user groups. Listing 7.1 exemplarily shows the implementation details required for allowing users to login with their Facebook credentials.

Listing 7.1: Login with Facebook using the Facebook JavaScript SDK

```javascript
function _fb (redirect) {
  FB.init({
    appId: '558929667608649', // The Facebook App ID
    status: true, // Some SDK specific details
    cookie: true, // Some SDK specific details
    version: 'v2.6' // The Facebook API version
  });

  FB.login(function (response) {
    // Handle the response
  }, {
    onSuccess: function (access_token) {
      // Access token was successful
    },
    onFailure: function (error) {
      // Error handling
    }
  });
}
```

[https://developers.facebook.com/docs/javascript](https://developers.facebook.com/docs/javascript) (access on January 24, 2017)
When integrating with Facebook, a corresponding Facebook App needs to be created. In the course code listing from above (cf. Listing 7.1), this becomes evident when building the configuration object used for the initialization of the Facebook SDK in lines 2 - 7. By this means, Facebook controls some basic properties of the integration, such as the website’s URL, the name space, associated roles, and access permissions, the latter also referring to the scope defined in line 17 of the source code listing [7.1]. The associated access permissions, for instance whether the App is allowed to access a user’s personal wall or might publish posts on behalf of the user, are granted during initial setup and login.

Once a user account is connected with Facebook and granted access to request the respective data, information on user groups and the personal wall can be integrated in the form of interactions. Listing 7.2 shows the implementation details in terms of the separate commands required for querying and transforming data objects.

### Listing 7.2: Integrating the news feed of Facebook user groups

```javascript
function _groups () {
    var defer = $q.defer();
    FB.getLoginStatus(function () {
        FB.api('/me/groups', {}, function (response) {
            if (!response || response.error) {
                defer.reject(response.error);
            } else {
                defer.resolve(response.data.map(function (group) {
                    return { name: group.name, id: group.id });
                }));
            }
        }, true);
    return defer.promise;
}
```

7.3. Summary

In this chapter, the web-based learning application Ueber Learn was described as one potential approach to make accessible features and data provided by the
7.3. Summary

AEOLION framework. Managing the interactions with the framework, Ueber Learn is designed to be responsible for creating appropriate requests as well as processing responses including obtained data objects. Instead of providing features by means of separated and isolated containers, however, Ueber Learn follows an integrative approach where the different features are combined and integrated on the user interface with the purpose of increasing user experience (cf. Section 7.1). In order to allow situation-specific accessibility, not only the user interface is designed to be responsive (i.e., adapt to the different types of devices and therefore browsers), but also Facebook is integrated to be used as tool for communication and collaboration (cf. Section 7.2).

7.3.1. Relevance of Findings

The findings presented in this chapter illustrate the architecture and design of the web-based learning tool Ueber Learn including implementation details. Using the AEOLION framework and respective interfaces (cf. Chapter 6), appropriate visualizations and navigation paths were conceptualized and implemented.

RQ 3. How to operationalize an integrated learning design?

Appropriate visualizations and navigation paths were developed using the AEOLION framework and respective interfaces. The integrative arrangement of features makes for a combined and integrated view on features and data respectively. The implementation of flexible layouts (i.e., responsive user interface design) and the integration of Facebook enhance accessibility in various situations (e.g., stationary and mobile).

7.3.2. Outlook

The web-based learning application Ueber Learn together with the AEOLION framework are used as basis for both the technical analysis as well as empirical studies (cf. Chapters 8 and 9).
Part III.

Review & Evaluation
**Introduction**

Based on the theoretical findings presented in Part I and Part II of this work, Part III focuses on assessing the value of the proposed learning tool with respect to supporting self-regulated learning under the consideration of situative conditions. In Chapter 8, the learning tool is assessed based on the requirements including functional and non-functional aspects. The code structure as well as some statistics are presented additionally in order to give some technological insights of both the AEOLION framework and Ueber Learn. Chapter 9 describes the empirical findings from the usability testing and the application analysis. While the first study (usability testing) was concerned with gathering feedback early in the development process, the application analysis was intended to assess the value of the learning tool perceived by the user in a real-world usage scenario. Figure 7.5 shows the overall context of this part including the dependencies among the abovementioned chapters. The dotted lines show the relevance of findings from Part I and Part II in particular referring to the theoretical findings concerned with the situative perspective of self-regulated learning and the conceptualization in terms of development goals and requirements.

---

**Figure 7.5.:** Overall context of the evaluation
8. Technical Analysis

In this chapter, both, the AEOLION framework and Ueber Learn are evaluated with respect to technological characteristics and requirements. Section 8.1 presents a software architecture and design review focusing on the code structure and basic statistics, for instance, related to the distribution of code across the different plugins in the AEOLION framework. Section 8.2 then illustrates the completeness of implementation with respect to the requirements introduced in Part I. Both, functional and non-functional aspects are considered in this context (cf. Sections 8.2.1 and 8.2.2).

8.1. Software Architecture & Design Review

In this section, a software architecture and design review is presented for the proposed web-based learning tool, that is both the AEOLION framework and Ueber Learn. The code structures are analyzed as well as basic statistics are illustrated to give a general overview of the learning tool.

8.1.1. AEOLION Framework

The analysis of the AEOLION framework is mainly based on 4 different metrics describing not only the size of the framework with reference to the lines of code, but also regarding the number of classes, traits and messages used. The analysis is intended to give an overview on the size of the AEOLION framework, however, is not well suited to judge the complexity of the source code in terms of dependencies, algorithms, and so forth.

In total, the AEOLION framework has 15,118 lines of code (LOC) which are distributed across 8 different plugins, that is the kernel, the documents plugin, the interactions plugin, the notifications plugin, the workspaces plugin, the resources plugin, the server, and the utils plugin. The framework is structured based on 68 traits and 527 classes, the latter including a total of 163 messages used for the interaction among the kernel and the plugins. In terms of size, the kernel is considered the largest plugin in the AEOLION framework, consisting of 6,655 (44%) lines of code, 268 (51%) classes, 39 (57%) traits, and 82 (50%) messages. The documents and workspaces plugin are ranked second and third and, while almost equally ranked, are considered the second largest plugins.
in the AEOLION framework. With 2.633 (17%) and 2.264 (15%) lines of code both plugins make up 32% of the total number of lines of code. The same holds true for the number of classes and messages, that is 87 (18%)/19 (12%) and 57 (11%)/33 (20%). Only with respect to the number of traits, the interactions plugin is ranked between the documents and the workspaces plugin. The interactions and the resources plugin again are almost equally ranked, followed by the notifications plugin. The server and the utils plugin are ranked last since they only contain some basic definitions required for start up and help functions.

Focusing on the separate metrics, Figure 8.1 graphically shows the ratios of the separate plugins. Each metric therefore is represented as separate column, showing the plugins and their ratios. Alongside the ratios in the context of the individual ratios, the graph also shows that across the different metrics the ra-

Table 8.1.: Code statistics of the AEOLION framework

<table>
<thead>
<tr>
<th></th>
<th>LOC</th>
<th>Classes</th>
<th>Traits</th>
<th>Messages</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Kernel</strong></td>
<td>6.655 (44%)</td>
<td>268 (51%)</td>
<td>39 (57%)</td>
<td>82 (50%)</td>
<td>5.45%</td>
</tr>
<tr>
<td>Source</td>
<td>4.561</td>
<td>43 (16%)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>API</td>
<td>2.094</td>
<td>225 (23)</td>
<td>82</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Documents</strong></td>
<td>2.633 (17%)</td>
<td>87 (17%)</td>
<td>9 (13%)</td>
<td>19 (12%)</td>
<td>2.71%</td>
</tr>
<tr>
<td>Source</td>
<td>1.668</td>
<td>11 (3)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>API</td>
<td>965</td>
<td>79 (6)</td>
<td>19</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Interactions</strong></td>
<td>1.523 (10%)</td>
<td>54 (10%)</td>
<td>7 (10%)</td>
<td>16 (10%)</td>
<td>0.22%</td>
</tr>
<tr>
<td>Source</td>
<td>1200</td>
<td>18 (5)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>API</td>
<td>323</td>
<td>36 (2)</td>
<td>16</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Notifications</strong></td>
<td>518 (3%)</td>
<td>18 (3%)</td>
<td>5 (7%)</td>
<td>4 (2%)</td>
<td>2.18%</td>
</tr>
<tr>
<td>Source</td>
<td>410</td>
<td>9 (3)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>API</td>
<td>108</td>
<td>9 (2)</td>
<td>4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Workspaces</strong></td>
<td>2.263 (15%)</td>
<td>57 (11%)</td>
<td>4 (6%)</td>
<td>33 (20%)</td>
<td>6.10%</td>
</tr>
<tr>
<td>Source</td>
<td>1932</td>
<td>6 (3)</td>
<td>33</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>API</td>
<td>351</td>
<td>51 (1)</td>
<td>33</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Resources</strong></td>
<td>1.157 (8%)</td>
<td>33 (6%)</td>
<td>3 (4%)</td>
<td>9 (6%)</td>
<td>1.36%</td>
</tr>
<tr>
<td>Source</td>
<td>846</td>
<td>6 (1)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>API</td>
<td>311</td>
<td>27 (2)</td>
<td>9</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Server</strong></td>
<td>225 (1%)</td>
<td>2 (&lt;1%)</td>
<td>0 (0%)</td>
<td>-</td>
<td>0.70%</td>
</tr>
<tr>
<td><strong>Utils</strong></td>
<td>144 (1%)</td>
<td>8 (2%)</td>
<td>1 (1%)</td>
<td>-</td>
<td>0.71%</td>
</tr>
</tbody>
</table>

Focusing on the separate metrics, Figure 8.1 graphically shows the ratios of the separate plugins. Each metric therefore is represented as separate column, showing the plugins and their ratios. Alongside the ratios in the context of the individual ratios, the graph also shows that across the different metrics the ra-

1SD, short for standard deviation
tios approximately stay the same. Two exceptions, however, can be identified concerning the kernel and the workspaces plugin. The details of the analysis with respect to the deviation reveal that the number of messages is above average, which means that the kernel and the workspaces plugin provide a broad range of features to other plugins. This is feasible from an implementation perspective due to the following reasons:

- The kernel plugin represents the core of the AEOLION framework and provides the basic functionality for a wide range of different features (cf. Section 6). It not only is responsible for managing plugins, but also provides features for managing users and their sessions as well as for the persistence of artifacts. Due to this range of functions, the total number of messages is above average when compared with other plugins.

- The workspaces plugin is not at the core of the AEOLION framework, however, combines all other plugins developed in the context of this thesis (cf. Section 6.3). Most requests therefore get routed over the workspaces plugin before they are forwarded to other plugins which, for instance, are responsible for managing documents or resources. This requires the workspaces plugin to specify separate messages which in the course of processing get translated into messages defined by other plugins.

![Figure 8.1: Code statistics of the AEOLION framework](image)

Figure 8.1.: Code statistics of the AEOLION framework

---

2From a statistical perspective, the kernel and the workspaces plugin are the most diverse plugins due to their standard deviations of 5.45% and 6.10%.
Chapter 8. Technical Analysis

8.1.2. Ueber Learn

The analysis of Ueber Learn is mainly based on two aspects which are concerned with the AngularJS framework and the respective visualization components, that is HTML and SCSS. The analysis is intended to give an overview of the software architecture & design of the web application, in particular with respect to the AngularJS framework and applied design practices (e.g., HTML, SCSS, etc.).

JavaScript

Ueber Learn is a web-based application using AngularJS as the main framework. According to the framework, Ueber Learn is structured based on the MVC\textsuperscript{3} pattern including services and directives (model) as well as controllers.

− Services. Services provide access to data which is requested from the backend-server, that is the AEOLION framework. In total, 15 different services (2,730 lines of code) are defined, providing access to data such as users, interactions, workspaces, and so forth.

− Controllers. Controllers are the link between services (i.e., data) and the visualization components available in Ueber Learn. In total, 17 different controllers (3,230 lines of code) are defined, processing data so that the data structures match the requirements and needs for the visualization components.

− Directives. Directives are one specific construct provided by AngularJS, allowing to define custom attributes and tags which may then be used in HTML directly. During runtime these attributes and tags are interpreted and replaced with the corresponding constructs and values. In total, 10 different directives (1,004 lines of code) are defined.

Visualization & Styles

The visualization components are based on HTML and are matched with the specific data structures provided by the controllers. In total, 26 different HTML files (1,507 lines of code) are defined, specifying the layout of the different components such as the general dashboard or the private notes view in the context of a workspace.

\textsuperscript{3}Model-View-Controller
8.2. Review for Completeness

Alongside the HTML files, the corresponding style sheets are specified using SCSS. In total, 64 different SCSS files (4,451 lines of code) are defined, specifying the exact look and feel of the web application in terms of the arrangement of components, colors, and so forth.

8.2. Review for Completeness

In this chapter, both functional and non-functional requirements (cf. Section 5.3) are reviewed for completeness with respect to implementation. Each requirement bundle is assessed by means of its individual constituents, that is the specific features associated with the respective bundle. Non-functional requirements are evaluated accordingly.

The general structure of the learning tool with respect to its user interface is consistent across all functional and non-functional requirements. It is composed of three basic components, namely the main and contextual header as well as the main content area (cf. Figure 8.2), which can be described as follows:

- **Main header.** The main header is permanently displayed and provides the user with some basic information and functions on the current status of the active session. On the right, the user’s name is displayed besides the main menu. The main menu’s items are accessible by means of a drop-down menu and provide links to both the resource and the document manager as well as to the user’s profile and the logout button. Additional menu items providing links to administrative functions are provided for more privileged users. On the left, the home button always links to the landing page of the learning tool.

- **Contextual header.** The contextual header is permanently displayed as well, but unlike the main header, provides information and functions that may change depending on the contextual circumstances. Nevertheless, the header is always composed of a context descriptor and a contextual menu, the latter providing a list of functions which are available to the user in the current context. Figure 8.2, for instance, shows the landing page of the learning tool listing all workspaces available to the current user. The context descriptor informs the user that he or she is currently viewing the landing page, i.e., the dashboard. The contextual header on the right side contains a single function allowing to create new workspaces.

- **Main content area.** The main content area displays the actual content available to the current user in the respective contexts.
Chapter 8. Technical Analysis

Figure 8.2.: Basic user interface layout of Ueber Learn

8.2.1. Functional Requirements

In this section, the functional requirements are reviewed for completeness. The review process involves all requirement bundles introduced in Section 5.3 and is structured accordingly. Each requirement bundle, therefore, is assessed based on its individual features and tested on completeness in terms of implementation, the latter following the traceability matrix of functional requirements (cf. Section 5.3.3).

**Resource management [R]**  The resource manager provided by the learning tool allows managing static resources, such as PDF documents, ZIP files, MS Word documents, and so forth. It is accessible via the main menu and is available for any user. The following features are available to the user:

R1. *List/Access existing resource(s).* Existing resources, given the requesting user is granted read or write permissions, are presented to the user in a single flat list. In case the number of resources exceeds the available space on the screen, a scroll bar appears on the right-hand side of the box containing the list.

R2. *Upload a new resource.* A new resource can be uploaded by dragging and dropping a file from the local file system into the resources area on the screen. A pop-up window appears prompting for the title of the resource before the file eventually is uploaded.

R3. *Update the name of a resource.* Given the requesting user is granted write permissions, the name of an existing resource can be updated using the interactive title field in the resources list. The editing mode is activate and a cursor is displayed after clicking on the title of the resource to be
updated. Changes to the title are confirmed once the editing mode is left by clicking anywhere outside the title.

R4. Replace existing resource. Given the requesting user is granted write permissions, an existing resource can be replaced by clicking on New Revision. A pop-up window appears prompting the user to drag and drop the new file into the designated area. After doing so, the new file is uploaded by replacing the existing resource.

Figure 8.3 shows the interface of the resource manager as provided by the learning tool. In the main content area, existing resources are presented to the user in a single flat list. Each resource entry is divided into four parts, namely the preview, the title, some additional information, and the associated action items. The action items allow for opening and replacing a resource. An input field on top of the list is available for name-based filtering.

![Interface for managing resources](image)

Figure 8.3.: Interface for managing resources

**Document management [D]** The document manager provided by the learning tool allows managing interactive documents. It is accessible via the main menu and is available for any user. The following features are available to the user:

D1. List/Access existing document(s). Existing documents, given the requesting user is granted read or write permissions, are presented to the user in a single flat list. In case the number of resources exceeds the available space on the screen, a scroll bar appears on the right-hand side of the box containing the list.

D2. Create a new document. A new document can be created by clicking the plus symbol displayed in the contextual header. A pop-up window
Chapter 8. Technical Analysis

appears prompting for the title of the document before the document eventually is created.

D3. Update the title of a document. Given the requesting user is granted write permissions, the name of an existing document can be updated using the interactive title field in the documents list. The editing mode is activate and a cursor is displayed after clicking on the title of the document to be updated. Changes to the title are confirmed once the editing mode is left by clicking anywhere outside the title.

D4. Update the content of a document. Given the requesting user is granted write permissions, the content of a document can be updated using the editor accessible via the action items on the right-hand side of each document entry in the list. The editor provides a rich set of features supporting users to format and structure documents by means of different headings, font-weights, background colors, and so forth. A preview function is available to provide immediate feedback on the appearance of the document to the editing user.

Figure 8.4 shows the interface of the document manager as provided by the learning tool. In the main content area, existing documents are presented to the user in a single flat list. Each document entry is divided into two parts, namely the title and the action items. The action items allow for opening a document both in editing mode and the mode for typecasting of content. An input field on top of the list is available for name-based filtering.

Figure 8.4.: Interface for managing documents

Typecasting of content [T]  The learning tool provides users with an editor for typecasting the content of a document. This allows for enriching specific
8.2. Review for Completeness

parts of a documents with additional information, such as further information on the structure or type of content blocks.

T1. Typecast the content of a document. Given the requesting user is granted write permissions, the content of documents can be typecasted using the dedicated editor accessible via the action items displayed in the document manager (cf. Figure 8.4). Once a document is opened with the editor, the editing user is able to assign specific tags to each of the content blocks available in the document. Figure 8.5, for instance, shows that the tag Motivation is assigned to the first content block of the document on the introduction of knowledge management. By clicking on a content block, a pop-up window appears offering available tags to be used for assigning.

T2. Change representation mode of a document based on typecasts. Given the requesting user is granted read or write permissions, the representation of existing documents can be changed based on available typecasts associated with the individual content block. Users, for instance, can only view the introductory parts of a document while hiding all other parts (e.g., examples, explanations, etc.). For navigation purposes the headings remain visible.

Figure 8.5 shows the interface of the documents editor, in particular with respect to features concerned with the typecasting of content. In this view, the user is able to assign specific tags to each of the content blocks available in the document. Changes are saved and made available for further use automatically.

![Figure 8.5: Typecasting the content of a document](image)

**Interaction management** [I] The learning tool allows managing interactions among selected users. By this means, user are allowed to asynchronously in-
Chapter 8. Technical Analysis

interact with each other by publishing posts on their opinions to a specific topic or question. The learning tool, however, does not allow managing interactions apart from a designated workspace. This means that in order to create an interaction, a specific workspace is required serving as some kind of contextual foundation for the interaction.

I1. List/Access existing interaction(s). Existing interactions, given the requesting user is granted read or write permissions, are presented to the user in a single flat list on the left-hand side of the main content area. In case the number of interactions exceeds the available space on the screen, a scroll bar appears on the right-hand side of the box containing the list.

I2. Create a new interaction. A new interaction can be created by entering the title into the Create Interaction input field on the top of the list of interactions. Once the input is confirmed by pressing the enter key, the interaction is created and added to the list of existing interactions. Initially, no participants except the creating user is invited to participate.

I3. Update the title of an interaction. Given the requesting user is granted write permissions, the name of an existing interaction can be updated using the interactive title field displayed once an interaction is selected. The editing mode is activated and a cursor is displayed after clicking on the title of the interaction to be updated. Changes to the title are confirmed once the editing mode is left by clicking anywhere outside the title.

I4. Manage the participants of an interaction. Given the requesting user is granted write permissions, the participants of an interaction can be managed by using the action items on the right-hand side of the screen. Initially, no participants are assigned to the interaction. The plus and minus symbol are available for the user to assign and remove participants to/from the interaction.

I5. Publish a post in an interaction. Given the requesting user is granted read or write permissions, a new post can be published in an interaction using the editor displayed on top of the interaction thread. Both, text and images are supported by the editor. Images automatically are extracted and, besides the actual post, provided as a separate resources accessible via the resource manager.

I6. Archive a post contained in an interaction. Given the requesting user is granted write permissions, an existing post can be archived by using the Archive action item displayed in the drop-down menu accessible via the arrow symbol in the top right corner of the post. The post, however, is not deleted, but rather made inaccessible for future use.
8.2. Review for Completeness

Figure 8.6 shows the interface for managing interactions in the context of a specific workspace. On the left-hand side, existing interactions are presented to the user in a single flat list. By clicking on a specific entry, the respective interaction is loaded including its interaction thread, that is the list of associated postings. The list of participants can be managed using the controls on the right-hand side of the screen. The plus and minus symbol are available to either add or remove participants to/from the interaction. Each post is composed of different elements, that is information on the user, the publishing date, and the actual content. Further options are available via the drop-down menu accessible via the arrow symbol in the top right corner of the post. Users can select from a list of different options, such as to archive the post in order to make it inaccessible for future use.

![Management of interactions in the context of a workspace](image)

**Figure 8.6.: Management of interactions in the context of a workspace**

**Constant update of interaction threads** [C] The learning tool provides features which allow reducing users’ effort required for interacting with other users.

C1. *Automatically reload an interaction thread.* Given the requesting user is granted read or write permissions, an existing interaction thread is updated automatically when new posts are published. The refresh interval is started once an interaction is displayed in the main content area.

**Integration of Facebook** [FB] The learning tool allows to facilitate the learning process by integrating Facebook.
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FB1. Login using a user’s Facebook account. Authentication not only is allowed using the tool specific credentials, but also using Facebook as authentication provider. Using Facebook as authentication provider, however, is not activated initially, but needs to be setup by each user separately. For this, the user account needs to be connected with the respective user account on Facebook granting the learning tool the required privileges, such as to access the user’s personal wall or the managed groups.

FB2. List Facebook groups. Besides the interactions managed by the learning tool, Facebook groups are integrated into the interactions area of a workspace. Once a user account is connected with Facebook, available groups are loaded and display in the documents view as interaction (cf. Figure 8.7).

Figure 8.7. shows the interface for managing interactions in the context of a specific workspace. In contrast to Figure 8.6, however, groups available on Facebook are loaded and made accessible via the list of interactions. One can see that posts are displayed in the same style as posts from interactions on Ueber Learn.

Sharing of information [S] The learning tool allows sharing posts between interactions, both available in Facebook and the learning tool.

S1. Republish an existing post in another interaction. An existing post can be republished in another interaction by using the Share feature accessible via the context menu of the corresponding post. The requesting user must be granted write permissions on the post as well as read or write
permissions on the interaction. A pop-up window appears offering a list of interactions which are available to the user. After an interaction has been selected, the post is linked with it and displayed accordingly. Republishing an existing post in another interaction can be done either by the author or any other user who has been granted the respective privileges.

S2. Republish an existing post on Facebook. An existing post can be re-published on Facebook by using the Facebook feature accessible via the context menu of the corresponding post. The requesting user must be granted write permissions on the post as well as read or write permissions on the interaction. A pop-up window appears offering to specify the visibility of the post on Facebook (e.g., friends or public). Republishing an existing post on Facebook can be done either by the author or any other user who has been granted the respective privileges.

S3. Republish an existing post on Facebook in another interaction. An existing post from Facebook can be republished in another interaction by using the Share feature accessible via the context menu of the corresponding post. The requesting user must be granted read or write permissions on the interaction. After an interaction has been selected, the post is linked with it and displayed accordingly. Republishing an existing post from Facebook in another interaction can be done by any user who is allowed to access the interaction representing the respective user group.

Figure 8.8 exemplarily shows a specific post with particular focus on the different options which are provided to the author. The first and the last options do not refer to the requirement discussed in terms of sharing of information. They are listed under the requirements concerned with interaction and workspace management. The second and the third option, namely Share and Facebook, allow the author to share the specific post in another interaction and on Facebook respectively.

Workspace management [W] The learning tool allows managing workspaces including their configurations in terms of assigned resources, materials, and interactions.

W1. List/Access exiting workspace(s). Existing workspaces, given the requesting user is granted read or write permissions, are presented to the user in a single flat list on the general dashboard provided by the learning tool. In case the number of workspaces exceeds the available space, a scroll bar appears on the right-hand side of the box containing the list.

W2. Create a new workspace. A new workspace can be created by clicking the plus symbol displayed in the contextual header. A pop-up window
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Figure 8.8.: Action items allowing to republish an existing post on Facebook or in another interaction provided by the learning tool appears prompting for the title of the workspace before the workspace eventually is created.

W3. Update the availability of a workspace. Given the requesting user is granted write permissions, the availability of a workspace can be updated. In the case of being locked, the workspace is available for configuration but remains unaccessible for users with read permission only.

W4. Manage the participants of a workspace. Initially, a workspace is only available to its creating user. Given the requesting user is granted write permissions, the participants of a workspace can be managed by using the administration area of the workspace. Assigned to a workspace, the respective user also gets access to associated learning materials, such as resources and documents. A user can be removed from the list of participants at any point in time accessing the administration area of the workspace.

W5. Associate an existing document with a workspace. Documents are organized in the content section of a workspace and can be managed by either the creating user or any other user who has been granted the respective privileges (manager role). An existing document is added to a workspace by clicking the paper clip symbol on the left-hand side in the list of available materials (document section). A pop-up window appears offering the existing documents available to be attached. The selected document are added after the selection has been confirmed.

W6. Disassociate an existing document from a workspace. An existing docu-
8.2. Review for Completeness

A document is disassociated from a workspace by clicking the trash which appears after the document is selected and displayed in the main content area. A pop-up window appears asking for confirmation. Disassociating an existing document from a workspace can be done by the managing user of the workspace (manager role).

W7. **Associate an exiting resource with a workspace.** Resources are organized in the content section of a workspace and can be managed by either the creating user or any other user who has been granted the respective privileges (manager role). An existing resource is added to a workspace by clicking the paper clip symbol on the left-hand side in the list of available materials (resource section). A pop-up window appears offering the exiting resources available to be attached. The selected resources are added after the selection has been confirmed.

W8. **Disassociate an exiting resource from a workspace.** An existing resource is disassociated from a workspace by clicking the trash which appears after the resource is selected and previewed in the main content area. A pop-up window appears asking for confirmation. Disassociating an existing resource from a workspace can be done by the managing user of the workspace (manager role).

W9. **Add a new interaction to a workspace.** A new interaction can be added to a workspace by entering the title of the interaction. After the input has been confirmed by pressing enter, the interaction appears in the list below and is accessible for the creating user. New interactions can be added to a workspace by any user involved in the workspace (team member).

W10. **List posts published in groups on Facebook.** Postings published in groups on Facebook are loaded and displayed in the interactions view once the user has connected his or her account with Facebook. This is done in the profile section of the user menu and requires the user to allow the Facebook App to grant access to his or her details on Facebook. This in particular involves access to the user’s personal wall and groups.

W11. **Tag an existing post as content.** Existing posts can be tagged as content which makes it appear in the collected contents list (i.e., documents view). Tagging an existing post as content can be done by the managing user of the workspace (manager role).

Figure 8.9 shows the general dashboard provided by the learning tool which is presented to the user after successful login. The general dashboard lists all workspaces available to the user. Workspaces which have not been unlocked yet are marked with a lock symbol.

Figure 8.10 shows the main content area of a workspace. On the left-hand side,
Chapter 8. Technical Analysis

Figure 8.9.: General dashboard showing available workspaces

the main menu is structured by means of the three categories documents, resources, and content. The first and the second categories contain the documents and resources associated with the workspace. The last category subsumes all posts that have been marked as content.

Figure 8.10.: Content area of a workspace

Figure 8.11 shows the workspace settings which are available to the creating user or any other user who has been granted the respective privileges (manager role). The setting area is structured into two main sections, one responsible for the basic settings of the workspace (cf. Figure 8.11a) while the other one allows configuring the workspace team (cf. Figure 8.11b).

E-Mail notification [M] The learning tool proactively notifies users about updates concerning interaction threads and workspaces. In doing so, users
8.2. Review for Completeness

(a) Basic configuration options of a workspace

(b) Permission settings (i.e., member list) of a workspace

Figure 8.11.: Administration area of a workspace

are kept up to date without constantly check for new content provided by the learning tool.

M1. Notify users about new posts. Users are notified about new posts via e-mail. The notification is composed of different parts and contains not only the content of the post, but also context information, such as the author of the post or the workspace in which it has been published.

M2. Notify users about new workspaces. Users are notified about new workspaces via e-mail.
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Overview of Implementation

The review for completeness is presented in this section based on the traceability matrix of functional requirements (cf. Section 5.3.3). The requirement bundles are reviewed according to their individual features, indicating their availability (avail.) in terms of implementation and functionality as well as their accessibility according to the defined access permissions (cf. Table 8.2).

Table 8.2.: Review for completeness of functional requirements

<table>
<thead>
<tr>
<th>ID</th>
<th>Name</th>
<th>Avail.</th>
<th>R</th>
<th>W</th>
</tr>
</thead>
<tbody>
<tr>
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<td>List/Access existing resource(s)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>R2</td>
<td>Upload a new resource</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R3</td>
<td>Update the name of a resource</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>R4</td>
<td>Replace existing resource</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>D1</td>
<td>List/Access existing document(s)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>D2</td>
<td>Create a new document</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D3</td>
<td>Update the title of a document</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>D4</td>
<td>Update the content of a document</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>Typecast the content of a document</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>T2</td>
<td>Change presentation mode of a document based on typecasts</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>I1</td>
<td>List/Access existing interaction(s)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>I2</td>
<td>Create a new interaction</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I3</td>
<td>Update the title of an interaction</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>I4</td>
<td>Manage the participants of an interaction</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>I5</td>
<td>Publish a post in an interaction</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>I6</td>
<td>Archive a post contained in an interaction</td>
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<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>C1</td>
<td>Automatically reload interaction threads</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>FB1</td>
<td>Login using a user’s Facebook account</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FB2</td>
<td>List Facebook groups</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S1</td>
<td>Republish an existing post in another interaction</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>S2</td>
<td>Republish an existing post on Facebook</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

(Continued)
8.2. Review for Completeness

Table 8.2.: (Continued)

<table>
<thead>
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<th>Avail.</th>
<th>R</th>
<th>W</th>
</tr>
</thead>
<tbody>
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<td>✓</td>
<td>✓</td>
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<tr>
<td>W1</td>
<td>List/Access existing workspace(s)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>W2</td>
<td>Create a new workspace</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W3</td>
<td>Update the availability of a workspace</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>W4</td>
<td>Manage the participants of a workspace</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>W5</td>
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<td>✓</td>
</tr>
<tr>
<td>W6</td>
<td>Disassociate an existing workspace from a workspace 1)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>W7</td>
<td>Associate an existing resource with a workspace 1)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>W8</td>
<td>Disassociate an existing resource from a workspace 1)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>W9</td>
<td>Add a new interaction to a workspace</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>W10</td>
<td>List posts published in groups on Facebook</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>W11</td>
<td>Tag an existing post as content 1)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>M1</td>
<td>Notify users about new posts</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>M2</td>
<td>Notify users about new workspaces</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

8.2.2. Non-functional Requirements

In this section, the non-functional requirements are reviewed for completeness involving the extensibility and integration ability of the learning tool as well as the reusability of content across different contexts and usage scenarios (cf. Section 5.3.2). Each requirement is assessed whether it is supported by the learning tool and further illustrated by means of specific examples and use cases.

Extensibility [NF:E]

Extensibility refers to the continuous development of the tool and whether existing features and learning artifacts can be reused in contexts other than
Chapter 8. Technical Analysis

The AEOLION framework allows for the continuous development by providing a basic set of features to all plugins registered at the plugin manager. This in particular concerns the plugin life cycle management, the management of users and sessions (i.e., authentication and permissions), the dispatching mechanism (i.e., message routing), the management of unique identifiers, as well as the unified endpoint. These features are provided to any plugins in the context of the AEOLION framework and ensure the consistency across the different plugins, for instance with respect to the generation of unique identifiers.

Existing artifacts can be reused in contexts other than the original one since artifacts are represented by unique identifiers. It is guaranteed by a centralized component which is used to generate the sequence of unique identifiers. For instance, in case a new workspace is generated, the unique identifier used for the workspace is not generated by the plugin itself, but requested from the centralized component. Actually, the plugin does not even know the responsible actor, it only sends the respective message to the dispatcher and waits for the corresponding result.

The capability of being extensible in the given sense mainly refers to the AEOLION framework, since it is responsible for handling and processing data requests received from the user. The development of new features therefore primarily concerns the framework, and just from a visualization perspective relates to and triggers development effort on the part of the web-based learning application Ueber Learn.

The extensibility of the learning tool, for instance, is illustrated by means of workspaces which only provide limited functionality by itself but integrate features, such as interaction, document, and resource management. From a data representation perspective, workspaces therefore only link the respective entities. Listing 8.1 shows the JSON-based representation of a specific workspace which links related entities, such as associated interactions, notepads, and documents. Using role-based access privileges, associated entities (e.g., interactions) are evaluated and either approved or denied for access. Respective routines are provided by the responsible plugins.

Listing 8.1: JSON-based representation of a specific workspace

```json
{
  "data": {
    "id": 272163,
    "owner": 23,
    "created": 1480711068286,
    "state": "Available",
    "interactions": [8935, 8938, 8978, 8981, 10450],
    "notepads": [8938, 8978, 8981],
    "documents": [8932, 8933, 8934]
  }
}
```
Integration Ability [NF:1]

The ability to integrate refers to the learning tool as being adaptable to different contexts and usage scenarios. The following two aspects are supported:

- The learning tool, in particular the separation between front- and back-end services, allows for the adaptation to different context and usage scenarios. Since all features are abstracted using a REST-based endpoint, the front-end application is flexible in terms of being adapted to the requirements of a specific use case or scenario. For instance, if the usage scenario suggests interactions to be the starting point of the application, only the front-end needs to be adapted accordingly. The back-end server remains the same since no additional functionality is required.

- The learning tool allows other platforms or third-party tools to be integrated using one of two connection points or interfaces. First, external applications can be integrated by using the plugin mechanism provided by the AEOLION framework. The plugin then is equally entitled as compared to other plugins in the same context. The integration of a workflow engine, for instance, can be integrated using this mechanism. Second, external applications can be integrated by extending the front-end application directly. As already shown in the case of Facebook, the vendor-specific SDK\footnote{SDK, short for software development kit} was integrated to not only provide Facebook-based authentication, but also in order to exchange data (e.g., postings in a group).

According to the two different aspects described above, the ability to integrate mainly concerns the front-end application (e.g., learning tool), in particular with reference to being adaptable to different context and usage scenarios as well as the integration of other platforms and third-party tools. The latter, however, also concerns the AEOLION framework, since the integration can also be achieved at the level of the framework.

The ability to integrate is demonstrated on the one hand by separating of concerns, that is the isolated consideration of back-end and front-end functionality. This in particular is enabled by the REST-based endpoint which allows the integration of applications ranging from general purpose to highly specialized tools. The learning tool is considered a tool supporting situative self-regulated learning processes in the context of higher education. Listing\ref{lst:18.2} for instance,
Chapter 8. Technical Analysis

shows the endpoint available to retrieve interactions either in general or considering the context of a specific workspace, the latter only returning interactions which are linked to the workspace and approved for access by the requesting user.

Listing 8.2: GET requests for retrieving interactions

```plaintext
GET https://<ip>:<port>/api/interactions
GET https://<ip>:<port>/api/workspaces/<workspace-id>/interactions
```

On the other hand, the ability to integrate is shown by the seamless linking of Facebook, particularly concerning communication support through groups. Available groups on Facebook including associated posts are requested and commonly presented in the list of interactions (cf. Figure 8.7).

Reusability of Content [NF:U]

Reusability of content refers to the ability to reuse learning artifacts across different contexts and usage scenarios. The common representation format used by the AEOLION framework and Ueber LEARN fulfills this requirement. The underlying data structure makes use of respective patterns that ensure appropriate flexibility with respect to the different requirements of usage scenarios. Postings in the context of specific interactions, for instance, can be referenced and embedded in other learning artifacts (e.g., documents) for documentation purposes. Vice versa, content used in the context of specific documents (e.g., images) can be used as resources and in further consequence, for example, assigned to specific workspaces.

The reusability of content is demonstrated by means of a specific document or post, which both only serve as wrappers augmenting content with additional information, such as the title (document) or the associated interaction (post). Listing 8.3 shows that in either case the consistent representation of the associated content. In particular, it is demonstrated that both, the document and the post, reference the same content which consequently get resolved in different contexts. Hence, in case of the document, the content is presented as continuous text, while in the case of the post it is part of an interaction and therefore put into context by prior posts.

Listing 8.3: JSON-based representation of content to ensure reusability

```json
// representation of a document (output truncated)
{
  "id": 272242,
  "title": "Document name",
  "content": 57
}
```

180
8.3. Summary

In this chapter, both the AEOLION framework and Ueber Learn were evaluated and analyzed based on their code structure as well as with respect to the requirements identified in Section 5.3. In Section 8.1 the code structure as well as basic statistics were presented, in particular focusing on metrics such as code distribution across the different plugins or with respect to the organization according to MVC principles. Subsequently, in Section 8.2 the given requirements including functional and non-functional aspects were reviewed for completeness with respect to implementation.

8.3.1. Relevance of Findings

The findings presented in this chapter are concerned with the review for completeness. All requirement bundles were assessed with respect to their specifications (i.e., individual features) and tested by their functionality. The findings in further consequence provide the basis for the usability and application study respectively.

8.3.2. Outlook

The technical analysis is one of two parts of the evaluation and primarily focuses on the review for completeness of requirements. More specifically, both AEOLION and Ueber Learn were assessed from a static perspective, including

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MVC, short for model-view-controller
Chapter 8. Technical Analysis

aspects such as static code analysis, consistency checking, or tests for completeness. The latter, in particular, refers to the review for completeness and, therefore, checks whether the requirement bundles were implemented according to the specification of the associated features. The results allow performing the empirical study including the usability and application analysis.
9. Empirical Evaluation

In this chapter, the proposed web-based learning tool is evaluated with respect to its applicability and usefulness in the context of two specific learning scenarios, focusing on the usability of the learning tool and respective features (cf. Chapter 9.1) as well as the application analysis in the context of the development goals introduced as part of the requirements analysis (cf. Chapter 9.2). Section 9.3 eventually interprets the findings in the context of the development goals, including the three intellectual phases – idea generation, idea organization, and intellectual convergence – with regards to the cognitive, social, and teaching dimension.

From a methodological perspective, system design and implementation processes are highly intertwined with the evaluation including the identification and definition of respective evaluation criteria. Schwabe et al. (2012) in their paper on the development process of CSCL systems argue that system development needs to be adapted iteratively based on the results of formative evaluation processes. The summative assessment of the applicability and usefulness of the learning tool, therefore, is not sufficient since it only considers effects at the very end of the development (cf. Pfister & Wessner (2000); Schwabe et al. (2012)). Figure 9.1 exemplary shows the different activities and steps required in the development process and operations of CSCL systems. First and foremost, both, specifications of organizational conditions as well as principles of teaching and didactics are used to identify respective requirements. These requirements on a higher level describe the goals of the system and therefore the qualities with respect to applicability and usefulness for users. Specific use cases as well as learning and teaching scenarios respectively determine the design of the system in the second step. The implementation eventually leads to the actual system which then is taken into operation either in testing or live environments. Instead of passing through the process directly, however, several feedback loops are provided, which enable system designers and developers to constantly adapt and re-design the system according to user feedback.

The work in hand follows the same activities and steps as illustrated in the development process and operations of CSCL systems (cf. Figure 9.1). Both, specifications of teaching and didactics as well as organizational conditions were the main drivers for the identification of development goals and requirements (cf. Part I and Chapter 3.2). The requirements were then used as input for actual system design and implementation processes. Constant assessment cycles and feedback loops were in place in order to identify errors with respect to both the design and implementation of the system at an early stage. The
Chapter 9. Empirical Evaluation

Figure 9.1.: The development process and operations of CSCL systems (Schwabe et al., 2012, p. 300)

usability testing, in particular, is associated with activities and steps at this stage of development (cf. Section 9.1). Finally, the application analysis using the system in operation is considered relevant in the last step, providing respective feedback on both the specifications on teaching and didactics as well as organizational conditions (cf. Section 9.2).

9.1. Usability Testing

The evaluation concerned with the usability of the tool was conducted with a limited set of features in order to address potential design and implementation errors at an early stage of the development process. In this section, both the evaluation design and methodology (cf. Section 9.1.1) as well as the findings (cf. Sections 9.1.2 and 9.1.3) are presented.
9.1. Usability Testing

9.1.1. Evaluation Design & Methodology

The evaluation concerned with the usability of the learning tool was conducted on November 21, 2015 in the context of the graduate program on applied knowledge management at Johannes Kepler University in Linz. “The program is aimed at conveying theory-led, integral negotiation and decision-making skills which participants can effectively apply on the job or as responsible citizens within an aspiring knowledge-based society, qualifying them to effectively and efficiently deal with concepts, technology, and tools in knowledge management.” Participants from the eighth iteration of the program were selected to partake in the study.

The evaluation from a methodologically perspective was organized as follows. First, the learning tool in particular with respect to available features was introduced and presented in class to all participants. As a practical exercise, the participants were asked to log in and interact with each other using the interactions area. The participants then were organized into four groups of 3 members, where each of the groups had to work together on the following task for approximately 30 minutes. The task was composed of the following three main activities:

1. **Setting up the interaction space.** In order to ensure the availability of an appropriate working environment (collaboration, access permissions, etc.), the participants were asked to set up a group-specific interaction space. This procedure included (1) logging in, (2) navigating to the interactions area, (3) creating the group-specific interaction, and (4) inviting the other group members.

2. **Researching content.** Once the working environment was set up, the participants were asked to search for video footage where the 5th Discipline developed by Peter Senge is introduced and presented including the main components and thoughts. Although this activity is not directly concerned with the learning tool, the participants were required to document their findings using tool.

3. **Documenting results.** Finally, the participants were asked to document their findings using the learning tool, in particular the interaction space which was set up previously. They furthermore had to argue for their findings and present their rationale why they would consider the referenced video footage as valuable.

A set of features was identified prior to the study which was anticipated to be used in the course of processing the task. The respective features are described

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2. http://www.jku.at/content/e213/e86/e15478/e2904 (accessed on August 31, 2016)
Chapter 9. Empirical Evaluation

in the form of actions and are presented in the following:

A1. Logging in
A2. Finding and navigating to the respective workspace (W1)
A3. Finding and navigating to the interactions area (I1)
A4. Creating new interaction (I2)
A5. Inviting participants (I4)
A6. Searching for video footage
A7. Documenting video footage (I5)
A8. Documenting arguments (I5)
A9. Logging out

In the course of processing the task, the participants were asked to think-aloud in order to identify potential shortcomings of the learning tool and respective features. The spoken was recorded so as to ensure the assessment and evaluation at a later point in time, that is after the actual evaluation. In addition, screen-casts were recorded in order to get feedback on the usability of the learning tool, in particular with respect to the design and arrangement of features. From an evaluation perspective, the video footage was assessed considering the features which were anticipated to be used in the course of processing the task. When a new aspect (e.g., shortcoming of a feature, feature request, etc.) has been identified, the assessment was stopped at this point and started from the beginning considering the extended set of features and shortcomings respectively.

9.1.2. Presentation of Results

The results of the usability study are discussed in this section. For each group, the transcripts are presented including associated actions as well as comments relevant to the corresponding sections in the video.

Group 1

In the following, the results of group 1 are presented (cf. Table 9.1).

---

3Think-aloud protocols are used to gather data in usability testing environments, in particular supporting system design and development processes at an early stage (cf. Fonteyn et al. (1993)).

4Screen-casts, in particular in the context of computer-supported learning applications, are one potential approach to directly record and assess the usability of specific features (cf. Haake et al. (2012); Hans-Rüdiger (2012))
9.1. Usability Testing

Table 9.1.: Results of group 1

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
<th>Action</th>
<th>Commands</th>
</tr>
</thead>
<tbody>
<tr>
<td>00:00</td>
<td>14:24</td>
<td>A6</td>
<td>No comments</td>
</tr>
<tr>
<td>14:24</td>
<td>14:48</td>
<td>A1</td>
<td>No comments</td>
</tr>
<tr>
<td>14:48</td>
<td>15:11</td>
<td>A2</td>
<td>Confused by dashboard, workspace not found immediately</td>
</tr>
<tr>
<td>15:11</td>
<td>19:06</td>
<td>-</td>
<td>Private notes used in the course of preparation, feature for clickable links requested</td>
</tr>
<tr>
<td>19:07</td>
<td>19:11</td>
<td>A3</td>
<td>No comments</td>
</tr>
<tr>
<td>19:11</td>
<td>19:55</td>
<td>A4</td>
<td>No comments</td>
</tr>
<tr>
<td>19:55</td>
<td>22:37</td>
<td>A7/A9</td>
<td>Button to publish post not recognized immediately</td>
</tr>
<tr>
<td>22:37</td>
<td>23:06</td>
<td>A4</td>
<td>Feature for having list of users ordered alphabetically</td>
</tr>
<tr>
<td>23:06</td>
<td>23:16</td>
<td>A9</td>
<td>No comments</td>
</tr>
</tbody>
</table>

Group 2

In the following, the results of group 2 are presented (cf. Table 9.2). Due to the recording setup, the video was segmented into 2 parts, which are indicated in the results below.

Table 9.2.: Results of group 2

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
<th>Action</th>
<th>Commands</th>
</tr>
</thead>
<tbody>
<tr>
<td>00:00</td>
<td>00:12</td>
<td>A1</td>
<td>No comments</td>
</tr>
<tr>
<td>00:12</td>
<td>00:18</td>
<td>A2</td>
<td>No comments</td>
</tr>
<tr>
<td>00:18</td>
<td>00:21</td>
<td>A3</td>
<td>No comments</td>
</tr>
<tr>
<td>00:21</td>
<td>01:06</td>
<td>A4</td>
<td>No comments</td>
</tr>
<tr>
<td>01:06</td>
<td>01:30</td>
<td>A5</td>
<td>Feature for having list of users ordered alphabetically</td>
</tr>
<tr>
<td>01:30</td>
<td>02:12</td>
<td>-</td>
<td>Separate interaction for reporting bugs created</td>
</tr>
</tbody>
</table>

(Continued)
### Chapter 9. Empirical Evaluation

#### Table 9.2.: (Continued)

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
<th>Action</th>
<th>Commands</th>
</tr>
</thead>
<tbody>
<tr>
<td>02:12</td>
<td>03:53</td>
<td>A7/A8</td>
<td>No comments</td>
</tr>
<tr>
<td>03:53</td>
<td>04:10</td>
<td>-</td>
<td>User state (online/offline) recognized</td>
</tr>
<tr>
<td>04:10</td>
<td>04:18</td>
<td>A6</td>
<td>No comments</td>
</tr>
<tr>
<td>04:18</td>
<td>04:49</td>
<td>-</td>
<td>User changed, navigated to created interaction</td>
</tr>
<tr>
<td>04:49</td>
<td>05:06</td>
<td>-</td>
<td>Confused by not having owner and own user shown in list of participants</td>
</tr>
<tr>
<td>05:06</td>
<td>05:19</td>
<td>-</td>
<td>Feature for clickable links requested</td>
</tr>
<tr>
<td>05:19</td>
<td>06:02</td>
<td>A6</td>
<td>No comments</td>
</tr>
<tr>
<td>00:00</td>
<td>01:49</td>
<td>-</td>
<td>Feature for clickable links requested</td>
</tr>
<tr>
<td>01:49</td>
<td>02:08</td>
<td>A9</td>
<td>No comments</td>
</tr>
<tr>
<td>02:08</td>
<td>02:35</td>
<td>A1</td>
<td>Multiple login works</td>
</tr>
<tr>
<td>02:35</td>
<td>02:40</td>
<td>A2/A3</td>
<td>No comments</td>
</tr>
<tr>
<td>02:40</td>
<td>03:05</td>
<td>A3</td>
<td>Navigated through various interactions, other interactions recognized</td>
</tr>
<tr>
<td>03:04</td>
<td>03:33</td>
<td>A5</td>
<td>List of participants could be changed without being owner</td>
</tr>
<tr>
<td>03:33</td>
<td>04:45</td>
<td>A3</td>
<td>No comments</td>
</tr>
<tr>
<td>04:45</td>
<td>04:50</td>
<td>A9</td>
<td>No comments</td>
</tr>
</tbody>
</table>

#### Group 3

In the following, the results of group 3 are presented (cf. Table 9.3).

#### Table 9.3.: Results of group 3

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
<th>Action</th>
<th>Commands</th>
</tr>
</thead>
<tbody>
<tr>
<td>00:00</td>
<td>00:23</td>
<td>A1</td>
<td>No comments</td>
</tr>
<tr>
<td>00:23</td>
<td>18:05</td>
<td>A5</td>
<td>No comments</td>
</tr>
<tr>
<td>18:05</td>
<td>18:15</td>
<td>A2</td>
<td>No comments</td>
</tr>
</tbody>
</table>

(Continued)
9.1. Usability Testing

### Table 9.3.: (Continued)

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
<th>Action</th>
<th>Commands</th>
</tr>
</thead>
<tbody>
<tr>
<td>18:15</td>
<td>18:33</td>
<td>A3</td>
<td>First navigated to materials section (collected materials)</td>
</tr>
<tr>
<td>18:33</td>
<td>18:55</td>
<td>A4</td>
<td>No comments</td>
</tr>
<tr>
<td>18:55</td>
<td>19:34</td>
<td>A6/A7</td>
<td>Formatting meta data included after copy/paste from YouTube, button to publish post not recognized immediately</td>
</tr>
<tr>
<td>19:34</td>
<td>20:15</td>
<td>A4</td>
<td>Feature for selecting all participants requested</td>
</tr>
<tr>
<td>20:15</td>
<td>20:43</td>
<td>-</td>
<td>Discussion about where to publish video footage (collected materials), after testing “mark as content” (error message appeared saying no permissions) group recognized that this would be moderated content</td>
</tr>
<tr>
<td>20:43</td>
<td>23:00</td>
<td>-</td>
<td>Feature for clickable links requested</td>
</tr>
<tr>
<td>23:00</td>
<td>30:39</td>
<td>A5</td>
<td>No comments</td>
</tr>
<tr>
<td>30:39</td>
<td>36:01</td>
<td>A7</td>
<td>No comments</td>
</tr>
</tbody>
</table>

### Group 4

In the following, the results of group 4 are presented (cf. Table 9.4).

### Table 9.4.: Results of group 4

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
<th>Action</th>
<th>Commands</th>
</tr>
</thead>
<tbody>
<tr>
<td>00:00</td>
<td>12:33</td>
<td>A6</td>
<td>No comments</td>
</tr>
<tr>
<td>12:33</td>
<td>12:54</td>
<td>A1</td>
<td>No comments</td>
</tr>
<tr>
<td>12:54</td>
<td>13:23</td>
<td>A2</td>
<td>Confused by dashboard, workspace not found immediately</td>
</tr>
<tr>
<td>13:23</td>
<td>14:29</td>
<td>A3</td>
<td>Discussion about where to publish video footage (collected content)</td>
</tr>
<tr>
<td>14:29</td>
<td>15:24</td>
<td>A4</td>
<td>No comments</td>
</tr>
<tr>
<td>15:24</td>
<td>15:40</td>
<td>A5</td>
<td>No comments</td>
</tr>
</tbody>
</table>

(Continued)
Table 9.4.: (Continued)

<table>
<thead>
<tr>
<th>From</th>
<th>To</th>
<th>Action</th>
<th>Commands</th>
</tr>
</thead>
<tbody>
<tr>
<td>15:40</td>
<td>17:25</td>
<td>A7/A8</td>
<td>No comments</td>
</tr>
<tr>
<td>17:25</td>
<td>17:41</td>
<td>-</td>
<td>Feature request for clickable links</td>
</tr>
<tr>
<td>17:41</td>
<td>24:04</td>
<td>A7</td>
<td>No comments</td>
</tr>
<tr>
<td>24:04</td>
<td>26:27</td>
<td>A5</td>
<td>No comments</td>
</tr>
<tr>
<td>26:27</td>
<td>28:13</td>
<td>-</td>
<td>Unclear about implications when removing</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>user from list of participants (restriction</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>with respect to accessible posts, etc.)</td>
</tr>
<tr>
<td>28:13</td>
<td>28:57</td>
<td>-</td>
<td>Feature request for clickable links</td>
</tr>
<tr>
<td>28:57</td>
<td>33:30</td>
<td>-</td>
<td>Feature request for inserting images (post)</td>
</tr>
</tbody>
</table>

9.1.3. Identification of Improvement Measures

In general, all groups were able to accomplish the given task using the features anticipated prior to the study. Variations in terms of execution order could be identified. The execution order, however, is not considered relevant in the context of this study and therefore not further assessed with respect to the identification of measures. In the following, the identified measures are presented:

- **Clickable links.** Clickable links were requested by all groups during the evaluation. In particular when referencing external sources (e.g., videos on YouTube), clickable links would increase the usability of the learning tool.

- **List of users sorted alphabetically.** The list of users when granting or revoking permissions to an interaction was requested to be sorted alphabetically. In particular when having a large number of users available for selection, alphabetical order would increase the usability of the learning tool.

- **Increase visibility of button for publishing posts.** Users showed difficulties with respect to publishing posts since the designated button did not attract sufficient attention. Reconsidering the positioning of the input field and button respectively as well as the coloring would increase the usability of the learning tool.
9.2. Application Analysis

− Show all interaction participants. Difficulties became obvious with respect to the participants assigned to an interaction. Showing all participants, including the owner of the interaction as well as the own user, would increase the usability of the learning tool.

− Only interaction owner can change participants. Other users than the owner could change the list of participants. Restricting the permission to the owner only would increase the usability of the learning tool.

− Discard meta data when inserting content into input field for publishing posts. Copying external content led to inconsistencies related to the representation of content, in particular since the editor did not allow adaptations with respect to the formatting. Discarding all meta data therefore would ensure the consistent representation of content available in the context of the learning tool.

9.2. Application Analysis

The application analysis mainly is concerned with assessing the value of the learning tool perceived by the user. Both, the evaluation design and methodology (cf. Section 9.2.1) as well as the findings are presented (cf. Section 9.2.2).

9.2.1. Evaluation Design & Methodology

The evaluation was conducted in the context of the application-oriented course Communications Engineering (CE UE) which is concerned with concepts and methods for the design of distributed and interactive systems in organizational contexts. According to the official curriculum\footnote{https://lss.jku.at/studienhandbuch/60377 (accessed on January 4, 2017)} the objectives are defined as enabling “[students to] distinguish between organizational, technical, and human resource requirements and to utilize elaborated procedures and methods for distributed information processing. [Students] not only have analytical skills, but also have the ability to work in an integrated and reflective way.” Offered at Johannes Kepler University in Linz every other semester (winter term), the course is taught in parallel with the theoretical lecture (CE VL) on the foundations of the corresponding subjects.

Pedagogically, both courses are designed to be intertwined with respect to both the time schedule and the content respectively (cf. Figure 9.2). In this year’s schedule, the dates for CE VL were set in a range between October 4, 2016 and December 3, 2016. Starting on October 4, the lecture is organized based
Chapter 9. Empirical Evaluation

on four subject areas dealing with topics on computer networks, models for distributed communication, enterprise architecture, and work design. Each of the topics covered in the lecture is assigned a separate exercise, also referred to as atelier, which is elaborated in the course of CE UE. Since the respective ateliers are based on the theoretical contents taught in CE VL, the first atelier does not start at the same time but is shifted backwards until the next subject area is covered. For instance, while covering the second subject area in CE VL, the first atelier is elaborated which is composed of different tasks related to the first subject area. In general, each atelier starts not until the theoretical foundations have been taught in the CE VL.

From a pedagogical perspective, each atelier follows the same design and is composed of three to four separate tasks, each of which is dedicated to a specific problem area. Each task is presented in a consistent manner which not only includes the description of the task, but also the goal required prior knowledge, suggestions for documentation, an estimated effort, as well some guidance for self-testing. These aspects are discussed in the following:

− **Goal.** This section describes the educational goal based on which the actual task is defined. It provides information on one’s capabilities after successful task completion.

− **Prior Knowledge.** This section refers to particular chapters in the lecture manuscript. Chapters referenced in this section are considered relevant for task completion.

− **Task.** This section contains the actual task description. It provides appropriate information on the scope of the task as well as a list of requirements to be accomplished for successful task completion.

− **Documentation.** This section provides guidance for documenting the processing of the task as well as its results. Different strategies are described as means to express and document gained knowledge in the form of educational artifacts, such as documents.
9.2. Application Analysis

- **Estimated Effort.** This section gives an estimate of the effort required for successful task completion.

- **Self-testing.** This section provides guidance to test whether the capabilities required for successful task completion has been acquired or not. Different strategies are described as means to support these self-testing procedures.

The evaluation conducted in the course of this thesis was focused on the second atelier covering models for distributed communication. This restriction was due to three main reasons. At first, students were able to accustom with the pedagogical design of ateliers in general. Since the structure was consistent across all ateliers, the cognitive effort required to become acquainted with the descriptions of tasks could be reduced (cf. Section 2.2.2 on Cognitive Load Theory). The second reason is concerned with the tasks itself. In comparison to tasks from the other ateliers, the second atelier provided a specific focus on programming tasks, meaning that students had to work on small applications which helped them to develop competences in the implementation of low-level request-/response protocols, web-services, and a distributed actor system using message-based communication approaches. Due to this, students were supported in their communication and collaboration since source code can be shared more easily (source code, code snippets, etc.) than, for instance, comprehensive models which are created using modeling tools such as ArchiMate\(^6\). Finally, focusing the evaluation on the second atelier enabled to measure self-regulated learning in the context of an event, allowing to link experience reports with specific conditions, such as the task or the group work. This approach, in particular, differs from other approaches in that it does not intend to measure self-regulated learning as aptitude, but rather measures behavior in the context of specific events or conditions ([Endedijk et al.]\(^7\), 2016).

Covering the subject area on models for distributed communication, the second atelier includes tasks related to topics on low-level network communication, Web services, and distributed actor systems using message-based communication. These tasks are described in the following:

1. **Low-level network communication using sockets.** The goal of this task is to enable students to implement simple and stateless request-/response protocols using Plain Old Java Objects (POJOs). In this regard, students get to know the possibilities and limitations with respect to the serialization of Java objects.

2. **Simple object access protocol.** The goal of this task is to enable students to interpret Web services by means of their interface descriptions and to integrate those in client applications. In this regard, students get to

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\(^6\)http://www.opengroup.org/.../archimate (accessed on January 4, 2017)

\(^7\)The full length description of the tasks can be found in the appendix (cf. Appendix B.1).
know the possibilities and limitations with respect to the provision and discovery of Web services based on directory services.

3. **Transparent communication using distributed actor systems.** The goal of this task is to enable students to implement distributed systems using an actor-based approach. In this regard, students get to know the possibilities and limitations of message-based systems and get qualified to distinguish those from other implementation strategies.

### Learning Materials

To begin with, the students were provided with a set of learning materials including the description of tasks, the lecture notes covering the related subject areas on computer networks and models for distributed communication, a code framework, and a guide explaining the features of the learning tool.

- **Description of tasks.** The description of tasks was provided specifying the requirements to be implemented.

- **Lecture notes.** The lecture notes from CE VL were provided covering the subject areas on computer networks and models for distributed communication. With this, students were able to revisit not only the basic in computer networks, for instance, with respect to the technical fundamentals, the layer model, the Ethernet standard, or the Internet protocol (IP), but also were provided with the required conceptual learning materials in the context of models for distributed communication, the latter covering topics on, for instance, communication and distribution patterns, network communication abstraction, remote procedure calls (RPC), or Web services.

- **Code framework.** A code framework was provided supporting students in the basic setup of an application integrating Web services made available through an external service provider. As a consequence, students were able to focus on the task itself, rather than spending time with workspace setup routines which are not related to the actual tasks.

- **Guide to the learning tool.** A guide was provided in order to support students in using the features of the learning tool. The guide was covering the functional areas related to the workspace, document, and resource management.
9.2. Application Analysis

Setup of the Learning Tool

For the evaluation, the students were granted access to a dedicated instance of the learning tool. This not only was advantageous with respect to the performance and availability of the learning tool, but also provides better support for data analyses due to the separated management of databases. In the following, the specific setup of the learning tool which was used during evaluation is described:

- **Permissions.** In terms of permissions, the learning tool was setup so as to provide the most flexibility to the students. This, in particular, means that the students were granted to not only participate in existing workspaces, but also to organize their work by being able to create and manage new workspaces. All other features provided by the learning tool were setup according to their inherent permission structure. For instance, the user creating a new interaction in the context of a specific workspace needs to

- **Integration of Facebook.** In addition to the features provided by the learning tool itself, the Facebook integration was enabled also. Students therefore were able to login using their Facebook credentials. More importantly, however, discussions among students were facilitated both by the learning tool and in the context of specific groups on Facebook. Dedicated features ensured that the interaction results could be reintegrated seamlessly with events in the context of the learning tool. For instance, students were able to import specific contributions on Facebook into interactions managed by the learning tool.

- **Notifications.** In addition to Facebook which continually informs their users on any kind of news, the learning tool was setup so as to send out notification e-mails based on specific events. For instance, once a user had created a new workspace, all assigned team members were notified via a dedicated e-mail.

Working Groups

In total, 29 students took part in the study and were organized into 4 groups of 6 and 1 group of 5, each of which was collaboratively working on the given tasks. The study progress among participants was nearly consistent, since they were recruited in the course on distributed systems (Communications Engineering), which is scheduled in the 5th semester of the program Business Information Systems.

Since age is considered an important aspect with respect to social media use
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(cf. Correa et al. (2010)), the demographics of each group in this regard are as follows. The minimum and maximum age was 20 and 42 respectively. The mean age was 23. The age range of the groups were between 21 and 30 (group 1), 20 and 35 (group 2), 21 and 22 (group 3), 21 and 27 (group 4), and 20 and 42 (group 5). The mean age was 27 (group 1), 26.5 (group 2), 22 (group 3), 22.5 (group 4), and 23.5 (group 5). Sufficient awareness and/or experience with respect to social media therefore is presumed. Table 9.5 shows the abovementioned group characteristics.

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Min. Age</th>
<th>Max. Age</th>
<th>Mean Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1</td>
<td>6</td>
<td>21</td>
<td>30</td>
<td>27</td>
</tr>
<tr>
<td>Group 2</td>
<td>6</td>
<td>20</td>
<td>35</td>
<td>26.5</td>
</tr>
<tr>
<td>Group 3</td>
<td>5</td>
<td>21</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>Group 4</td>
<td>6</td>
<td>21</td>
<td>27</td>
<td>22.5</td>
</tr>
<tr>
<td>Group 5</td>
<td>6</td>
<td>20</td>
<td>42</td>
<td>23.5</td>
</tr>
</tbody>
</table>

Event-based Measurement of Self-regulated Learning

As described in the conceptual models of Pintrich et al. (2000) and Zimmermann (2000), self-regulated learning is composed of three main phases, that is the forethought phase, the performance phase, and the self-reflection phase. Endedijk et al. (2016) follow this conceptualization and propose a questionnaire for measuring self-regulated learning. In contrast to other approaches, however, they do not measure self-regulated learning by means of de-contextualized self-reports but focus on instruments based on a specific event. Based on the findings of a review study published by Dinsmore et al. (2008), they argue for event-based measures since learners more likely have in mind specific situations to which they reference when completing the study (e.g., questionnaire). In the context of this work, event-based measures are regarded more suitable since the actual value of the learning tool in the context of the collaborative processing of given tasks (i.e., event) is at the core of the study. Endedijk et al. (2016, p. 4) further emphasize event-based instruments in this context, stating that they are “[. . . ] more suitable for finding relations between specific aspects of real time self-regulated learning in authentic contexts.”

*Each of the participants except one had an active account on Facebook prior to the evaluation.

Winne & Perry (2000) classify instruments for measuring self-regulated learning into two different categories, namely instruments that measure self-regulated learning as an aptitude or based on a specific event.
9.2. Application Analysis

The study presented in this work is based on the open question learning report developed and proposed by [Endedijk et al. (2016)]. Assessing self-regulated learning based on a specific event, the questions encompass the three main phases of self-regulated learning, namely the forethought, the performance, and the self-reflection phase. The forethought phase, also referred to as metacognitive knowledge by [Pintrich et al.], is considered an entering metacognitive state and, compared to the constructs associated with the performance phase, relatively static ([Akyol & Garrison, 2011]). It not only concerns knowledge of cognition and cognitive strategies, but also knowledge of the self as well as of the tasks and the respective contexts. Questions Q2 to Q4 from the questionnaire are associated with this phase and cover the aspects related to goal orientation, sources of self-efficacy, and strategic planning. Q4 on strategic planning is complemented with the Questions Q4.1 to Q4.6, allowing to further detail the usefulness of features provided by the learning tool.

Q2. Did you plan to learn this, and if so, why did you want to learn this?

This question is concerned with the actual goal of learning and the factors which are responsible for the motivation to learn a specific subject. Relevant factors include but are not limited to judgments of current situations and learning goals or direction of growth with respect to the learning goal.

Q3. Did you expect to succeed in learning this and what made you think you would (not) succeed in learning this?

This question is concerned with sources of self-efficacy. Relevant factors include but are not limited to experiences with learning objects, learning strategies, or learning contexts.

Q4. How did you learn this?

This question is concerned with the strategic planning. Relevant factors include but are not limited to reflection and evaluation of learning processes or the level of interaction and feedback.

Q4.1. Did the learning tool support you in your learning processes, and if so, which features were especially useful and how did you use them?

Q4.2. Are there any features that would have supported you better in your learning process, and if so, which features would have been especially useful?

Q4.3. Did the provided learning materials help you in your learning process, and if so, which ones were especially useful?

Q4.4. Are there any further learning materials that would have helped you
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better, and if so, which ones would have been especially useful?

Q4.5. Did the group work support you, and if so, how did you observe this?

Q4.6. Did Facebook help you, and if so, how did you use it?

The performance phase, also referred to as metacognitive judgments and monitoring by Pintrich et al., is considered more dynamic in the inquiry process as compared to the forethought phase (Akyol & Garrison, 2011). It concerns the assessment of tasks with respect to their levels of difficulty, comprehension monitoring of learning, self-assessment, and confidence of judgments. Questions Q5 and Q6 from the questionnaire are associated with this phase and cover the aspects related to learning strategy control and monitoring of the learning results. Q6 on monitoring of learning results is complemented with the Questions Q6.1 to Q6.4, allowing to further detail the usefulness of features provided by the learning tool.

Q5. Why did you learn it in this way?

This question is concerned with the control of learning strategies. Relevant factors include but are not limited to the way of teaching, arguments for specific learning strategies, or provided instructions.

Q6. How did you realize that you had learned something?

This question is concern with the monitoring learning results. Relevant factors include but are not limited to reflection processes on own performance, experiences of what works, or reflection on information provided by others.

Q6.1. Did the description of tasks help you realize that you had learned something, and if so, which statements were especially useful?

Q6.2. Is there anything that would have helped you better realize that you had learned something, and if so, what would have been especially useful?

Q6.3. Did the collaborative elaboration of tasks help you realize that you had learned something, and if so, how did you observe this?

Q6.4. Did discussions help you realize that you had learned something, and if so, how did you observe this?

The self-reflection phase, also referred to as self-regulation and control by Pintrich et al., concerns the planning of activities, the selection and use of strategies, the allocation of resources, and volitional control. Questions Q1, Q7, and
Q8 from the questionnaire are associated with this phase and cover the aspects related to self-reflection on the learning outcome, self-evaluation of the learning experience, and inferences for subsequent learning experiences. Q1 on self-reflection on the learning outcome is complemented with the Questions Q1.1 and Q1.2, allowing to further detail whether the description of tasks was helpful or not. In addition, Q8 on inferences for subsequent learning experiences is complemented with the Questions Q8.1 to Q8.3, allowing to further detail the usefulness of features provided by the learning tool.

Q1. What did you learn?

This question is concerned with the self-reflection on the learning outcome. Relevant factors include but are not limited to the learning experience or teaching practices.

Q1.1. Did the description of tasks help you, and if so, which statements were especially useful?

Q2.2. Is there anything what would have helped you better elaborate the tasks, and if so, what would have been especially useful?

Q7. If you look back, are you completely satisfied, or what would you do differently next time?

This question is concerned with the self-evaluation of learning experience. Relevant factors include but are not limited to the evaluation of learning strategies or learning contexts, learning processes which are under control of others, or the evaluation of learning content.

Q8. How will you proceed with this learning experience?

This question is concerned with the inference for subsequent learning experiences. Relevant factors include but are not limited to the consolidation of learning experiences and results or the application of the learned to practice.

Q8.1. Did the elaboration of tasks qualified you to successfully apply the learned, and if so, how did you observe this? If not, what was missing?

Q8.2. Did the learning tool support you in preparing the learned for further application, and if so, which features were especially useful and how did you use them?

Q8.3. Are there any features that would have helped you better in documenting the learned, and if so, which features would have been especially
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useful?

The questions presented above were translated for presentation purposes. The questionnaire used for the evaluation (i.e., German translation) is included in the appendix (cf. Appendix B.2).

9.2.2. Presentation of Results

In this section, the results of the evaluation are presented. Methodologically, the data was evaluated based on the qualitative content analysis \(\text{[Mayring, 2015]}\). The individual statements of each question were extracted and paraphrased. The statements were reduced so that just the relevant content remained in a short form. In preparation for comparison, the paraphrases then were generalized to a common abstraction level. The deduction of categories eventually led to the categorization of statements and therefore the results of questions presented in this chapter.
Q1. What did you learn?

Question 1 is concerned with what one has learned during elaboration of the tasks. This question is part of the questionnaire on self-regulated learning and covers the dimension of self-reflection on the learning outcome. In total, 19 different statements have been identified including aspects related, for instance, the use of technologies, conditions for collaboration, or relationships between technologies. 42.11% (8 out of 19) of the statements are subsumed under the first category which is related to how technology was applied in the context of the tasks’ scenarios. The second most category with 21.05% (4 out of 19) of all statements relates to conditions for collaboration, that is the importance of communication, the reliability of team members, or the organization of work. With 10.53% (2 out of 19) of all statements both the relationships between technologies and collaboration in itself was states by the students as learning outcome. With 5.26% (1 out of 19) of all statements students’ were referring to consequences of using new technologies and the lack of new insights in terms of learning support. Finally, 5.26% (1 out of 19) of all statements have been identified irrelevant in the context of this question.

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of technologies</td>
<td>8</td>
<td>42.11%</td>
</tr>
<tr>
<td>Conditions for collaboration</td>
<td>4</td>
<td>21.05%</td>
</tr>
<tr>
<td>Relationships between technologies</td>
<td>2</td>
<td>10.53%</td>
</tr>
<tr>
<td>Collaboration</td>
<td>2</td>
<td>10.53%</td>
</tr>
<tr>
<td>Consequences of using new technologies</td>
<td>1</td>
<td>5.26%</td>
</tr>
<tr>
<td>No new insights in terms of learning support</td>
<td>1</td>
<td>5.26%</td>
</tr>
<tr>
<td>No specific answer</td>
<td>1</td>
<td>5.26%</td>
</tr>
</tbody>
</table>
Chapter 9. Empirical Evaluation

Q1.1. Did the description of tasks help you, and if so, which statements were especially useful?

Question 1.1 is concerned with the description of tasks and whether it helped students during elaboration. In total, 23 different statements have been identified including aspects related to, for instance, the comprehensibility of requirements, the code framework, or prior knowledge which was recognized as helpful for self-assessment and further research. 21.74% (5 out of 23) of all statements indicated that the provided description of tasks was helpful during elaboration. However, no further details were stated which could have given some indication of what was particularly helpful. 17.39% (4 out of 23) of all statements indicated that the description of tasks was not helpful during elaboration. Similarly to the first category, also not further details were stated which could have given some indication of why the description was not helpful. With 13.04% (3 out of 23) of all statements the description was helpful since the requirements of the tasks were clearly stated and comprehensible. With 8.70% (2 out of 23) of all statements students’ refer to the code framework and requirements in terms of prior knowledge as particularly helpful. The section related to the requirements on prior knowledge, especially, was useful for self-assessment and further research. With 4.35% (1 out of 23) of all statements students’ were supported by the description with respect to understanding the goals of the tasks. Similarly, with 4.35% (1 out of 23) of all statements the description of tasks was insufficient. Finally, 13.04% (3 out of 19) of all statements have been identified irrelevant in the context of this question.

Table 9.7.: Results of question Q1.1

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes without argumentation</td>
<td>5</td>
<td>21.74%</td>
</tr>
<tr>
<td>No without argumentation</td>
<td>4</td>
<td>17.39%</td>
</tr>
<tr>
<td>Yes due to comprehensible requirements</td>
<td>3</td>
<td>13.04%</td>
</tr>
<tr>
<td>No specific answer</td>
<td>3</td>
<td>13.04%</td>
</tr>
<tr>
<td>Code framework for development</td>
<td>2</td>
<td>8.70%</td>
</tr>
<tr>
<td>Prior knowledge helpful for self-assessment</td>
<td>2</td>
<td>8.70%</td>
</tr>
<tr>
<td>Prior knowledge helpful for further research</td>
<td>2</td>
<td>8.70%</td>
</tr>
<tr>
<td>No due to additional needs for learning materials</td>
<td>1</td>
<td>4.35%</td>
</tr>
<tr>
<td>Description of tasks helpful for understanding of goals</td>
<td>1</td>
<td>4.35%</td>
</tr>
</tbody>
</table>
Q1.2. Is there anything that would have helped you better to elaborate the tasks, and if so, what would have been especially useful?

Question 1.2 is concerned with the shortcomings related to the description of tasks. In total, 20 different statements have been identified including aspects related to, for instance, the details of the description or the provision of exercises and application examples. 35% (7 out of 20) of all statements ask for a more detailed description of tasks in terms of instructions. With 10% (2 out of 20) of all statements in each case students’ stated that additional links to learning materials and further input for self-assessment would have been helpful. 5% (1 out of 20) of all statements ask for additional input in the form of exercises and application examples. 15% (3 out of 20) of all statements stated that the provided description of tasks was helpful and sufficient in terms of level of detail. However, no further details were stated which could have given some indication of what was particularly helpful. Finally, 25% (5 out of 20) of all statements have been identified irrelevant in the context of this question.

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>More detailed description of tasks and instructions</td>
<td>7</td>
<td>35.00%</td>
</tr>
<tr>
<td>No specific answer</td>
<td>5</td>
<td>25.00%</td>
</tr>
<tr>
<td>No without argumentation</td>
<td>3</td>
<td>15.00%</td>
</tr>
<tr>
<td>Links to further learning materials</td>
<td>2</td>
<td>10.00%</td>
</tr>
<tr>
<td>Input for self-assessment</td>
<td>2</td>
<td>10.00%</td>
</tr>
<tr>
<td>Exercise and application examples</td>
<td>1</td>
<td>5.00%</td>
</tr>
</tbody>
</table>

20
Q2. Did you plan to learn this, and if so, why did you want to learn this?

Question 2 is concerned with whether one has planned to learn the subject, and if so, the rationale behind the student’s motivation. This question is part of the questionnaire on self-regulated learning and covers the dimension of goal orientation. In total, 23 different statements have been identified including aspects related to, for instance, the success of completion, interest in the subject, or personal development and future perspective. 34.78% (8 out of 23) of all statements are related to the successful completion of the course, meaning that students were referring to the requirements defined by the lecturers for passing the course. The second most category with 30.43% (7 out of 23) of all statements subsumes statements on students’ interests in the subject. With 21.74% (5 out of 23) of all statements students’ were motivated due to personal development and future perspective. 4.35% (1 out of 23) of all statements are concerned with the relevance of the subject in terms of future profession. Finally, 8.70% (2 out of 23) of all statements have been identified irrelevant in the context of this question.

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Successful completion of the course</td>
<td>8</td>
<td>34.78%</td>
</tr>
<tr>
<td>Interest in the subject</td>
<td>7</td>
<td>30.43%</td>
</tr>
<tr>
<td>Personal development and future perspective</td>
<td>5</td>
<td>21.74%</td>
</tr>
<tr>
<td>No specific answer</td>
<td>2</td>
<td>8.70%</td>
</tr>
<tr>
<td>Professional relevancy</td>
<td>1</td>
<td>4.35%</td>
</tr>
</tbody>
</table>

23
Q3. Did you expect to succeed in learning this and what made you think you would (not) succeed in learning this?

Question 3 is concerned with students’ expectation whether to succeed in learning the given subject or not. This question is part of the questionnaire on self-regulated learning and covers the dimension of self-efficacy. In total, 22 different statements have been identified including aspects related to, for instance, prior knowledge, conditions related to the group work, or the confidence due to the availability of learning materials. 22.73% (5 out of 22) of all statements indicate students’ confidence due to the assessable effort and level of difficulty of the tasks. 9.09% (2 out of 22) of all statements also indicate some confidence, but attribute this confidence to sufficient experience with the subject and the collaborative setting. 4.55% (1 out of 22) of all statements show confidence due to the availability of learning materials. Equally ranking with the first category, 22.73% (5 out of 22) of all statements, however, indicate concerns due to missing knowledge required for solving the tasks. 18.18% (4 out of 22) of all statements also refer to some concerns, but do not give any indication of underlying factors. 4.55% (1 out of 22) of all statements indicate concerns related to the absence of learning materials required for solving the tasks. Finally, 4.55% (1 out of 21) of all statements have been identified irrelevant in the context of this question. 50% (11 out of 22) of all statements have been identified as positive with respect to students’ confidence on the success of learning this subject. 45.45% (10 out of 22) of all statements, however, give some indication of concerns due to the organization of work or the availability of learning material. 4.55% (1 out of 22) of all statements have been identified irrelevant in the context of this question.

Table 9.10.: Results of question Q3

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assessable effort and level of difficulty</td>
<td>5</td>
<td>22.73%</td>
</tr>
<tr>
<td>Concerns due to missing knowledge</td>
<td>5</td>
<td>22.73%</td>
</tr>
<tr>
<td>Concerns without argumentation</td>
<td>4</td>
<td>18.18%</td>
</tr>
<tr>
<td>Experience with and interest in the subject</td>
<td>2</td>
<td>9.09%</td>
</tr>
<tr>
<td>Confidence due to group work</td>
<td>2</td>
<td>9.09%</td>
</tr>
<tr>
<td>Confidence without argumentation</td>
<td>1</td>
<td>4.55%</td>
</tr>
<tr>
<td>Confidence due to the availability of learning materials</td>
<td>1</td>
<td>4.55%</td>
</tr>
<tr>
<td>No specific answer</td>
<td>1</td>
<td>4.55%</td>
</tr>
<tr>
<td>Concerns due to missing learning materials</td>
<td>1</td>
<td>4.55%</td>
</tr>
</tbody>
</table>

22
Chapter 9. Empirical Evaluation

Q4. How did you learn this?

Question 4 is concerned with the strategies used for learning the given subject. This question is part of the self-regulated learning questionnaire and covers the dimension of strategic planning. In total, 29 different statements have been identified including aspects related to, for instance, the Internet, the provided learning materials, or the interaction with colleagues. 55.17% (16 out of 29) of all statements refer to the Internet as important resource used during the elaboration of tasks. Equally ranking, the provided materials and the interaction with colleagues has been identified as crucial with 20.69% (6 out of 29) of all statements in each case. Finally, 3.45% (1 out of 29) of all statements have been identified irrelevant in the context of this question.

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Searching the Internet</td>
<td>16</td>
<td>55.17%</td>
</tr>
<tr>
<td>Working with provided learning materials</td>
<td>6</td>
<td>20.69%</td>
</tr>
<tr>
<td>Interacting with colleagues</td>
<td>6</td>
<td>20.69%</td>
</tr>
<tr>
<td>No specific answer</td>
<td>1</td>
<td>3.45%</td>
</tr>
</tbody>
</table>

29
Q4.1. Did the learning tool support you in your learning processes, and if so, which features were especially useful and how did you use them?

Question 4.1 is concerned with the learning tool and whether it provided supported in students’ learning processes. In total, 26 different statements have been identified including aspects related to, for instance, the interaction via Facebook, the usability of the learning tool, or the use of other tools and platforms. 23.08% (6 out of 26) of all statements refer to the interaction via Facebook as relevant to their learning processes. 19.23% (5 out of 26) of all statements stated that the learning tool did not support them in their learning processes. However, no further details were stated which could have given some indication of why the learning tool did not provide any support. 26.92% (7 out of 26) of all statements indicate that the learning tool did not help due to insufficient or erroneous functionality and poor usability respectively. 11.54% (3 out of 26) of all statement suggest that the learning tool provided support in students’ learning processes due to good usability and interaction support. 7.69% (2 out of 26) of all statement indicate that other tools and platforms were used throughout the tasks. Finally, 3.85% (1 out of 26) of all statement have been identified irrelevant in the context of this question.

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interaction via Facebook</td>
<td>6</td>
<td>23.08%</td>
</tr>
<tr>
<td>No without argumentation</td>
<td>5</td>
<td>19.23%</td>
</tr>
<tr>
<td>Insufficient or erroneous functionality</td>
<td>4</td>
<td>15.38%</td>
</tr>
<tr>
<td>No specific answer</td>
<td>3</td>
<td>11.54%</td>
</tr>
<tr>
<td>No due to insufficient usability</td>
<td>3</td>
<td>11.54%</td>
</tr>
<tr>
<td>Yes due to good usability</td>
<td>2</td>
<td>7.69%</td>
</tr>
<tr>
<td>No due to use of other tools and platforms</td>
<td>2</td>
<td>7.69%</td>
</tr>
<tr>
<td>Yes due to interaction support</td>
<td>1</td>
<td>3.85%</td>
</tr>
</tbody>
</table>

26
Q4.2. Are there any features that would have supported you better in your learning process, and if so, which features would have been especially useful?

Question 4.2 is concerned with the shortcomings of the learning tool in terms of features that would have provided better support in students’ learning processes. In total, 32 different statements have been identified including aspects related to, for instance, the navigation support, the usability, the integration of existing collaboration platforms, or additional modes of communication. Equally ranking, 15.63% (5 out of 32) of all statements are related to both better support in structuring interactions and enhanced content editing features. 12.5% (4 out of 32) of all statements address insufficiencies related to the navigation. Poor usability of the learning tool and inadequate features available for managing resources are of equal rank represented through 9.38% (3 out of 32) of all statements. With 3.13% (1 out of 32) of all statements, the integration of existing collaboration platforms, an enhanced Facebook integration, and additional modes of communication were stated as further improvements of the learning tool. 12.5% (4 out of 32) of all statements were satisfied with the provided features. Finally, 15.63% (5 out of 32) of all statements have been identified irrelevant in the context of this question.

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Support for structuring interactions</td>
<td>5</td>
<td>15.63%</td>
</tr>
<tr>
<td>Enhanced editor</td>
<td>5</td>
<td>15.63%</td>
</tr>
<tr>
<td>No specific answer</td>
<td>5</td>
<td>15.63%</td>
</tr>
<tr>
<td>No without argumentation</td>
<td>4</td>
<td>12.50%</td>
</tr>
<tr>
<td>Enhanced navigation support</td>
<td>4</td>
<td>12.50%</td>
</tr>
<tr>
<td>Enhanced usability</td>
<td>3</td>
<td>9.38%</td>
</tr>
<tr>
<td>Enhanced support for managing resources</td>
<td>3</td>
<td>9.38%</td>
</tr>
<tr>
<td>Integration of existing collaboration platforms</td>
<td>1</td>
<td>3.13%</td>
</tr>
<tr>
<td>Enhanced Facebook integration</td>
<td>1</td>
<td>3.13%</td>
</tr>
<tr>
<td>Additional modes of communication</td>
<td>1</td>
<td>3.13%</td>
</tr>
</tbody>
</table>

32
9.2. Application Analysis

Q4.3. Did the provided learning materials help you in your learning process, and if so, which ones were especially useful?

Question 4.3 is concerned with the provided learning materials and whether they were helpful during elaboration of the tasks or not. In total, 19 different statements have been identified including aspects related to, for instance, the code framework, lecture notes, or the user guide of the learning tool. 26.32% (5 out of 19) of all statements refer to the code framework provided as starting point for elaboration. 15.79% (3 out of 19) of all statements consider the provided learning materials as useful during elaboration, whereas 10.53% (2 out of 19) of all statements in particular refer to the lecture notes as important. 5.26% (1 out of 19) of all statements state that the provided learning materials were helpful during elaboration, however, do not give any indication which ones were especially helpful. Similarly, the user guide of the learning tool is considered important by 5.26% (1 out of 19) of all statements. 21.05% (4 out of 19) of all statements indicate that the provided learning materials were not helpful during elaboration, but do not provide any details which could have given some indication of why the learning materials were not helpful. Finally, 15.79% (3 out of 19) of all statements have been identified irrelevant in the context of this question.

Table 9.14.: Results of question Q4.3

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Code framework for development</td>
<td>5</td>
<td>26.32%</td>
</tr>
<tr>
<td>No without argumentation</td>
<td>4</td>
<td>21.05%</td>
</tr>
<tr>
<td>No specific answer</td>
<td>3</td>
<td>15.79%</td>
</tr>
<tr>
<td>Provided learning materials</td>
<td>3</td>
<td>15.79%</td>
</tr>
<tr>
<td>Lecture notes</td>
<td>2</td>
<td>10.53%</td>
</tr>
<tr>
<td>Yes without argumentation</td>
<td>1</td>
<td>5.26%</td>
</tr>
<tr>
<td>User guide of Ueber Learn</td>
<td>1</td>
<td>5.26%</td>
</tr>
</tbody>
</table>

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Chapter 9. Empirical Evaluation

Q4.4. Are there any further learning materials that would have helped you better, and if so, which ones would have been especially useful?

Question 4.4 is concerned with learning materials that would have provided better support during elaboration of the tasks. In total, 19 different statements have been identified including aspects related to, for instance, additional information on the tasks, exercises and application examples, code frameworks, or basic principles of programming. 26.32% (5 out of 19) of all statements ask for additional and more detailed information on the tasks, whereas 21.05% (4 out of 19) of all statements indicate that exercises and application examples would have been useful during elaboration. 15.79% (3 out of 19) of all statements claim more comprehensive code frameworks available to be used as starting point for elaboration. 10.53% (2 out of 19) of all statements confirm that the provided learning materials were sufficient in order to solve the tasks. 5.26% (1 out of 19) of all statements are satisfied with the provided learning materials since the Internet was used to compensate missing learning materials and information. More basic information and learning materials on the basic principles of programming is asked by 5.26% (1 out of 19) of all statements. Finally, 15.79% (3 out of 19) of all statements have been identified irrelevant in the context of this question.

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additional / more detailed information on tasks</td>
<td>5</td>
<td>26.32%</td>
</tr>
<tr>
<td>Exercise and application examples</td>
<td>4</td>
<td>21.05%</td>
</tr>
<tr>
<td>No specific answer</td>
<td>3</td>
<td>15.79%</td>
</tr>
<tr>
<td>Code framework for development</td>
<td>3</td>
<td>15.79%</td>
</tr>
<tr>
<td>No without argumentation</td>
<td>2</td>
<td>10.53%</td>
</tr>
<tr>
<td>No, additional information available on the Internet</td>
<td>1</td>
<td>5.26%</td>
</tr>
<tr>
<td>Principles of programming</td>
<td>1</td>
<td>5.26%</td>
</tr>
</tbody>
</table>
Q4.5. Did the group work support you, and if so, how did you observe this?

Question 4.5 is concerned with the group work and whether it provided any benefits to the team group members. In total, 19 different statements have been identified including aspects related to, for instance, the work load, capabilities for knowledge sharing among colleagues, or the collaborative work on a joint solution. 27.78% (5 out of 18) of all statements address the aspect of knowledge sharing through the interaction with colleagues. 16.67% (3 out of 18) of all statements indicate that there was less effort due to cooperative group work, meaning that tasks were split into parts which were elaborated by individual group members. Similarly and equally ranking, 16.67% (3 out of 18) of all statements concern the support in working on own solution and the collaborative work on a joint solution. 16.67% (3 out of 18) of all statements say that there was no benefit through the group work. Finally, 5.56% (1 out of 18) of all statements show that the benefits are not assessable since there was no group work.

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge sharing through interaction with colleagues</td>
<td>5</td>
<td>27.78%</td>
</tr>
<tr>
<td>Less effort through apportionment of work</td>
<td>3</td>
<td>16.67%</td>
</tr>
<tr>
<td>No without argumentation</td>
<td>3</td>
<td>16.67%</td>
</tr>
<tr>
<td>Support in working on own solution</td>
<td>3</td>
<td>16.67%</td>
</tr>
<tr>
<td>Collaborative work on joint solution</td>
<td>3</td>
<td>16.67%</td>
</tr>
<tr>
<td>No collaboration</td>
<td>1</td>
<td>5.56%</td>
</tr>
</tbody>
</table>

18
Q4.6. Did Facebook help you, and if so, how did you use it?

Question 4.6 is concerned with the Facebook integration and whether is provided any benefits to the students. In total, 17 different statements have been identified including aspects related to better communication and organization support or insufficiencies due to poor usability. 41.18% (7 out of 17) of all statements show that the integration of Facebook was beneficial for communication. 29.41% (5 out of 17) of all statements indicate that the Facebook was not used during elaboration of the tasks. 11.76% (2 out of 17) of all statements show that the integration of Facebook was beneficial for organization. 5.88% (1 out of 17) of all statements indicate poor usability since the integration was too cumbersome to use. Similarly, 5.88% (1 out of 17) statements do not see any benefits, but do not provide any further details on why the integration was not useful. Finally, 5.88% (1 out of 17) of all statements have been identified irrelevant in the context of this question.

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication support</td>
<td>7</td>
<td>41.18%</td>
</tr>
<tr>
<td>Facebook integration not used</td>
<td>5</td>
<td>29.41%</td>
</tr>
<tr>
<td>Organization support</td>
<td>2</td>
<td>11.76%</td>
</tr>
<tr>
<td>No without argumentation</td>
<td>1</td>
<td>5.88%</td>
</tr>
<tr>
<td>No specific answer</td>
<td>1</td>
<td>5.88%</td>
</tr>
<tr>
<td>Too cumbersome to use</td>
<td>1</td>
<td>5.88%</td>
</tr>
</tbody>
</table>

17
Q5. Why did you learn it this way?

Question 5 is concerned with the rationale behind the way students have learned the subject. This question is part of the self-regulated learning questionnaire and covers the dimension of learning strategy control. In total, 20 different statements have been identified including aspects related to, for instance, the comprehensibility of provided learning materials or the interaction with colleagues. 50% (10 out of 20) of all statements assess the learning materials as comprehensive and efficient source of information. 15% (3 out of 20) of all statements attribute the selection of learning strategy to the instruction and therefore as inherent part of the tasks. 15% (3 out of 20) of all statements do not give some indication of an explicit approach for selecting learning strategies. 10% (2 out of 20) of all statements include the collaborative setting in the sense that the interaction with colleagues was identified as opportunity to exchange experiences. Finally, 10% (2 out of 20) of all statements have been identified irrelevant in the context of this question.

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning materials as comprehensive and efficient source of information</td>
<td>10</td>
<td>50.00%</td>
</tr>
<tr>
<td>Part of the instruction</td>
<td>3</td>
<td>15.00%</td>
</tr>
<tr>
<td>No conscious choice</td>
<td>3</td>
<td>15.00%</td>
</tr>
<tr>
<td>Interaction with colleagues as opportunity to exchange experiences</td>
<td>2</td>
<td>10.00%</td>
</tr>
<tr>
<td>No specific answer</td>
<td>2</td>
<td>10.00%</td>
</tr>
</tbody>
</table>

20
Chapter 9. Empirical Evaluation

Q6. How did you realize that you had learned something?

Question 6 is concerned with how students realized that they have learned something during elaboration of the tasks. This question is part of the self-regulated learning questionnaire and covers the dimension of monitoring learning results. In total, 20 different statements have been identified including aspects related to, for instance, the reflection on own performance, the experience of what works, the ability to share knowledge, or information from others. 35% (7 out of 20) of all statements show that the reflection on own performance is important in this respect. In each case, 20% (4 out of 20) of all statements link how learnings are realized to either experiences of what actually works or the degree of novels of information. Similarly, 5% (1 out of 20) of all statements say it is the ability to share knowledge or information that is communicated by others. Finally, 5% (1 out of 20) of all statements have been identified irrelevant in the context of this question.

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reflection on own performance</td>
<td>7</td>
<td>35.00%</td>
</tr>
<tr>
<td>Experience of what works</td>
<td>4</td>
<td>20.00%</td>
</tr>
<tr>
<td>Novelty of information</td>
<td>4</td>
<td>20.00%</td>
</tr>
<tr>
<td>No specific answer</td>
<td>3</td>
<td>15.00%</td>
</tr>
<tr>
<td>Ability to share knowledge</td>
<td>1</td>
<td>5.00%</td>
</tr>
<tr>
<td>Information from others</td>
<td>1</td>
<td>5.00%</td>
</tr>
</tbody>
</table>

20
9.2. Application Analysis

Q6.1. Did the description of tasks help you realize that you had learned something, and if so, which statements were especially useful?

Question 6.1 is concerned with the description of tasks, in particular with respect to how it helped students to realize that they have learned something. In total, 18 different statements have been identified including aspects related to self-testing capabilities or the structure of tasks. 27.78% (5 out of 18) of all statements show that the description of tasks in general have helped to realize new learnings. More specially, 22.22% (4 out of 18) of all statements show that the self-testing section was particularly helpful to assess new learnings. 5.56% (1 out of 18) of all statements consider the structure of tasks as helpful to realize new learnings, whereas 5.56% (1 out of 18) of all statements indicate that the description was helpful in general. 16.67% (3 out of 18) of all statements, however, indicate without giving further details that the description of tasks did not provide any help to realize new learnings. Finally, 22.22% (4 out of 18) of all statements have been identified irrelevant in the context of this question.

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description of tasks</td>
<td>5</td>
<td>27.78%</td>
</tr>
<tr>
<td>Self-testing as learning support</td>
<td>4</td>
<td>22.22%</td>
</tr>
<tr>
<td>No specific answer</td>
<td>4</td>
<td>22.22%</td>
</tr>
<tr>
<td>No without argumentation</td>
<td>3</td>
<td>16.67%</td>
</tr>
<tr>
<td>Structure of tasks as learning support</td>
<td>1</td>
<td>5.56%</td>
</tr>
<tr>
<td>Yes without argumentation</td>
<td>1</td>
<td>5.56%</td>
</tr>
</tbody>
</table>
Q6.2. Is there anything that would have helped you better realize that you had learned something, and if so, what would have been especially useful?

Question 6.2 is concerned with how students realized that they have learned something during elaboration of the task, in particular, if there is anything that would have helped them better. In total, 18 different statements have been identified including aspects such as additional input for self-assessment. 38.89% (7 out of 18) of all statements indicate that there is nothing that would have helped them better realize new learnings. 27.78% (5 out of 18) of all statements, however, show that additional input for self-assessment would have helped better in this regard. 11.11% (2 out of 18) of all statements ask for additional input in general. Finally, 22.22% (4 out of 18) of all statements have been identified irrelevant in the context of this question.

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>No without argumentation</td>
<td>7</td>
<td>38.89%</td>
</tr>
<tr>
<td>Input for self-assessment</td>
<td>5</td>
<td>27.78%</td>
</tr>
<tr>
<td>No specific answer</td>
<td>4</td>
<td>22.22%</td>
</tr>
<tr>
<td>Additional input</td>
<td>2</td>
<td>11.11%</td>
</tr>
</tbody>
</table>

18
9.2. Application Analysis

Q6.3. Did the collaborative elaboration of tasks help you realize that you had learned something, and if so, how did you observe this?

Question 6.3 is concerned with whether the collaborative elaboration of tasks helped students realize that they had learned something. In total, 17 different statements have been identified including aspects related to the interaction with colleagues, collaboration, or opportunities to compare solutions. 35.29% (6 out of 17) of all statements say that the collaborative elaboration provided the appropriate context to compare the developed solutions with colleagues. 29.41% (5 out of 17) of all statements show that the interaction with colleagues helped them realize that they had learned something. 5.88% (1 out of 17) of all statements are positive in this respect, however, do not give any indication of how the collaborative elaboration helped them. 11.76% (2 out of 17) of all statements are negative and do not give any further indication of why the collaboration elaboration did not help them. 5.88% (1 out of 17) indicate that there was no group work in order to evaluate whether the collaborative elaboration helped to realize that students have learned something. Finally, 11.76% (2 out of 18) of all statements have been identified irrelevant in the context of this question.

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opportunities to compare</td>
<td>6</td>
<td>35.29%</td>
</tr>
<tr>
<td>Interaction with other colleagues</td>
<td>5</td>
<td>29.41%</td>
</tr>
<tr>
<td>No without argumentation</td>
<td>2</td>
<td>11.76%</td>
</tr>
<tr>
<td>No specific answer</td>
<td>2</td>
<td>11.76%</td>
</tr>
<tr>
<td>Yes without argumentation</td>
<td>1</td>
<td>5.88%</td>
</tr>
<tr>
<td>No collaboration</td>
<td>1</td>
<td>5.88%</td>
</tr>
</tbody>
</table>
Q6.4. Did discussions help you realize that you had learned something, and if so, how did you observe this?

Question 6.4 is concerned with whether the discussion in the group context helped students realize that they had learned something. In total, 17 different statements have been identified including aspects related to the ability to share knowledge, the understanding of the task, or the assessment of the personal learning process. 23.53% (4 out of 17) of all statements show that the ability to share knowledge helped to realize new learnings. 17.65% (3 out of 17) of all statements are positive, however, do not give any indication of how the discussion helped them. Equally ranking, 5.88% (1 out of 17) of all statements indicate that the understanding of tasks, the assessment of the personal learning process, and the clarification of open issues helped them realize that they had learned something. 17.65% (3 out of 17) of all statements are negative in this respect and do not give any further indication of why the group discussion did not help them. Finally, 23.53% (4 out of 18) of all statements have been identified irrelevant in the context of this question.

58.82% (10 out of 17) of all statements are positive with respect to the added value of group discussions in order to realize new learnings. In this regard, aspects regarding the ability to share knowledge, the understanding of the tasks, the assessment of the personal learning process, and the clarification of open issues are considered relevant. 17.65% (3 out of 18) of all statements, however, show that the group discussion was not helpful in this context. 23.53% (4 out of 18) of all statements have been identified irrelevant in the context of this question.

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ability to share knowledge</td>
<td>4</td>
<td>23.53%</td>
</tr>
<tr>
<td>No specific answer</td>
<td>4</td>
<td>23.53%</td>
</tr>
<tr>
<td>No without argumentation</td>
<td>3</td>
<td>17.65%</td>
</tr>
<tr>
<td>Yes without argumentation</td>
<td>3</td>
<td>17.65%</td>
</tr>
<tr>
<td>Understanding of tasks</td>
<td>1</td>
<td>5.88%</td>
</tr>
<tr>
<td>Assessment of personal learning progress</td>
<td>1</td>
<td>5.88%</td>
</tr>
<tr>
<td>Clarification of open issues</td>
<td>1</td>
<td>5.88%</td>
</tr>
</tbody>
</table>
Q7. If you look back, are you completely satisfied, or what would you do differently next time?

Question 7 is concerned with the satisfaction of students regarding their learning processes and whether they would learn differently next time. This question is part of the self-regulated learning questionnaire and covers the dimension of self-evaluation of the learning experience. In total 19 different statements have been identified including aspects related to the intensification of group work, more detailed elaboration of tasks, the improvement of time management, or the evaluation of the own learning process. 31.58% (6 out of 19) of all statements are positive in this respect, but do not give any indication of what was satisfying in particular. 15.79% (3 out of 19) of all statements show the need of intensification of the group work in order to take advantage of others’ knowledge. 15.79% (3 out of 19) of all statements indicate dissatisfaction regarding the elaboration of tasks, in particular with the level of detail during engagement. Equally ranking, 10.53% (2 out of 19) of all statements are not satisfied with either the time management or the evaluation of the learning processes. Finally, 15.79% (3 out of 19) of all statements have been identified irrelevant in the context of this question.

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes without argumentation</td>
<td>6</td>
<td>31.58%</td>
</tr>
<tr>
<td>Intensification of group work</td>
<td>3</td>
<td>15.79%</td>
</tr>
<tr>
<td>More detailed elaboration of tasks</td>
<td>3</td>
<td>15.79%</td>
</tr>
<tr>
<td>No specific answer</td>
<td>3</td>
<td>15.79%</td>
</tr>
<tr>
<td>Improvement of own time management</td>
<td>2</td>
<td>10.53%</td>
</tr>
<tr>
<td>Evaluation of own learning process</td>
<td>2</td>
<td>10.53%</td>
</tr>
</tbody>
</table>

Table 9.24.: Results of question Q7
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Q8. How will you proceed with this learning experience?

Question 8 is concerned with how students’ proceed with the learnings experienced during the elaboration of tasks. This question is part of the self-regulated learning questionnaire and covers the dimension of interferences for subsequent learning experiences. In total, 19 different statements have been identified including aspects related to the occasion-related application, the application in professional and in the university context, or the usage of created learning materials. 26.32% (5 out of 19) of all statements indicate that further use of this learning experience depends on future occasions, meaning that students do not have any specific plans for application but will make use of this learning experience when necessary. Equally ranking, 21.05% (4 out of 19) of all statements show that this learning experience may be useful in a professional or the university context. 5.26% (1 out of 19) of all statements anticipate the usage of the created learning materials. Finally, 26.32% (5 out of 19) of all statements have been identified irrelevant in the context of this question.

Table 9.25.: Results of question Q8

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occasion-related application</td>
<td>5</td>
<td>26.32%</td>
</tr>
<tr>
<td>No specific answer</td>
<td>5</td>
<td>26.32%</td>
</tr>
<tr>
<td>Application in a professional context</td>
<td>4</td>
<td>21.05%</td>
</tr>
<tr>
<td>Application in the university context</td>
<td>4</td>
<td>21.05%</td>
</tr>
<tr>
<td>Usage of the created learning materials</td>
<td>1</td>
<td>5.26%</td>
</tr>
</tbody>
</table>
Q8.1. Did the elaboration of tasks qualified you to successfully apply the learned, and if so, how did you observe this? If not, what was missing?

Question 8.1 is concerned with whether the elaboration of tasks qualified students to successfully apply the learning. In total, 18 different statements have been identified including aspects related to insufficient expertise due to the scope and complexity of tasks or the feedback used for assessment. 38.89% (7 out of 18) of all statements indicate that students are not feeling qualified due to insufficient expertise brought about the scope and complexity of the tasks. 11.11% (2 out of 18) of all statements show that additional feedback on the solutions would have helped for self-assessment. 5.56% (1 out of 18) indicate that students are not feeling qualified due to insufficient expertise brought about the partial elaboration of tasks. 5.56% (1 out of 18) of all statements show that the assessment of being qualified is not possible. 22.22% (4 out of 18) of all statements show that students feel qualified due to the successful completion of the tasks. Finally, 16.67% (3 out of 18) of all statements have been identified irrelevant in the context of this question.

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insufficient expertise due to scope and complexity of tasks</td>
<td>7</td>
<td>38.89%</td>
</tr>
<tr>
<td>Qualified due to completion of tasks</td>
<td>4</td>
<td>22.22%</td>
</tr>
<tr>
<td>No specific answer</td>
<td>3</td>
<td>16.67%</td>
</tr>
<tr>
<td>Feedback used for the assessment of elaborated solution</td>
<td>2</td>
<td>11.11%</td>
</tr>
<tr>
<td>Not assessable</td>
<td>1</td>
<td>5.56%</td>
</tr>
<tr>
<td>Insufficient expertise due to partial elaboration of tasks</td>
<td>1</td>
<td>5.56%</td>
</tr>
</tbody>
</table>

18
Q8.2. Did the learning tool support you in preparing the learned for further application, and if so, which features were especially useful and how did you use them?

Question 8.2 is concerned with how the learning tool provided support in preparing the learned for further application. In total, 24 different statements have been identified including aspects related to content editing capabilities, limited reusability of created content, or modes of communication. 16.67% (4 out of 24) of all statements indicate that there is insufficient functionality with respect to the content editor. 12.5% (3 out of 24) of all statements report on insufficient features for managing resources. 12.5% (3 out of 24) of all statements are positive regarding learning tool support in the creation and processing of content. 12.5% (3 out of 24) of all statements, without giving any further details, indicate no support in preparing the learned for further application provided by the learning tool. Equally ranking, 8.33% (2 out of 24) of all statements either criticize the limited reusability of created content beyond the scope of the learning tool or state that the learning tool was not used during the elaboration of tasks. Insufficient navigation support and modes of communication are brought up respectively by 4.17% (1 out of 24) of all statements. In contrast, 4.17% (1 out of 24) of all statements are positive with respect to the support in preparing the learning for further application provided by the learning tool. Equally ranking, 4.17% (1 out of 24) of all statements indicate support through the organization based on workspaces and the creation of content based on interactions among colleagues. Finally, 8.33% (2 out of 24) of all statements have been identified irrelevant in the context of this question.

Table 9.27.: Results of question Q8.2

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insufficient functionality of the editor</td>
<td>4</td>
<td>16.67%</td>
</tr>
<tr>
<td>Insufficient features for managing resources</td>
<td>3</td>
<td>12.50%</td>
</tr>
<tr>
<td>Creation and processing of content supported by the learning tool</td>
<td>3</td>
<td>12.50%</td>
</tr>
<tr>
<td>No without argumentation</td>
<td>3</td>
<td>12.50%</td>
</tr>
<tr>
<td>No specific answer</td>
<td>2</td>
<td>8.33%</td>
</tr>
<tr>
<td>Limited reusability of created content</td>
<td>2</td>
<td>8.33%</td>
</tr>
<tr>
<td>No use of the learning tool</td>
<td>2</td>
<td>8.33%</td>
</tr>
<tr>
<td>Yes without argumentation</td>
<td>1</td>
<td>4.17%</td>
</tr>
<tr>
<td>Insufficient navigation support</td>
<td>1</td>
<td>4.17%</td>
</tr>
<tr>
<td>Insufficient modes of communication</td>
<td>1</td>
<td>4.17%</td>
</tr>
<tr>
<td>Organization based on workspaces</td>
<td>1</td>
<td>4.17%</td>
</tr>
<tr>
<td>Creation of content based on interactions</td>
<td>1</td>
<td>4.17%</td>
</tr>
</tbody>
</table>
Q8.3. Are there any features that would have helped you better in documenting the learned, and if so, which features would have been especially useful?

Question 8.3 is concerned with the documentation capabilities of the learning tool, in particular with respect to features that would have helped better in this context. In total, 27 different statements have been identified including aspects related to the collaborative creation and processing of content, navigation support, workspace management, and extended modes of communication. 22.22% (6 out of 27) of all statements ask for enhanced support for the (collaborative) creation and processing of content. This category, in particular, addresses the features provided by the editor with respect to collaborative editing capabilities. 18.52% (5 out of 27) of all statements ask for enhanced resource management capabilities. 11.11% (3 out of 27) of all statements criticize the learning tool with respect to navigation support. Equally ranking, 3.7% (1 out of 27) of all statements either ask for enhanced workspace management capabilities, better support for structuring interactions, extended modes of communication, features supporting the linking of content and interactions, or better usability of the learning tool. 11.11% (3 out of 11) of all statements are positive, meaning that no features were missing that would have helped students better in documenting the learned. Finally, 18.52% (5 out of 27) of all statements have been identified irrelevant in the context of this question.

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enhanced support for the (collaborative) creation and processing of content</td>
<td>6</td>
<td>22.22%</td>
</tr>
<tr>
<td>Enhanced resource management</td>
<td>5</td>
<td>18.52%</td>
</tr>
<tr>
<td>No specific answer</td>
<td>5</td>
<td>18.52%</td>
</tr>
<tr>
<td>No without argumentation</td>
<td>3</td>
<td>11.11%</td>
</tr>
<tr>
<td>Enhanced navigation support</td>
<td>3</td>
<td>11.11%</td>
</tr>
<tr>
<td>Support for the linking of content and interactions</td>
<td>1</td>
<td>3.70%</td>
</tr>
<tr>
<td>Enhanced workspace management</td>
<td>1</td>
<td>3.70%</td>
</tr>
<tr>
<td>Support for structuring interactions</td>
<td>1</td>
<td>3.70%</td>
</tr>
<tr>
<td>Enhanced usability of the learning tool</td>
<td>1</td>
<td>3.70%</td>
</tr>
<tr>
<td>Extended modes of communication</td>
<td>1</td>
<td>3.70%</td>
</tr>
</tbody>
</table>
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Q9. Do you have any other comments?

Question 9 is concerned with any other comments related to the usability of the learning tool. Feedback provided by the participants mainly concerned (1) the group work in general and (2) implementation details with respect to the learning tool. Related to the group work, students were critical of being randomly assigned to groups as well as group dynamics, the latter referring to insufficient incentives for the collaborative elaboration of tasks. Related to implementation details, the following shortcomings were stated:

− Limited browser support
− No global search, in particular in the context of interactions
− Response times considered as limiting factor in communication

9.3. Interpretation

In this section, the results of the application analysis are interpreted with respect to the development goals and the relevance of features. While the development goals are discussed irrespective of self-regulated learning, the relevance of features is addressed with reference to the three phases associated with self-regulated learning, that is the forethought, performance, and reflection phase.

9.3.1. Validation of Goals

The development goals concerned with the three intellectual phases proposed by the online collaborative learning theory – idea generation, idea organization, and intellectual convergence – are discussed in this section based on the results of the application analysis. In addition to the general assessment, the individual goals are evaluated from the three perspective cognition, social, and teaching.

Generation of ideas (G1) The forethought phase particularly is considered relevant with regards to the generation of ideas (G1) as it gives some indication of the learners’ motivation and motives towards the learning process as well as insights into planning. The results of question Q2 show that about half of the learners were intrinsically motivated, either due to interest in the subject, personal development and future perspective, or professional relevancy.
9.3. Interpretation

Approximately a third of the learners were driven by more superficial factors, that is the successful completion of the course. Related to expectancy of success, the learners were of different opinions (cf. question Q3). About half of the learners were positive about to succeed in the given tasks due to an assessable effort and level of difficulty, experience with the subject, group work, and the availability of learning materials. The other half reported doubts as to missing knowledge or learning materials.\(^\text{10}\)

About three quarters of all learners state that they were primarily focusing on the Internet and the provided learning materials in order to organize their learning.\(^\text{11}\) Merely 20.69% of all statements (question Q4) indicate to rely on the interaction with other learners during this phase of learning. These results are further strengthened as brainstorming is considered mainly a cognitive process (cf. Section 5.1). In terms of cognitive support, the provided learning materials were assessed positively. 63.16% of all statements (question Q4.3) provide confirmation and state that, in particular, the code framework for development (26.32%) and the lecture notes (10.53%) were evaluated as being supporting. Needs for improvement, however, were identified with respect to the description of tasks\(^\text{12}\) or exercises and application examples\(^\text{13}\).

In terms of the pedagogical design of learning materials, no major shortcomings were reported. 21.05% of all statements (question Q4.3) state that the learning materials did not provide support in the learning process, but in this context give no indication of how to improve or adapt those. Related to the learning tool, only 34.62% of all statements (question Q4.1) assessed the provided technological support as being helpful, in particular due to the integration of Facebook and interaction support. About half report shortcomings with respect to insufficient and erroneous functionality or usability\(^\text{14}\) while the remaining did not provide specific answers\(^\text{15}\). A more detailed distinction in terms of improvement is provided by the results of question Q4.2. 71.91% of all statements report improvement suggestions, such as supporting structured interactions, enhanced editing capabilities, enhanced navigation support and usability, the integration of existing collaboration platforms, or additional modes of communication.

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\(^{10}\)27.28% of all statements (question Q3) indicate concerns due to missing knowledge or learning materials. 18.18% of all statements (question 3) report concerns but did not state any reasons.

\(^{11}\)75.86% of all statements (question Q4) indicate that either the Internet or the provided learning materials were used for learning.

\(^{12}\)26.32% of all statements (question Q4.4) ask for additional or more detailed information on tasks.

\(^{13}\)21.05% of all statements (question Q4.4) ask for more exercises and application examples in the context of the given tasks.

\(^{14}\)53.84% of all statement (question Q4.4) indicate shortcoming of the learning tool with respect to, for instance, the usability, insufficient or erroneous functionality, of usability.

\(^{15}\)11.54% of all statements (question 4.1) did not provide any specific answer whether the learning tool supported their learning processes or not.
From a social perspective, 77.79% of all statements (question Q4.5) report that the group work helped during elaboration of tasks. Knowledge sharing processes, less effort through the apportionment of work, support in working on own solution, and collaborative work on joint solution was given as explanations in this regard. The remaining 22.23% of all statements either do not provide an answer or state that no collaborative activities were performed. With respect to interaction support, the integration of Facebook is valued positively by 52.94% of all statements (question Q4.6). The results show that it was primarily used as communication and organization support, and possibly is not well suited for supporting learning processes in general. The remaining 47.06% of all statements (question Q4.6) either do not provide an answer or state the Facebook integration was not useful or used at all.

Organization of ideas (G2)  The organization of ideas is concerned with finding relationships and similarities in order to get them organized in the sense of having multiple perspectives aligned and arranged. In terms of self-regulated learning it is concerned with the performance phase which addresses the monitoring of learning activities and processes. Important to realizing whether someone has learned something or not primarily is not attributed to social performance directly. 75% of all statements (question Q6) show that learners either evaluate learning outcomes based on their own performance, functionality, or the novelty of information. Only 10% of all statements rely on others, that is the ability to share knowledge or information from others. The remaining 15% of all statements do not provide any specific answers. The individual focus in this context is further strengthened by the results of question Q6.2. 38.89% of all statements (question Q6.2) ask for additional input, in particular with respect to self-assessment. The remaining 61.11% of all statements either do not provide any specific answer or do not give any further indication of what was impeding.

Despite the focus on the individual performance, the majority of statements value the collaborative elaboration of tasks and respective discussions as positive with respect to evaluating the learning outcome. 70.58% of all statements (question Q6.3) state that collaborative activities were useful in this context, in particular in terms of opportunities to compare and interaction with colleagues. Merely 29.4% of all statements (question Q6.3) did not see any value in such activities. Similar results are shown related to the assessed value of discussions. 58.82% of all statements (question 6.4) report that discussions were considered important as to share knowledge, the understanding of tasks, the assessment of personal learning progress, and the clarification of open issues. The remaining 41.18% of all statements (question Q6.4) either do not provide any specific answer or do not give any further indication of what was impeding.

The pedagogical perspective addresses the description of tasks in particular. 61.12% of all statements (question Q6.1) state that it was assessed as useful
9.3. Interpretation

during the elaboration of tasks. The descriptions, information on self-testing, and the structure of tasks are indicated as especially useful. The remaining 38.89% of all statements either do not provide any specific answer or do not give any indication of what was missing.

**Intellectual convergence (G3)** Intellectual convergence eventually leads to a shared understanding among learners in terms of both agreeing and disagreeing. The results may be represented as an artifact, such as a solution to a problem, a written report of an assignment, a publication or any similar output which is collaboratively created by the learning group. In terms of self-regulated learning, it is concerned with the reflection phase as it allows assessing the learning outcome respectively. 57% of all statements (question Q1) assessed technological know-how as the primary learning outcome during the tasks. 36.84% of all statements (question Q1), however, report experiences with respect to collaboration and respective conditions. From the perspective of the teaching dimension, 65.23% of all statements (question Q1.1) indicate that the description of tasks was useful during the elaboration, in particular with reference to the code framework, prior knowledge, and the understanding of goals. 60% of all statements (question Q1.2), however, asked for improvements, including more details of tasks and instructions, exercises and application examples, links to further learning materials, and input for self-assessment.

In terms of applicability of the learned, which also is described as one potential outcome of the online collaborative learning theory, 26.32% of all statements (question Q8) report that it becomes occasionally relevant, but do not give any indication concerning specific situations. 41.10% of all statements (question Q8), however, state that the learned may be used in either a professional or university context. Only 5.26% of all statements (question Q8) consider the created learning materials as directly relevant for future application. The remaining 26.32% did not provide any specific answer.

With respect to intellectual convergence, that is the collaborative creation of a joint report, only 33.34% of all statements (question Q8.2) show that the learning tool provided support in preparing the learned for further application. 58.34% of all statements (question Q8.2), however, report shortcomings in this context, in particular related to the content editor, resource management capabilities, the limited reusability of created content, or navigation support. The results of question Q8.3 in this context provide a more detailed assessment of shortcomings and therefore potential features of the learning tool. 40.74% of all statements (question Q8.3), for instance, either ask for better collaboration support in terms of creating and processing content or enhanced resource management capabilities.

Despite the existing shortcomings, 31.58% of all statements (question Q7) report that learners were satisfied with their learning processes. 52.64% of all
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statements (question Q7) show that learners basically were satisfied, but state need for improvement, in particular with respect to the intensification of group work, more detailed elaboration of tasks, own time management, or the evaluation of own learning process. The remaining 15.79% of all statement (question Q7) did not provide any specific answer.

9.3.2. Relevance of Features

In this section, the relevance of features is addressed with reference to the three main phases of self-regulated learning, namely the forethought, performance, and reflection phase.

Forethought Phase

The specification and use of learning artifacts is associated with the forethought phase in self-regulated learning and therefore precedes the actual performance (i.e., learning strategy control or monitoring of the learning results). In terms of the questionnaire, the questions Q2, Q3, and Q4 are concerned with this phase and cover the aspects regarding goal orientation, sources of self-efficacy, and strategic planning. Question Q4 is further detailed by the questions Q4.1 - Q4.6 which explicitly refer to the use of learning materials, features, and Facebook.

With respect to the learning tool, the following features are recognized as important to the forethought phase.

− **Resource management.** The evaluation results indicate that resources are considered important for learning processes associated with the forethought phase. Question Q4.3 in particular shows that the code framework and other resources helped students in their learning processes. Potentials for improvement are demonstrated with respect to specific exercise and application examples, as well as information on the provided code framework.

Features concerned with the management of resources are addressed with respect to their comprehensiveness. The evaluation results of question Q4.2, for instance, show that it would need enhanced features for uploading resources in dedicated contexts, such as specific workspaces or interactions. The usability of the learning tool as well as issues related to the navigation support may be improved by respective features as well.

− **Document management.** The evaluation results indicate that documents are considered important for learning processes associated with the fore-
thought phase. Question Q4.3 in particular shows that not only the description of tasks, but also lecture notes and other documents helped students in their learning processes. Potentials for improvement are demonstrated with respect to information on the tasks.

Features concerned with the management of documents are addressed with respect to the functionality of the editor. The evaluation results of question Q4.2, for instance, show that it would need enhanced editing capabilities when it comes to the authoring of documents.

- **Interaction management.** The management of interactions is considered important for learning processes associated with the forethought phase. This is demonstrated in particular through the evaluation results of question Q4.1 and Q4.2. In both cases, interactions are addressed as central aspect supporting learning processes. Some limitations, however, are shown with respect to features supporting the structuring of interactions. This includes features supporting multi-level interactions (allowing to comment on existing posts) or additional modes of communication.

The group work in general is considered useful for learning processes associated with the forethought phase. The evaluation results of question Q4.5 show that it was particular useful for sharing knowledge and distribution of work.

- **Integration of Facebook.** The integration of Facebook basically is considered useful for learning processes associated with the forethought phase. The evaluation results of question Q4.6 show that it was particular useful for communication, but also provided support with respect to the organization of work. The Facebook integration, however, was not used consistently across the different groups. This may be attributed to the individual team members, but could be caused through limitations in the integration also, the latter, for instance, referring to the linking between postings provided by the learning tool and Facebook.

- **Sharing of information.** The sharing of information is not considered directly relevant for learning processes associated with the forethought phase. The evaluation results do not show any indication of how respectively features were used during elaboration of the tasks.

**Performance Phase**

The monitoring of learning processes is associated with the performance phase in self-regulated learning. In terms of the questionnaire, the questions Q5 and Q6 are concerned with this phase and cover the aspects regarding learning strategy control and monitoring of the learning results. Question Q6 is further
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detailed by the questions Q6.1 - Q6.4 which explicitly refer to the description of tasks and features supporting students in monitoring their learning results.

With respect to the learning tool, the following features are recognized as important to the performance phase:

− **Resource management.** The evaluation results indicate that resources are considered important for learning processes associated with the performance phase. In particular with respect to the selection of learning strategies, resources were assessed as comprehensive and efficient source of information.

− **Document management.** Since some learning materials were provided by means of documents, their importance to the learning process was recognized. Students, however, did not address particular features provided by the learning tool for managing resources, but rather focused on the content in particular with respect to the aspect of self-testing. Additional information was claimed by students in this regard for the purpose of better assessing their learning progress.

− **Interaction management.** Features supporting the management of interactions were considered relevant in the context of the collaborative elaboration of the tasks. Students, however, did not limit these features to the ability to exchange and share knowledge, but also used them for monitoring their own learning progress.

− **Sharing of information.** The sharing of information is not directly addressed by the evaluation results, but is closely linked with statements related to the ability to exchange and share knowledge. Students recognized the importance of respective features in this context.

Not all requirements are addressed by the evaluation results associated with the performance phase. In particular the typecasting of content as well as the management of workspaces and e-mail notifications were not mentioned explicitly. This does not imply the irrelevance of respective features, however, indicates that they were not as important to the performance phase (i.e., the monitoring of learning processes) as compared to other features. The constant update of interaction threads and the integration of Facebook were not addressed either, but may be included in statements recognizing the importance of interactions for the purpose of monitoring learning processes.

**Reflection Phase**

The self-reflection on one’s learning processes is associated with the reflection phase in self-regulated learning. In terms of the questionnaire, the questions
Q1, Q7, and Q8 are concerned with this phase and cover the aspects regarding self-reflection on the learning outcome, self-evaluation of the learning experience, and interferences for subsequent learning experiences. Questions Q1 and Q8 are further detailed by the questions Q1.1 - Q1.2 and Q8.1 - Q8.3 which explicitly refer to the description and elaboration of task as well as features supporting students in preparing the learned for further application.

With respect to the learning tool, the following features are recognized as important to the reflection phase.

- **Resource management.** The evaluation results indicate that resources are considered important for learning processes associated with the reflection phase. Respective features, however, were criticized due to substantial shortcomings, in particular when used for preparing and documenting the learned. Students explicitly asked for improvements, most importantly when working with resources in the context of specific workspaces.

- **Document management.** The management of documents was considered important in the reflection phase. Students were able to basically prepare and document the learned for future application. Substantial limitations with respect to the functionality of the content editor as well as related to the reusability of created content, however, are addressed in the evaluation results.

- **Interaction management.** Similar to the forethought and performance phase, interactions were considered important to the reflection phase as well. Students, however, ask for better support in structuring interactions, such as being able to post comments with reference to specific posts in the context of an interaction.

- **Workspace management.** Workspace management was considered important to the reflection phase. In particular when preparing the learning for future application, workspaces were addressed as useful for organization purposes. Despite this usefulness, however, some limitations and shortcomings were identified by the students with respect to the management of permissions, the handling of resources and documents, and so forth.

**9.4. Summary**

In this chapter, the proposed tool was assessed according to its applicability and usefulness in the context of a specific learning scenario. The evaluation was composed of two main parts, focusing on the usability of the learning tool and respective features (cf. Section 9.1) as well as the application analysis (cf. Section 9.2). The findings eventually were interpreted with respect to the
development goals as well as self-regulated learning (cf. Section \ref{sec:methodology}).

From the perspective of the learning tool and its support, the findings can summarized as follows:

\begin{itemize}
\item \textit{Non-functional requirements.} In terms of non-functional requirements, only those relevant to the learning scenario were implemented and positively assessed, namely extensibility, integration ability, and reusability of learning artifacts. Other non-functional requirements, such as performance, security, availability, and scalability, are considered important but were out of scope of this work. In a next step, therefore, adequate test scenarios are to be defined, allowing the methodological assessment of the current state of implementation and the development of an appropriate plan of action.
\item \textit{Usability.} The usability of the learning tool was evaluated in the course of this work, however, was not considered primary object of research. The learners admittedly were able to successfully apply the learning tool in the context of the given scenario, but indicated several usability issues, particularly with respect to navigation support, structuring and visualization of interactions, organization of workspaces, and so forth. In a next step, therefore, dedicated research and development effort needs to be put into respective questions evaluating different design and usability approaches. Methodologically, A/B tests may be conducted and used as input for future releases and novel use cases potentially.
\item \textit{Communication.} The learning tool provides communication support, not only with respect to the interaction area but also through the integration of Facebook. The results show positive effects in this regard, but also demonstrate limitations and expectations with respect to flexibility and range of functions. In particular, options to further structure interactions were reported to be missing and conducive for better learning support. A potential approach to solving this issue is the hierarchical arrangement of postings, that is providing a comments section for each post. Learners would then not need to textually quote specific posts, but could use the comments section respectively.
\item \textit{Collaborative content authoring.} Collaborative activities and respective support measures play a key role in the proposed approach. With respect to the content editor, however, several limitations were discovered and reported during the evaluation. In a next step, therefore, available frameworks and tools are to be evaluated whether to be used in the context of the learning tool or not. Due to the wide spread of web-based collaboration tools as for instance Google’s GSuite\textsuperscript{16} or Microsoft Office
\end{itemize}

\textsuperscript{16}\texttt{https://gsuite.google.com} (accessed on June 8, 2017)
36 integrative approaches via REST-based APIs are to be considered as well. Important when following an integrative approach, however, is to maintain the current flexibility in working with the content, for instance with respect to annotations.

9.4.1. Relevance of Findings

The findings presented in this chapter are concerned with the validation of the identified requirements and provide the basis for assessing the implications in learning with respect to the main research objective as well as subgoals.

9.4.2. Outlook

In the final conclusion (cf. Chapter 10), the findings are summarized with reference to the thesis’ main objective, including the associated subgoals and research questions.

\[\text{accessed on June 8, 2017}\]
10. Conclusion

Learning has become increasingly interactive and collaborative in recent years (Järvenoja et al., 2015). This development, however, is not reflected in changes in the conceptualizations of learning (i.e., fundamental theories and theoretical approaches have not changed), but rather was triggered by technological advances, changes in learners, as well as teaching methods in the learning domain (Ertmer & Newby, 2013). While technology has emerged as an enabling factor to the distributed and collaborative creation of content, learners have increasingly taken advantage of these technological possibilities, in particular due to diminishing boundaries between formal and informal learning (Prensky, 2010). Although technological progress provides a wide range of different benefits, said advances at the same time expose learners to new challenges with respect to regulation and self-management. Being able to strategically regulated one’s own learning processes therefore has become a crucial capability and is considered an important aspect in learning processes (cf. Järvenoja et al. (2015); Liaw et al. (2007)). According to Järvenoja et al. (2015, p. 204), in suchlike situations “[…] through regulation, it is possible to influence and adjust one’s cognitive, motivational, and emotional behaviors, as well as those of others, for optimal learning and working.” Self-regulated learning capabilities therefore not only help to develop one’s own knowledge (e.g., through goal setting and strategic planning), but also ensure the achievement of objectives by continuous assessment of learning strategies and outcomes (cf. Pintrich et al. (2000); Zimmerman (1998b)). Self regulation, however, has been conceptualized mainly from a static individual perspective, which does not meet all requirements necessary to understand and support learning processes today. It has become crucial to apply an integrative perspective on learning, addressing both the cognitive and social dimension in the context of situational factors (i.e., learning context).

The main objective of this work was concerned with addressing learning from the situative perspective, that is considering the cognitive and social dimension as equally balanced and interdependent. A literature review was conducted to identify the relevant properties and features to be considered relevant in constructivist learning designs (RQ 1), exposing situational factors (i.e., learning context) as important to learning processes. Investigating how to conceptualize learning context (RQ 2), an integrated learning design was operationalized and proposed to adding value to self-regulated learning through situative learning support.

In the following, the findings are summarized with respect to the subgoals and
Chapter 10. Conclusion

associated research questions (cf. Section 10.1) before individual contributions are discussed in the context of the main objective (cf. Section 10.2). Section 10.3 finally presents the limitations of this work and gives an outlook on future research questions and activities.

10.1. Summary of Findings

The main objective of this work was investigated by means of two subgoals, referring to the interdependence of the cognitive and social dimension in learning as well as the adaptive support in learning processes. Each subgoal was further refined by specific research questions which were addressed in the course of this work. To assess the implications on learning, high level objectives (i.e., development goals), which were introduced in the course of requirements analysis, are matched with the subgoals. The development goals include:

G1. Generation of ideas

G2. Organization of ideas

G3. Intellectual convergence

10.1.1. Interdependence of Cognitive and Social Dimension in Learning

Supporting situative self-regulated learning requires considering both the individual and social dimension as interdependent perspectives. In the course of the first research question (RQ 1), properties and features which are considered crucial to constructivist learning designs were investigated. The learning context as linking factor between the two perspectives was identified and conceptualized within the scope of the second research question (RQ 2).

RQ 1. What to consider in constructivist learning designs?

Constructivism views learning as an active process in which new knowledge is constructed by the learning individual. The degree to which learners are responsible for building their own knowledge therefore rises. Due to increasing levels of interactivity and collaboration, however, not only individual capacities addressed by theories like cognitive load theory, situated cognition, or cognitive constructivism, but also the social dimension (e.g., social constructivism, online collaborative learning theory) is considered relevant. This bipartite view has led to consider learning either from the one or the other perspective mainly. The other perspective admittedly was not neglected, but just considered as minor influencing factor. The need to consider both perspectives interdependently
10.1. Summary of Findings

has emerged in literature and promises to contribute to a better understanding of learning processes, particularly due to the consideration of situation factors.

RQ 2. How to conceptualize learning context?

The learning context becomes a relevant constituent when considering the cognitive and social dimension as interdependent perspectives. From a theoretical point of view, the situative perspective on learning reflects this integrative approach and aims to increase the understanding of respective processes by identifying and addressing a complex web of situational factors which are specific to time and place. Given these findings, the community of inquiry model was used as guiding framework not only for the conceptualization of learning context, but also for putting it into perspective with regards to the cognitive and social dimension. While social and cognitive aspects relate to the engagement with participants and content respectively, the contextual aspect addresses underlying learning structures and processes which are relevant to collaborative activities as well as regulation on learning.

10.1.2. Adaptive Support in Learning Processes

Since learning context is considered as being specific to time and place, support measures are required to be adaptive with regards to respective situational factors. The third research question (RQ 3) addresses this issue as an integrated learning design was operationalized by means of the community of inquiry model.

RQ 3. How to operationalize an integrated learning design?

An integrated learning design was operationalized based on the community of inquiry model, which considers the cognitive, social, and teaching presence as relevant for creating a deep and meaningful (collaborative constructivist) educational experience. The online collaborative learning theory was used as guiding framework, referring to three intellectual phases including idea generation, idea organization, and intellectual convergence. The intellectual phases as well as the presences defined by the community of inquiry model, specific requirement bundles – functional and non-functional – were identified. The implementation of the middleware framework AEOLION and the web-based learning tool Ueber Learn respectively was the enabler to empirical test the effects on students learning processes.
10.1.3. Adding Value to Self-regulated Learning through Situative Learning Support

Situative self-regulated learning requires to achieve interdependence between the cognitive and social dimension (subgoal 2) by considering situational factors as important constituents so as to provide adaptive learning support (subgoal 2). In the following, the findings associated with the respective subgoals are discussed in terms of their contributions to the main objective.

Considering the cognitive and social dimension as equally balanced and interdependent requires an integrative approach on what to consider relevant in constructivist learning designs, in particular with reference to self-regulated learning. The community of inquiry model meets the requirements of such an approach, referring to the cognitive, social, and teaching presence as being crucial to learning and the educational experience respectively. Figure 10.1 illustrates the main features of the model and reflects the individual presences based on the findings.

- The cognitive presence as being defined through the engagement with content is concerned with aspects of self-regulated learning, in particular with respect to the intersection with the teaching presence. The model suggests that selecting content and regulating one’s learning processes is affected by existing structures and processes (e.g., the pedagogical design or technology support).

- The social presence as being defined through the engagement with participants has gained in importance since learning is increasingly interactive and collaborative. Information technology is considered as the enabling factor and conceptualized as part of the teaching presence.

- The teaching presence as defined through learning structures and processes allows integrating the learning context. As being crucial to setting the climate for social interaction as well as selecting content and regulating learning, the teaching presence addresses adaptive nature of learning with reference to situational factors.

The relevance of the cognitive dimension is not only reflected in the context of self-regulation, but also becomes evident as being influence by the social and teaching presence respectively. By implication, this means that it becomes increasingly important to explicitly consider the social and teaching presence in constructivist learning designs.

Since the situative perspective is specific to time and place (i.e., situational factors, such as learning tasks, technology support, or pedagogical designs, may change over time), support measures need to be able to cope with dynamic changes in learning situations. The three intellectual phases as related to idea
Figure 10.1.: The community of inquiry model in the context of the situative perspective on learning

generation, idea organization, and intellectual convergence outline the scope of potential changes with respect to activities and roles relevant to learning processes. The role of the instructor, in particular, is emphasized as providing the link to relevant knowledge communities specific to current learning tasks and situations.

10.2. Main Contributions & Shortcomings

The findings indicate that in particular the collaborative aspect was perceived as being useful to realize one’s learning progress. In particular, opportunities to compare as well as the ability to share knowledge was assessed as being useful in this regard. In terms of the individual perspective, monitoring processes were limited to the use of provided learning materials, such as the lecture notes. Related to the reflection on learning processes, about one third of the students were completely satisfied, leaving two thirds being critical of their learning experiences with respect to the intensity of group work, a more detailed elaboration of tasks, better time management and better evaluation of the own learning process. The main contributions to supporting self-regulated learning under the consideration of situative conditions as well as shortcomings can be summarized as follows:

− Learning artifacts as potential approach to support self-regulated learning.
  Considering learning artifacts as emergent in the course of time while
being durable, accessible, and materially present in the learning environment opens up a variety of different possibilities to support self-regulated learning under the consideration of situative conditions. The findings show that learning artifacts generally were considered useful, however, primarily were assumed to be given by the instructor instead of being used and adapted throughout the learning process.

- **Limited reusability of learning artifacts beyond the scope of the learning tool.** The findings show that the learning tool was perceived as being limited with respect to the reusability of learning artifacts beyond the scope of the learning tool. The integration of third-party applications, such as Google Drive or MS One Drive, would increase reusability in this regard. At the same time, however, features concerned with the specification and use of learning artifacts as well as their convergence would be limited.

- **Integration of Facebook as means for communication and organization.** In the context of enhancing pervasive connectedness, the integration of Facebook generally was perceived as being useful. The scope of application, however, did not refer to working with learning artifacts directly, but rather was focused on communication and organization support. The findings imply that by means of Facebook learners were able to integrate communication and organization related tasks into their personal environments using features such as the notification mechanism or the news feed.

### 10.3. Future Work

The limitations of this work as well as an outlook on future research questions and activities are presented in this chapter. It particularly concerns the requirements analysis, the reflection based on the three main phases of self-regulated learning, and further developments of the learning tool.

#### Questioning Requirements

With respect to the development process and operations of CSCL systems proposed by Schwabe et al. (2012), this work involved all activities from requirements analysis to the assessment and operation of the system. Feedback loops, however, only were passed through during the design and implementation phase. The underlying specification of teaching principles and didactics as well as organizational conditions therefore were not questioned. The following questions appear to be relevant:

- **Do we need to change the underlying assumptions with respect to the principles of teaching and didactics?**
This first question relates to the principles of teaching and didactics which were considered relevant for the identification of requirements and therefore the conceptualization of the learning tool. Questioning these assumptions as a consequence would not only concern the structuring of tasks, but also the way collaborative work is organized and incentivized. For instance, the findings of this work, in particular with respect to the collaborative elaboration of tasks, indicate that the structure of tasks did not encourage group work in general. The threefold division, in contrast, rather promoted the apportionment of work without having to consolidate the individual experience for the purpose of collaborative knowledge generation.

Do we need to change the underlying assumptions with respect to organizational conditions?

The second question is concerned with organizational conditions which are given by an organization or institution, as for instance a university. In contrast to the first question, however, organizational conditions are limited in terms of being changed and adapted to the needs of the envisioned learning and teaching scenario. Nevertheless, the explicit consideration of these conditions would reduce and minimize possible negative impact on the identification of requirements.

**Self-regulated Learning**  Self-regulated learning in general is conceptualized according to three main phases, including the forethought, performance, and self-reflection phase. The forethought phase, also referred to as metacognitive knowledge, is considered an entering metacognitive state and, compared to the constructs associated with the performance phase, relatively static. It not only concerns knowledge of cognition and cognitive strategies, but also knowledge of the self as well as of the tasks and the respective contexts. The performance phase by contrast is considered to be more dynamic, since it concerns the assessment of tasks with respect to their levels of difficulty, comprehension monitoring of learning, self-assessment, and confidence of judgments. Eventually, the self-reflection phase addresses the planning of activities, the selection and use of strategies, the allocation of resources, as well as volitional control.

In the course of this work, however, neither the conceptualization of the tool nor the findings were considered in light of these phases. Only the relevance of features was discussed with respect to the forethought, performance, and self-reflection phase. Future work therefore could investigate the relevance of the forethought, performance, and self-reflection phase in the context of the development goals as well as requirements. Potential suggestions are proposed in the following:

The monitoring of learning processes addresses aspects concerned with the performance phase of self-regulated learning. It allows learners to
actively monitor their learning processes and attempt to utilize learning strategies which are assessed as being helpful.

- The self-reflection on learning processes addresses aspects concerned with the self-reflection phase of self-regulated learning. It facilitates reflective processes after the actual performance and allows learners to compare the outcomes of learning processes with the respective goals.

- The specification and use of learning artifacts, the convergence of learning artifacts, as well as the facilitation of social discourse cannot be associated with one particular phase of self-regulated learning. With respect to the forethought phase, for instance, learning artifacts are used as input for the selection of learning strategies. Learners might consider different learning artifacts dependent on the specific task or learning scenario at hand. During the performance phase, by contrast, learning artifacts might be involved more actively. In this regard, however, learning artifacts only are addressed indirectly as their usefulness is assessed by means of the efficiency of learning strategies. The same holds true for self-reflective processes, since learning artifacts are assessed in the context of one’s performance in the learning process.
Appendix
A. Implementation Details

Details of both the AEOLION framework and the web-based learning tool Ueber Learn are presented in this chapter. Section A.1 introduces the conventions in terms of notations used in this work, in particular with respect to the actor notation. The setup of the projects, that is dependencies on third party libraries, as well as the plugins developed in this context are described (cf. Sections A.2 and A.3). Finally, in Section A.4 the representation format used for representing learning artifacts is introduced based on an example.

A.1. Conventions

Conventions in terms of notations used in this work are introduced and explained in this section. This particularly is concerned with the actor notation.

A.1.1. Actor Notation

The actor notation used in this work follows the the notation proposed by [Ahlgård (1985); Vernon (2015)]. Each actor thereby is represented as circle, where long-lived actors are drawn with solid and short-lived actors with dashed lines (cf. Figure A.1).

![Actor Notation Diagram](image)

(a) Long-lived actor  (b) Short-lived actor

Figure A.1.: Actor representation

Actors can instantiate (spawn) other actors which allows the parent actor to monitor the states of subordinated actors and interfere in the case of errors (cf. Figure A.2).
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An available actor hierarchy, that is all subordinated actors, is indicated by an triangle with three circles (cf. Figure A.3).

An actor can terminate itself when there is no need for the provided service. In this case, a circle with a cross is used to show the self-termination process (cf. Figure A.4).

An actor can also terminate other actors by sending respective signals. A circle, as shown for self-termination also, is used but is not self-referential but points to the actor to be terminated (cf. Figure A.5).

During the existence of an actor, it sends and receives messages to and from other actors. The lifeline used to illustrated incoming and outgoing messages is represented as a solid line (cf. Figure A.6).
Communication among actors is provided using message passing, that is messages sent from one to another actor. The receiving actor thereby specifies further processing steps and whether to react or ignore incoming requests. Each message is represented as a rectangle attached to a circle, which both are referenced to its sender and receiver (cf. Figure A.7).

A.2. Project Setup & Dependencies

The project setup as well as the relevant dependencies on third-party libraries are described in this section.

A.2.1. AEOLION

Listing A.1 shows the dependencies on third-party libraries of the AEOLION framework. Using Gradle\footnote{https://gradle.org (accessed on June 17, 2017)} as package manager and build tool, the setup of the framework and dependencies among both the separate plugins and third-party libraries are shown.
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Listing A.1: Dependencies of the AEOLION framework

```groovy
allprojects {
    apply plugin: 'scala'
    apply plugin: 'java'
    apply plugin: 'gradle-one-jar'

    repositories {
        mavenCentral()
        maven { url 'http://repo.spray.io' }
    }

    dependencies {
        // scala
        compile 'org.scala-lang:scala-library:2.11.8'
        // akka actors
        compile 'com.typesafe.akka:akka-actor_2.11:2.4.4'
        // mongodb
        compile 'org.mongodb:casbah-core_2.11:3.1.1'
        // spray
        compile 'io.spray:spray-routing_2.11:1.3.3'
        compile 'io.spray:spray-json_2.11:1.3.2'
        compile 'io.spray:spray-testkit_2.11:1.3.2'
        // helpers
        compile 'org.json4s:json4s-jackson_2.11:3.3.0.RC6'
        compile 'commons-codec:commons-codec:1.10'
        // logging
        compile 'com.typesafe.scala-logging:scala-logging-slf4j_2.11:2.1.2'
        compile 'com.typesafe.scala-logging:scala-logging-api_2.11:2.1.2'
        compile 'org.slf4j:slf4j-api:1.7.7'
        compile 'ch.qos.logback:logback-classic:1.1.2'
        compile 'com.sun.mail:javax.mail:1.5.5'
        compile 'org.codehaus.groovy:groovy-all:2.4.6'
        compile 'com.typesafe:config:1.3.0'
        testCompile 'junit:junit:4.12'
    }

    subprojects {
        repositories {
            flatDir {
                dirs '../libs'
            }
        }
    }

    project(':aeolion-utils') {
        dependencies {
            compile 'io.spray:spray-client_2.11:1.3.3'
        }
    }

    project(':aeolion-remote') {
        dependencies {
        }
    }
}
```

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A.2. Project Setup & Dependencies

```scala
// Project Setup & Dependencies

// Kernel project('':aeolion-kernel_src'') {
  dependencies {
    // akka actors
    compile 'com.typesafe.akka:akka-remote_2.11:2.4.4'
    compile project('':aeolion-kernel_api'')
    // spray
    compile 'io.spray:spray-http_2.11:1.3.2-20140909'
    compile 'io.spray:spray-can_2.11:1.3.2-20140909'
    // utills
    compile project('':aeolion-utils'')
    compile 'org.scalaj:scalaj-http_2.11:2.3.0'
    compile 'org.clapper:classutil_2.11:1.0.5'
    compile 'com.typesafe.akka:akka-actor_2.11:2.3.11'
    compile project('':aeolion-plugin-notifications_api'')
  }
}

// Notifications project('':aeolion-plugin-notifications_api'') {
  dependencies {
    project('':aeolion-kernel_api'')
  }
}

project('':aeolion-plugin-notifications_src'') {
  dependencies {
    compile project('':aeolion-plugin-notifications_api'')
  }
}
```

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// Projects
project(':aeolion-plugin-projects_api') {
    dependencies {
        compile project(':aeolion-kernel_api')
        compile project(':aeolion-plugin-interactions_api')
        compile project(':aeolion-plugin-documents_api')
        compile project(':aeolion-plugin-notifications_api')
    }
}

project(':aeolion-plugin-projects_src') {
    dependencies {
        compile project(':aeolion-plugin-projects_api')
    }
}

// Interactions
project(':aeolion-plugin-interactions_api') {
    dependencies {
        compile project(':aeolion-kernel_api')
        compile project(':aeolion-plugin-documents_api')
    }
}

project(':aeolion-plugin-interactions_src') {
    dependencies {
        compile project(':aeolion-plugin-interactions_api')
    }
}

// Documents
project(':aeolion-plugin-documents_api') {
    dependencies {
        compile project(':aeolion-kernel_api')
        compile project(':aeolion-plugin-resources_api')
        compile 'com.itextpdf:itextpdf:5.5.15'
    }
}

project(':aeolion-plugin-documents_src') {
    dependencies {
        compile project(':aeolion-plugin-documents_api')
    }
}

// Resources
project(':aeolion-plugin-resources_api') {
    dependencies {
        compile project(':aeolion-kernel_api')
        compile 'com.sksamuel.scrmage:scrmage-core_2.11:2.1.5'
    }
}

project(':aeolion-plugin-resources_src') {
    dependencies {

A.2. Project Setup & Dependencies

```kotlin
compile project(':aeolion-plugin-resources_api')

// Build
buildscript {
    repositories {
        mavenCentral()
        maven { url 'http://repo.spray.io' }
    }
    dependencies {
        classpath 'com.github.rholder:gradle-one-jar:1.0.4'
    }
}
```

A.2.2. Ueber Learn

Listing A.2 shows the dependencies on third-party libraries of the web-based learning tool Ueber Learn. Using npm as package manager for JavaScript, dependencies on third-party libraries are shown.

Listing A.2: Dependencies of Ueber Learn

```json
{

   "name": "aeolion-learning",
   "version": "0.0.0",
   "private": true,
   "scripts": {
      "start": "node ./bin/www"
   },
   "dependencies": {
      "angular": "1.4.6",
      "angular-moment": "1.0.0-beta.3",
      "angular-route": "1.5.5",
      "angular-ui-date": "1.0.1",
      "body-parser": "1.13.3",
      "bootstrap": "3.3.6",
      "bootstrap-switch": "3.3.2",
      "cookie-parser": "1.3.5",
      "cytoscape": "2.6.12",
      "cytoscape-cxtmenu": "2.7.1",
      "cytoscape-dagre": "1.3.0",
      "debug": "2.2.0",
      "dropzone": "4.2.0",
      "express": "4.13.1",
      "express-session": "1.12.1",
      "font-awesome": "4.5.0",
      "gulp": "3.9.1",
      "jade": "1.11.0",
      "jquery": "2.2.0"
   }
}
```

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```
"jquery-ui": "1.10.5",
"morgan": "1.6.1",
"ng-load": "1.0.2",
"node-sass": "3.4.1",
"nodejs-config": "1.0.1",
"request": "2.67.0",
"serve-favicon": "~2.3.0",
"summernote": "0.7.3",
"swig": "~1.4.2"
}
```

```
"devDependencies": {
  "jasmine-core": "2.3.4",
  "karma": "0.13.11",
  "karma-chrome-launcher": "0.2.1",
  "karma-jasmine": "0.3.6"
}
```

A.3. Plugin Specifications

Multiple plugins have been developed for the purpose of supporting situative self-regulated learning processes. In this chapter, each plugin is presented by means of its general descriptor and interface, the latter defining messages used for communication with other plugins (actors).

A.3.1. Workspaces

Listing A.3: The workspaces plugin descriptor

```
package at.jku.ce.aeolion.workspaces.api

object WorkspacesDescriptor extends Descriptor {
  override val id = "workspaces"
  override val actorClass = "at.jku.ce.aeolion.workspaces.WorkspacesActor"
  override val dependencies = Vector(InteractionsDescriptor.id)
}
```

Listing A.4: The workspaces plugin interface

```
package at.jku.ce.aeolion.workspaces.api

abstract class WorkspacesMessage extends AeolionMessage {
  override val origin = WorkspacesDescriptor.id
}
```

```
object WorkspacesPlugin {
  object API {
```

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```scala
final case class CreateWorkspace(name: String)(implicit val token: AeolionToken) extends WorkspacesMessage

final case class GetWorkspace(workspace: AeolionID)(
  implicit val token: AeolionToken) extends WorkspacesMessage


final case class $Workspace(workspace: Workspace) extends WorkspacesMessage

final case class $Submissions(submissions: Vector[Submission]) extends WorkspacesMessage

final case class $Submission(submission: Submission) extends WorkspacesMessage

final case class $Settings(settings: Map[String, String]) extends WorkspacesMessage

final case class $Workspaces(workspaces: Vector[Workspace]) extends WorkspacesMessage

final case class $WorkspacesIds(workspaces: Vector[AeolionID]) extends WorkspacesMessage

final case class AddMember(workspace: AeolionID, user: AeolionID)(implicit val token: AeolionToken) extends WorkspacesMessage

final case class RemoveMember(workspace: AeolionID, user: AeolionID)(implicit val token: AeolionToken) extends WorkspacesMessage

final case class GetInteractions(workspace: AeolionID)(
  implicit val token: AeolionToken) extends WorkspacesMessage

final case class GetDocuments(workspace: AeolionID)(
  implicit val token: AeolionToken) extends WorkspacesMessage

final case class GetDownloads(workspace: AeolionID)(
  implicit val token: AeolionToken) extends WorkspacesMessage

final case class GetSettings(workspace: AeolionID)(implicit val token: AeolionToken) extends WorkspacesMessage

final case class SubmitSubmission(workspace: AeolionID, submission: AeolionID)(implicit val token: AeolionToken) extends WorkspacesMessage

final case class CloseSubmissions(workspace: AeolionID)(
  implicit val token: AeolionToken) extends
```
Appendix A. Implementation Details

```scala
final case class DownloadSubmission(workspace: AeolionID)(
  implicit val token: AeolionToken) extends WorkspacesMessage

final case class GetSubmissions(workspace: AeolionID)(
  implicit val token: AeolionToken) extends WorkspacesMessage

final case class CreateSubmission(workspace: AeolionID, submission: AeolionID, data: Array[Byte], dataType: DataType.Value)(implicit val token: AeolionToken)
  extends WorkspacesMessage

final case class GetContents(workspace: AeolionID)(implicit val token: AeolionToken) extends WorkspacesMessage

final case class TagContent(workspace: AeolionID, content: AeolionID)(implicit val token: AeolionToken) extends WorkspacesMessage

final case class UntagContent(workspace: AeolionID, content: AeolionID)(implicit val token: AeolionToken) extends WorkspacesMessage

final case class GetNotepad(workspace: AeolionID)(implicit val token: AeolionToken) extends WorkspacesMessage

final case class CreateInteraction(workspace: AeolionID, data: InteractionData)(implicit val token: AeolionToken) extends WorkspacesMessage

final case class UpdateWorkspace(update: WorkspaceUpdate)(implicit val token: AeolionToken) extends WorkspacesMessage

final case class GetMembers(workspace: AeolionID, resolve: Boolean = true)(implicit val token: AeolionToken) extends WorkspacesMessage

final case class CreateDocument(workspace: AeolionID, title: String)(implicit val token: AeolionToken) extends WorkspacesMessage

final case class AttachDocument(workspace: AeolionID, document: AeolionID)(implicit val token: AeolionToken) extends WorkspacesMessage

final case class AttachDownload(workspace: AeolionID, download: AeolionID)(implicit val token: AeolionToken) extends WorkspacesMessage

final case class DetachDownload(workspace: AeolionID, download: AeolionID)(implicit val token: AeolionToken) extends WorkspacesMessage

final case class AddDownload(workspace: AeolionID, data: Array[Byte])(implicit val token: AeolionToken) extends WorkspacesMessage
```

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A.3. Plugin Specifications

A.3.2. Interactions

Listing A.5: The interactions plugin descriptor

```scala
package at.jku.ce.aeolion.interactions.api

object InteractionsDescriptor extends Descriptor {
  override val id = "interactions"
  override val actorClass = "at.jku.ce.aeolion.interactions.actors.InteractionsActor"
  override val dependencies = Vector(DocumentsDescriptor.id)
}
```

Listing A.6: The interactions plugin interface

```scala
package at.jku.ce.aeolion.interactions.api

abstract class InteractionMessage extends AeolionMessage {
  override val origin = InteractionsDescriptor.id
}

object InteractionsPlugin {
  object API {
    // Interactions
    final case class CreateInteraction(data: InteractionData, participants: Vector[AeolionID] = Vector())(implicit val token: AeolionToken) extends InteractionMessage
    final case class $Interaction(interaction: Interaction) extends InteractionMessage
  }
}
```
Appendix A. Implementation Details

Listing A.7: The documents plugin descriptor

```scala
package at.jku.ce.aeolion.documents.api

object DocumentsDescriptor extends Descriptor {

  // Posts
  final case class CreatePost(interaction: AeolionID, content: ContentData)(implicit val token: AeolionToken) extends InteractionMessage

  final case class UpdatePost(update: PostUpdate)(implicit val token: AeolionToken) extends InteractionMessage

  final case class AddParticipant(interaction: AeolionID, user: AeolionID)(implicit val token: AeolionToken) extends InteractionMessage

  final case class DeleteParticipant(interaction: AeolionID, user: AeolionID)(implicit val token: AeolionToken) extends InteractionMessage

  final case class GetParticipants(interaction: AeolionID, recursive: Boolean = false)(implicit val token: AeolionToken) extends InteractionMessage

  final case class UpdateInteraction(update: InteractionUpdate)(implicit val token: AeolionToken) extends InteractionMessage

  final case class DeletePost(post: AeolionID)(implicit val token: AeolionToken) extends InteractionMessage

  final case class GetPost(post: AeolionID)(implicit val token: AeolionToken) extends InteractionMessage


  final case class $Post(post: Post) extends InteractionMessage

  final case class $Posts(posts: Vector[Post]) extends InteractionMessage

}
```

A.3.3. Documents
override val id = "documents"
override val actorClass = "at.jku.ce.aeolion.documents.actors.DocumentsActor"
}

Listing A.8: The documents plugin interface

package at.jku.ce.aeolion.documents.api

trait DocumentsMessage extends AeolionMessage {
override val origin = DocumentsDescriptor.id
}

object DocumentsPlugin {

object API {


final case class ResolveDocumentContent(document: AeolionID)(implicit val token: AeolionToken) extends DocumentsMessage

final case class GetContent(content: AeolionID)(implicit val token: AeolionToken) extends DocumentsMessage

final case class GetContents(contents: Vector[AeolionID])(implicit val token: AeolionToken) extends DocumentsMessage

final case class CreateDocument(name: String, content: Option[ContentItem] = None)(implicit val token: AeolionToken) extends DocumentsMessage

final case class UpdateDocument(update: DocumentUpdate)(implicit val token: AeolionToken) extends DocumentsMessage

final case class UpdateContent(update: ContentUpdate)(implicit val token: AeolionToken) extends DocumentsMessage

final case class CreateContent(content: ContentData)(implicit val token: AeolionToken) extends DocumentsMessage

final case class DeleteContent(content: AeolionID)(implicit val token: AeolionToken) extends DocumentsMessage

final case class AnnotateContent(content: AeolionID, annotation: JObject)(implicit val token: AeolionToken) extends DocumentsMessage

}
Appendix A. Implementation Details

```scala
extends DocumentsMessage

final case class GetAnnotation(annotation: AeolionID)(
  implicit val token: AeolionToken) extends DocumentsMessage

final case class ParseContent(content: String)(implicit val token: AeolionToken) extends DocumentsMessage

final case class DeleteAnnotation(content: AeolionID, annotation: AeolionID)(implicit val token: AeolionToken) extends DocumentsMessage

final case class $Document(document: Document) extends DocumentsMessage

final case class $Documents(documents: Vector[Document]) extends DocumentsMessage

final case class $Content(content: Content) extends DocumentsMessage

final case class $Annotation(annotation: Annotation) extends DocumentsMessage

final case class $Contents(contents: Vector[Content]) extends DocumentsMessage
```

A.3.4. Resources

Listing A.9: The resources plugin descriptor

```scala
package at.jku.ce.aeolion.resources.api

object ResourcesDescriptor extends Descriptor {
  override val id = "resources"
  override val actorClass = "at.jku.ce.aeolion.resources.ResourcesActor"
  override val dependencies = Vector()
}
```

Listing A.10: The resources plugin interface

```scala
package at.jku.ce.aeolion.resources.api

trait ResourcesMessage extends AeolionMessage {
  override val origin = ResourcesDescriptor.id
}

object ResourcesPlugin {
```
A.3. Plugin Specifications

A.3.5. Notifications

Listing A.11: The notifications plugin descriptor

```scala
package at.jku.ce.aeolion.notifications.api

abstract class NotificationsMessage extends AeolionMessage {
  override val origin = NotificationsDescriptor.id
}

object NotificationsPlugin {
  object API {
    final case class GetResource(resource: AeolionID, role: Resource.ROLES.Value = Resource.ROLES.Reader)(implicit val token: AeolionToken) extends ResourcesMessage
    final case class GetVTT(resource: AeolionID, role: Resource.ROLES.Value = Resource.ROLES.Reader)(implicit val token: AeolionToken) extends ResourcesMessage
    final case class GetResources(resources: Vector[AeolionID] = Vector.empty, role: Resource.ROLES.Value = Resource.ROLES.Reader, all: Boolean = false)(implicit val token: AeolionToken) extends ResourcesMessage
    final case class CreateResource(data: Array[Byte], name: Option[String], dataType: DataType.Value, validate: Boolean = true)(implicit val token: AeolionToken) extends ResourcesMessage
    final case class CreateWebResource(name: String, url: String)(implicit val token: AeolionToken) extends ResourcesMessage
    final case class CreateVTTResource(data: Array[Byte])(implicit val token: AeolionToken) extends ResourcesMessage
    final case class UpdateResource(update: ResourceUpdate)(implicit val token: AeolionToken) extends ResourcesMessage
    final case class $Resource(resource: Resource) extends ResourcesMessage
    final case class $Resources(resources: Vector[Resource]) extends ResourcesMessage
  }
}
```

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```scala
final case class Notify(users: Vector[AeolionID], scope: String, message: String)(implicit val token: AeolionToken) extends NotificationsMessage

final case class GetNotification(user: AeolionID)(implicit val token: AeolionToken) extends NotificationsMessage

final case class UpdateNotification(update: NotificationUpdate)(implicit val token: AeolionToken) extends NotificationsMessage

final case class $Notification(notification: Notification) extends NotificationsMessage

Listing A.12: The notifications plugin interface

package at.jku.ce.aeolion.notifications.api

object NotificationsDescriptor extends Descriptor {
  override val id = "notifications"
  override val actorClass = "at.jku.ce.aeolion.notifications.actors.NotificationsActor"
}

A.4. Common Representation Format

Listing A.13 shows the complete representation of the learning artifact illustrated in Section 6.3. It not only contains simple text elements, but also refers to headings, images, listings, and so forth.

Listing A.13: An example representation of a learning artifact

{  
  "data": {  
    "id": 272163,
    "owner": 23,
    "created": 1480711068286,
    "_type": "Collection",
    "items": [
      {
        "id": 272155,
        "owner": 23,
        "created": 1480711068850,
        "_type": "Heading",
        "level": 1,
        "items": [
          {
            "id": 272137,
            "owner": 23,
            "created": 14807110686286,
            "_type": "Collection",
            "level": 1,
            "items": [
              {
                "id": 272129,
                "owner": 23,
                "created": 14807110686286,
                "_type": "Collection",
                "level": 1,
                "items": [
                  {
                    "id": 272121,
                    "owner": 23,
                    "created": 14807110686286,
                    "_type": "Collection",
                    "level": 1,
                    "items": [
                      {
                        "id": 272113,
                        "owner": 23,
                        "created": 14807110686286,
                        "_type": "Collection",
                        "level": 1,
                        "items": [
                          {
                            "id": 272105,
                            "owner": 23,
                            "created": 14807110686286,
                            "_type": "Collection",
                            "level": 1,
                            "items": [
                              {
                                "id": 272097,
                                "owner": 23,
                                "created": 14807110686286,
                                "_type": "Collection",
                                "level": 1,
                                "items": [
                                  {
                                    "id": 272089,
                                    "owner": 23,
                                    "created": 14807110686286,
                                    "_type": "Collection",
                                    "level": 1,
                                    "items": [
                                      {
                                        "id": 272081,
                                        "owner": 23,
                                        "created": 14807110686286,
                                        "_type": "Collection",
                                        "level": 1,
                                        "items": [
                                          {
                                            "id": 272073,
                                            "owner": 23,
                                            "created": 14807110686286,
                                            "_type": "Collection",
                                            "level": 1,
                                            "items": [
                                              {
                                                "id": 272065,
                                                "owner": 23,
                                                "created": 14807110686286,
                                                "_type": "Collection",
                                                "level": 1,
                                                "items": [
                                                  {
                                                    "id": 272057,
                                                    "owner": 23,
                                                    "created": 14807110686286,
                                                    "_type": "Collection",
                                                    "level": 1,
                                                    "items": [
                                                      {
                                                        "id": 272049,
                                                        "owner": 23,
                                                        "created": 14807110686286,
                                                        "_type": "Collection",
                                                        "level": 1,
                                                        "items": [
                                                          {
                                                            "id": 272041,
                                                            "owner": 23,
                                                            "created": 14807110686286,
                                                            "_type": "Collection",
                                                            "level": 1,
                                                            "items": [
                                                              {
                                                                "id": 272033,
                                                                "owner": 23,
                                                                "created": 14807110686286,
                                                                "_type": "Collection",
                                                                "level": 1,
                                                                "items": [
                                                                  {
                                                                    "id": 272025,
                                                                    "owner": 23,
                                                                    "created": 14807110686286,
                                                                    "_type": "Collection",
                                                                    "level": 1,
                                                                    "items": [
                                                                      {
                                                                        "id": 272017,
                                                                        "owner": 23,
                                                                        "created": 14807110686286,
                                                                        "_type": "Collection",
                                                                        "level": 1,
                                                                        "items": [
                                                                          {
                                                                            "id": 272009,
                                                                            "owner": 23,
                                                                            "created": 14807110686286,
                                                                            "_type": "Collection",
                                                                            "level": 1,
                                                                            "items": [
                                                                              {
                                                                                "id": 272001,
                                                                                "owner": 23,
                                                                                "created": 14807110686286,
                                                                                "_type": "Collection",
                                                                                "level": 1,
                                                                                "items": [
                                                                                  {
                                                                                    "id": 271993,
                                                                                    "owner": 23,
                                                                                    "created": 14807110686286,
                                                                                    "_type": "Collection",
                                                                                    "level": 1,
                                                                                    "items": [
                                                                                      {
                                                                                        "id": 271985,
                                                                                        "owner": 23,
                                                                                        "created": 14807110686286,
                                                                                        "_type": "Collection",
                                                                                        "level": 1,
                                                                                        "items": [
                                                                                      {
                                                                                        "id": 271977,
                                                                                        "owner": 23,
                                                                                        "created": 14807110686286,
                                                                                        "_type": "Collection",
                                                                                        "level": 1,
                                                                                        "items": [
                                                                                      {
                                                                                        "id": 271969,
                                                                                        "owner": 23,
                                                                                        "created": 14807110686286,
                                                                                        "_type": "Collection",
                                                                                        "level": 1,
                                                                                        "items": [
                                                                                      {
                                                                                        "id": 271961,
                                                                                        "owner": 23,
                                                                                        "created": 14807110686286,
                                                                                        "_type": "Collection",
                                                                                        "level": 1,
                                                                                        "items": [
                                                                                      {
                                                                                        "id": 271953,
                                                                                        "owner": 23,
                                                                                        "created": 14807110686286,
                                                                                        "_type": "Collection",
                                                                                        "level": 1,
                                                                                        "items": [
                                                                                      {
                                                                                        "id": 271945,
                                                                                        "owner": 23,
                                                                                        "created": 14807110686286,
                                                                                        "_type": "Collection",
                                                                                        "level": 1,
                                                                                        "items": [
                                                                                      {
                                                                                        "id": 271937,
                                                                                        "owner": 23,
                                                                                        "created": 14807110686286,
                                                                                        "_type": "Collection",
                                                                                        "level": 1,
                                                                                        "items": [
                                                                                      {
                                                                                        "id": 271929,
                                                                                        "owner": 23,
                                                                                        "created": 14807110686286,
                                                                                        "_type": "Collection",
                                                                                        "level": 1,
                                                                                        "items": [
                                                                                      {
                                                                                        "id": 271921,
                                                                                        "owner": 23,
                                                                                        "created": 14807110686286,
                                                                                        "_type": "Collection",
                                                                                        "level": 1,
                                                                                        "items": [
                                                                                      {
                                                                                        "id": 271913,
                                                                                        "owner": 23,
                                                                                        "created": 14807110686286,
                                                                                        "_type": "Collection",
                                                                                        "level": 1,
                                                                                        "items": [
                                                                                      {
                                                                                        "id": 271905,
                                                                                        "owner": 23,
                                                                                        "created": 14807110686286,
A.4. Common Representation Format

```json
{
   "owner": 23,
   "created": 1480711068023,
   "_type": "Text",
   "value": "Heading 1",
   "annotations": []
}

{
   "id": 272135,
   "owner": 23,
   "created": 1480711068134,
   "_type": "Paragraph",
   "items": [
      {
         "id": 272157,
         "owner": 23,
         "created": 1480711068057,
         "_type": "Text",
         "value": "This is a bold text. And this is italic."
      },
      {
         "id": 272154,
         "owner": 23,
         "created": 1480711068024,
         "_type": "Text",
         "value": "Another bold text."
      }
   ],
   "annotations": []
}

{
   "id": 272145,
   "owner": 23,
   "created": 1480711068033,
   "_type": "Formatting",
   "group": "default",
   "section": {
      "begin": 10,
      "end": 14
   },
   "styles": {
      "bold": "true"
   }
}

{
   "id": 272146,
   "owner": 23,
   "created": 1480711068034,
   "_type": "Formatting",
   "group": "default",
   "section": {
      "begin": 33,
      "end": 39
   },
   "styles": {
      "italic": "true"
   }
}

"annotations": []
}

{
   "id": 272154,
   "owner": 23,
   "created": 1480711068024,
   "_type": "Text",
   "value": "Another bold text."
}
```

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"created": 1480711068048,
"_type": "Heading",
"level": 2,
"items": [
{
"id": 272136,
"owner": 23,
"created": 1480711068022,
"_type": "Text",
"value": "Heading 2",
"annotations": []
}
],
"annotations": []
},
{
"id": 272138,
"owner": 23,
"created": 1480711068052,
"_type": "Paragraph",
"items": [
{
"id": 272147,
"owner": 23,
"created": 1480711068037,
"_type": "Text",
"value": "Listing:",
"annotations": []
}
],
"annotations": []
},
{
"id": 272139,
"owner": 23,
"created": 1480711068053,
"_type": "List",
"numbering": "Bullets",
"items": [
{
"id": 272149,
"owner": 23,
"created": 1480711068053,
"_type": "Text",
"value": "Item 1",
"annotations": []
}
],
"annotations": []
},
{
"id": 272148,
"owner": 23,
"created": 1480711068038,
"_type": "Text",
"value": "Item 2",
"annotations": []
}
],
"annotations": []
},
{
A.4. Common Representation Format

```
"id": 272140,
"owner": 23,
"created": 1480711068285,
"_type": "Paragraph",
"items": [
  {
    "id": 272162,
    "owner": 23,
    "created": 1480711068284,
    "_type": "Image",
    "source": "aeolion://resources/272159"
  },
  "annotations": []
],
"annotations": []
},
{
  "id": 272156,
  "owner": 23,
  "created": 1480711068053,
  "_type": "Heading",
  "level": 3,
  "items": [
    {
      "id": 272141,
      "owner": 23,
      "created": 1480711068028,
      "_type": "Text",
      "value": "Enumeration",
      "annotations": []
    }
  ],
  "annotations": []
},
{
  "id": 272144,
  "owner": 23,
  "created": 1480711068055,
  "_type": "Paragraph",
  "items": [
    {
      "id": 272150,
      "owner": 23,
      "created": 1480711068041,
      "_type": "Text",
      "value": "Enumeration",
      "annotations": []
    }
  ],
  "annotations": []
},
{
  "id": 272142,
  "owner": 23,
  "created": 1480711068057,
  "_type": "List",
  "numbering": "Numbers",
  "items": [
    {"id": 272152,
     "owner": 23,
     "created": 1480711068059,
     "_type": "Paragraph",
     "items": []
    },
    {"id": 272143,
     "owner": 23,
     "created": 1480711068058,
     "_type": "Image",
     "source": "aeolion://resources/272159"
    }
  ],
  "annotations": []
}
```

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```
190  "owner": 23,
191  "created": 1480711068044,
192  "_type": "Text",
193  "value": "Item 1",
194  "annotations": []
195 },
196 {
197  "id": 272153,
198  "owner": 23,
199  "created": 1480711068045,
200  "_type": "Text",
201  "value": "Item 2",
202  "annotations": []
203 }
204 
205  "annotations": []
206 },
207 {
208  "id": 272143,
209  "owner": 23,
210  "created": 1480711068136,
211  "_type": "Paragraph",
212  "items": [
213   {
214     "id": 272158,
215     "owner": 23,
216     "created": 1480711068132,
217     "_type": "Text",
218     "value": "And that's a link.",
219     "annotations": [
220       {
221         "id": 272151,
222         "owner": 23,
223         "created": 1480711068042,
224         "_type": "Reference",
225         "group": "default",
226         "section": {
227           "begin": 13,
228           "end": 17
229         },
230         "target": "http://google.at"
231       }
232     ]
233   },
234   "annotations": []
235 }
236 
237 ]
238 }
239 ```
B. Evaluation

In this chapter, the tasks introduced in the context of the second atelier are included at full length (cf. Section B.1). The original questionnaire (German language) used within the scope of the application analysis (cf. Section 9.2) is listed subsequently (cf. Section B.2).

B.1. Atelier 2

B.1.1. Aufgabe 1: Low-Level-Netzwerkkommunikation via Sockets

Ziel  
Sie können unter Verwendung von Plain Old Java Objects (POJOs) einfache und zustandslose Request-/Response-Protokolle implementieren. Sie kennen in diesem Zusammenhang die Möglichkeiten und Einschränkungen bei der Serialisierung von POJOs.

Vorkenntnisse  
Thema 1.5 und alle vorgelagerten Themen des Skriptum CE, Thema 2.1 und alle vorgelagerten Themen des Skriptums CE

Aufgabe  
Erstellen Sie eine einfache Client-/Serveranwendung, die ein von Ihnen definiertes zustandsloses Request-/Response-Protokoll auf Basis einfacher Plain Old Java Objects (POJOs) unterstützt. Verwenden sie dazu die von Java standardmäßig zur Verfügung gestellten Klassen.

Dokumentation  
Dokumentieren sie

− das Verhalten Ihres Protokolls anhand geeigneter UML Diagramme (z.B. Sequenzdiagramm).

− den Quellcode Ihrer Client-/Serveranwendung inkl. Kommentare.

Geschätzter Zeitaufwand  
2-3h
Appendix B. Evaluation

Selbstkorrektur Testen Sie Ihre Client-/Serveranwendung, indem Sie die beiden Anwendungen (Server und Client) im Netzwerk verteilt ausführen. Nutzen Sie für die Kommunikation zwischen den beiden Anwendungen das von Ihnen definierten Request-/Response Protokolls und beobachten Sie das Verhalten der beiden Anwendungen. Überprüfen Sie die Funktionsfähigkeit der beiden Anwendungen unter besonderer Berücksichtigung der Herausforderungen bei der Implementierung verteilter Systeme, wie beispielsweise einem Netzwerkausfall.

B.1.2. Task 2: SOAP

Ziel Sie wissen Web-Dienste anhand ihrer Schnittstellenbeschreibung zu interpretieren und in eigene Anwendungen zu integrieren. In diesem Zusammenhang kennen Sie Möglichkeiten sowohl zur Bereitstellung und Verwendung, als auch hinsichtlich dem Auffinden entsprechender Dienste.

Vorkenntnisse Thema 2.4 und alle vorgelagerten Themen des Skriptum CE, Thema 1.6 und alle vorgelagerten Themen des Skriptum CE

Aufgabe Finden Sie mithilfe des zur Verfügung gestellten Verzeichnisdienstes (UDDI-Server) bzw. der Beschreibung eines Web-Services (WSDL) für Flugbuchungen konkrete Endpunkte und integrieren Sie diese in eine eigene Java-Anwendung. Die folgenden Minimalanforderungen sind zu erfüllen:

− Rufen Sie alle verfügbaren Flugverbindungen ab, die von den konkreten Endpunkten bereitgestellt werden.
− Stellen Sie sicher, dass Ihre Anwendung mit einem möglichen Ausfall des Verzeichnisdienstes bzw. der Endpunkte umgehen kann.

Dokumentation Dokumentieren Sie

− das Zusammenspiel der unterschiedlichen Komponenten, die für den Abruf verfügbarer Flugverbindungen bzw. für eine konkrete Buchung notwendig sind.
− den Quellcode Ihrer Anwendung inkl. Kommentare.
B.1. Atelier 2

Geschätzter Zeitaufwand 2-3h

Selbstkorrektur Testen Sie Ihre Anwendung, indem Sie sie starten und sämtliche verfügbaren Flugverbindungen abrufen bzw. eine konkrete Flugverbindung buchen. Definieren Sie gegebenenfalls entsprechende Konsolen-Outputs, um das Verhalten Ihrer Anwendung beobachten zu können. Buchen Sie eine nicht existierenden Flugverbindung um die Stabilität Ihrer Anwendung überprüfen zu können.

B.1.3. Task 3: Transparente Kommunikation mittels verteilter Actor-Systeme


Vorkenntnisse Thema 2.5 und alle vorgelagerten Themen des Skriptum CE

Aufgabe Erstellen Sie unter Verwendung des Akka-Actor Frameworks eine einfache Ping-Pong Anwendung, die die Zusammenarbeit zwischen zwei verteilten und asynchron agierenden Akteuren (Actors) zeigt. Die folgenden Minimalanforderungen sind zu erfüllen:

- Stellen Sie die involvierten Akteure (Ping-Actor, Pong-Actor) in voneinander getrennten Actor-Systemen bereit. Zur Vereinfachung der Aufgabenstellung können Sie die Zugriffspunkte der involvierten Akteure (Actor-Refs) statisch definieren und hinterlegen.

- Gewährleisten Sie die Kommunikation zwischen den involvierten Akteuren mittels einfacher Ping-/Pong-Nachrichten.

- Lösen Sie den Vorgang mit einer eigens definierten Start-Nachricht aus.

- Beenden Sie den Vorgang nach dem 100. Ping-Pong Zyklus und stoppen Sie die involvierten Akteure. Verwenden Sie dazu eine eigens definierte Stop-Nachricht.

Dokumentation Dokumentieren Sie
Appendix B. Evaluation

- das Verhalten Ihrer Anwendung anhand geeigneter UML Diagramme (z.B. Sequenzdiagramm).
- den Quellcode Ihrer Client-/Serveranwendung inkl. Kommentare.

Geschätzter Zeitaufwand 3-4h

Selbstkorrektur Testen Sie Ihre Anwendung, indem Sie die beiden Actor-Systeme starten, die involvierten Akteure erzeugen und den Ping-Pong Vorgang mittels der eigens definierten Start-Nachricht auslösen. Definieren Sie gegebenenfalls entsprechenden Konsolen-Outputs, um das Verhalten Ihrer Anwendung beobachten bzw. das Stoppen der involvierten Akteure überprüfen zu können. Zudem finden Sie mittels gängiger Suchmaschinen beispielhafte Lösungen, die Sie zum Vergleich heranziehen können.

B.2. Questionnaire for Evaluating Learning Support

Dieser Fragebogen dient zur Evaluierung der Lernunterstützung durch die Lernplattform "Ueber Learn". Die folgenden Fragen beziehen sich ausschließlich auf die Ausarbeitung der Aufgaben des zweiten Ateliers zum Thema "Abstraktionsmodelle für verteilte Kommunikation zwischen technischen Systemen". Als Referenzpunkt für die Lernplattform dient die ausschließlich Ihrer Gruppe zur Verfügung gestellte Instanz.

Der Fragebogen setzt sich aus drei Teilen zusammen, die sich mit unterschiedlichen Aspekten der Lernunterstützung beschäftigen. Um eine entsprechend hohe Qualität der Auswertung gewährleisten zu können, bitten wir Sie um eine möglichst detailreiche Darstellung Ihrer Erfahrungen.

Q1. Was haben Sie bei der Ausarbeitung dieser Aufgaben gelernt?

Q1.1 Hat Ihnen die Beschreibung (Ziel, Vorkenntnisse, Aufgabe, etc.) dieser Aufgaben bei der Ausarbeitung geholfen? Wenn ja, welche Aussagen bzw. Inhalte waren für Sie besonders hilfreich und warum?

Q1.2 Gibt es etwas, das Ihnen bei der Ausarbeitung dieser Aufgaben besser geholfen hätte? Wenn ja, welche Aussagen bzw. Inhalte wären besonders hilfreich für Sie gewesen und warum?

Q2. Hatten Sie sich jedenfalls vorgenommen, sich das für diese Aufgaben notwendige Wissen anzueignen? Wenn ja, was hat Sie dazu motiviert?
B.2. Questionnaire for Evaluating Learning Support

Q3 Haben Sie sich vor Beginn der Ausarbeitung zugetraut, diese Aufgaben eigenständig bewältigen zu können? Worauf hat sich Ihre Zuversicht begründet? Falls Sie Bedenken hatten, diese Aufgaben erfolgreich bewältigen zu können, worauf begründeten sich Ihre Bedenken?

Q4. Wie haben Sie sich das für diese Aufgaben notwendige Wissen angeeignet?

Q4.1. Hat Sie die Lernplattform in Ihrem Lernprozess unterstützt? Wenn ja, welche Features in den Kategorien Navigation, Arbeit mit Inhalten und Interaktion mit Studienkollegen waren besonders hilfreich und in welchen Aufgaben- oder Handlungskontexten haben Sie diese verwendet?

Q4.2. Gibt es Features, die Sie zur optimalen Unterstützung Ihres Lernprozesses gerne vorgefunden hätten? Wenn ja, welche Features in den Kategorien Navigation, Arbeit mit Inhalten und Interaktion mit Studienkollegen wären besonders hilfreich gewesen und in welchen Aufgaben- und Handlungskontexten hätten Sie sie im Rahmen der Ausarbeitung dieser Aufgaben verwendet?

Q4.3. Haben Sie die bereitgestellten Materialien in Ihrem Lernprozess unterstützt? Wenn ja, welche Materialien waren besonders hilfreich und wie haben Sie diese genutzt?

Q4.4. Gibt es Materialien, die Sie zur optimalen Unterstützung Ihres Lernprozesses gerne zur Verfügung gestellt bekommen hätten? Wenn ja, welche Materialien wären besonders hilfreich gewesen und in welchen Aufgaben- und Handlungskontexten hätten Sie sie im Rahmen der Ausarbeitung dieser Aufgaben verwendet?

Q4.5. Hat Sie die Gruppenarbeit in Ihrem Lernprozess unterstützt? Wenn ja, wie und woran haben Sie das festgestellt?

Q4.6. Hat Sie die Integration von Facebook in Ihrem Lernprozess unterstützt? Wenn ja, wie und in welchen Aufgaben- und Handlungskontexten hat Sie diese Integration unterstützt? Woran haben Sie diese Unterstützung festgestellt?

Q5. Warum haben Sie sich das für diese Aufgaben notwendige Wissen auf die von Ihnen gewählte Art und Weise angeeignet?

Q6. Wie haben Sie festgestellt, dass Sie etwas gelernt haben?

Q6.1. Hat Ihnen die Beschreibung (Ziel, Vorkenntnisse, Aufgabe, etc.) dieser Aufgaben geholfen festzustellen, dass Sie etwas gelernt haben? Wenn ja, welche Aussagen bzw. Inhalte waren für Sie besonders hilfreich und warum?
Appendix B. Evaluation

Q6.2. Gibt es etwas, das Ihnen bei der Ausarbeitung dieser Aufgaben besser geholfen hätte festzustellen, dass Sie etwas gelernt haben? Wenn ja, was wäre für Sie besonders hilfreich gewesen und warum?

Q6.3. Hat Ihnen die kollaborative Erstellung einer gemeinsamen Ausarbeitung geholfen festzustellen, dass Sie etwas gelernt haben? Wenn ja, wie und woran haben Sie das festgestellt?

Q6.4. Hat Ihnen die Diskussion über die Inhalte geholfen festzustellen, dass Sie etwas gelernt haben? Wenn ja, wie und woran haben Sie das festgestellt?

Q7. Sind Sie rückschauend mit ihrem Lernprozess zufrieden? Was würden Sie beim nächsten Mal anders machen?

Q8. Wie werden sie das Gelernte in Zukunft anwenden?

Q8.1. Hat sie die Ausarbeitung dieser Aufgaben qualifiziert, das Gelernte erfolgreich anwenden zu können? Wenn ja, wie und woran haben Sie das festgestellt? Wenn nein, was hätte passieren müssen, damit Sie sich als qualifiziert eingeschätzt hätten?

Q8.2. Hat sie die Lernplattform unterstützt, das Gelernte für die weitere Anwendung entsprechend aufzubereiten bzw. zu dokumentieren? Wenn ja, welche Features in den Kategorien Navigation, Arbeit mit Inhalten und Interaktion mit Studienkollegen waren besonders hilfreich und in welchen Aufgaben- und Handlungskontexten haben Sie diese verwendet?


Q9. Haben Sie sonstige Anmerkungen?
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