Knowledge Co-construction and Object-oriented Collaboration

A Study of Learning through Collaborative Construction of Knowledge Objects in Higher Education

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Abstract

Learning through small-group collaboration that exposes students to open-ended and complex knowledge problems is becoming part of a pedagogical strategy to prepare higher education students for the knowledge-driven professional life. This dissertation examines learning, conceptualized as a process of knowledge co-construction, in the context of a university bachelor program in educational sciences, respectively, a teacher-education program in a university of applied sciences. Students were required to address complex problems by engaging in collaborative construction of knowledge objects, such as research reports, instructional materials, analyses of assessment methods, etc.

While collaborative activities that stimulate knowledge construction are considered beneficial for learning, they remain complex and challenging for students. The aim of this research was to gain a deeper understanding of how students engage in interaction and how constructing knowledge objects in collaborative projects groups contributes to their learning. The studies included in this dissertation employed a sociocultural approach and qualitative research methodology to examine in depth how students collaborate in semester-long group projects. The analysis focused on groups' interaction and on how the knowledge objects were developed through joint efforts.

The findings showed that knowledge objects developed by the groups are more elaborated and complex when students engage in productive interaction of epistemic nature as opposed to when they work individually or use division of labor. For the former, they first must create shared understanding of the existing knowledge, discuss information and ideas, then generate knowledge, which can be elaborated through discussions, iterative construction of and mutual feedback on object versions. The findings also showed that the knowledge objects can represent more than just a product the group had to deliver for a grade. They mediated the discussions, grounded the analysis and elaboration of ideas and concepts; and guided the collaboration as groups addressed difficulties throughout the process that spans sites and time. Finally, the findings indicated that in order to address complex problems students must be highly aware of the importance of a joint collaborative strategy, and engage actively with the knowledge objects both individually and as a group. These findings support the idea that stimulating and supporting collaboration that entails epistemic interaction and joint work on knowledge objects is a diligent strategy to entice students into engaging with knowledge.

Acknowledgments

The point of departure for this dissertation was that we learn and we build our knowledge together with others. It is a social process in which people, ideas, resources, and context all play a role. I believe the work that went into this dissertation is a very good illustration of this assertion. It builds upon a great collection of scientific ideas, resources and traditions, and it is the result of inspiring and enriching interactions with diverse individuals and communities. Without all of these, both the process and the final result would have been different. I would like to acknowledge and thank all those who were part of this process in various ways, and at different moments in time. I would like to express my gratitude especially to:

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Blindern, June 2013

Crina Damşa

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Extended Abstract

1 Introduction

In recent years, learning in higher education has been profoundly influenced by developments taking place in a rapidly evolving knowledge society. The movement to make professions more knowledge-based, the expansion and increasing complexity of each domain's body of knowledge, and the use of state-of-the-art technologies have become governing principles in our modern world. The more dynamic relationship between professional fields and higher education brings to the latter the emerging developments of the former, but also accompanying challenges. Various studies of higher education have examined education and learning in relation to these processes within organizations (Muukkonen & Lakkala, 2010; Slotte & Tynjala, 2003; Stankovic, 2009). The general conclusion has been that learning in higher education predominantly takes place within established, more conventional knowledge systems, around well-defined problems with structured, prescribed solution strategies. Conversely, in professional settings, employees are expected to address ill-structured and open-ended problems, conceive new ideas, capitalize on collective expertise, show inquiring attitudes, skills, and pro-active behavior. These disparities have led to pressure from policy instances, the research field, and the professional domains on higher education institutions to reconsider some of their fundamental principles regarding learning and instruction.

In higher education, addressing open-ended and complex problems requires different strategies than those currently in place in the traditional curriculum and approaches to learning. The constantly changing and growing body of knowledge requires students' active engagement, ability to generate knowledge, collaboration with each other, the attainment of tools, and epistemic modes of practice (Goodyear & Zenios, 2005). For educational institutions, stimulating and supporting students to develop these capabilities is paramount. At the same time, while there has been agreement that such knowledge-driven activities are beneficial, they remain complex and challenging for students. Designing instruction that stimulates learning and perpetuates these ideas raises issues that are empirical and

theoretical in nature. It also highlights the importance of having a good understanding of these learning processes and how they unfold in the educational practice.

However, there have not been many studies that examined how learning designed according to these principles takes place. The empirical research on learning in higher education in the last two decades has been characterized by various trends. First, learning research has not been driven by learning theoretical perspectives; studies within the field have focused primarily on disciplinary knowledge and skills (Nerland, 2012). Second, the majority of studies of student learning examined cognitive aspects, mainly from an individual perspective (Entwistle & Peterson, 2005; Muis & Sinatra, 2006). Finally, recent developments in the knowledge field and new requirements graduates must fulfill when entering professions have started new trends in learning and research. In this regard, review studies (Haggis, 2003; Nerland, 2012; Tight, 2012) and reports (Boyer Report, 1998) emphasized the necessity to prepare students for the challenges of knowledge-driven professional work. To this end, a number of empirical studies (Muukkonen & Lakkala, 2009; Stankovic, 2009; Zimbardi & Myatt, 2012) pursued research that conceived learning as an activity that involves addressing complex knowledge-based problems. Nevertheless, while these studies provided valuable insights, further research is needed to develop a deeper understanding of the learning as a collaborative process that involves construction of knowledge and spans over longer periods of time.

This dissertation examines learning in higher education from a perspective that emphasizes its social character and the construction of knowledge in collaboration. It draws on research conducted mostly in secondary education that offers a better insight into the collaborative aspects of learning. Of particular relevance are studies that conceptualized and investigated learning as a process that generates knowledge through dialogical interaction among peers. Such studies shed light on a wide range of topics, among them, dialogical meaning making (Atwood, Turnbull, & Carpendale, 2010; Furberg & Ludvigsen, 2008), collaborative problem-solving (Hmelo-Silver, 2004; Stahl, 2009), the relational and procedural aspects of collaboration (Barron, 2003; Mullins, Rummel, & Spada, 2011), and the temporality of the interaction (Krange, 2007; Sarmiento-Klapper, 2009). In an approximately parallel development, studies related to the knowledge-building approach (Scardamalia & Bereiter, 2003) examined learning as a collective process of production and improvement of ideas. This approach asserts that while articulating, revising, improving, and sharing ideas with the community, learning occurs as a natural development. Empirical studies have examined how ideas can drive inquiry, strategies to assess this type of learning,

and how tailored online technology can support such processes (Hong, 2011; Zhang & Messina, 2010). Furthermore, ideas stemming from this approach were used in the development of the knowledge creation metaphor (Paavola & Hakkarainen, 2005), which posits that knowledge advancement and learning take place through joint efforts to develop shared knowledge objects. This metaphor stresses the importance of interaction and knowledge creation but adds the idea of the knowledge object, which emerges through the materialization of newly constructed knowledge. Empirical studies illustrated the role of knowledge objects in the collaborative process (Muukkonen, Lakkala, & Hakkarainen, 2005) and how skills related to object-oriented inquiry develop (Muukkonen & Lakkala, 2009). A few empirical studies attempted to investigate the role of knowledge objects during restructuring processes on organizations (MacPherson & Jones, 2008; Miettinen & Virkunnen, 2005). But none of these studies examined in depth the creation of knowledge objects or the interconnection between the aspects of the interaction and objects in the collaborative process.

Theoretically, this research follows the sociocultural stance and its main assumptions, primarily the idea that learning and development are social in nature and mediated by tools and signs (Vygotsky, 1978; Wertsch, 1991). A revealing perspective on these assumptions is that of Valsiner (1994b, 1996), which views learning and development as a process of *co-construction,* of knowledge that arises from interaction. This conceptualization addresses the person and society dualism by recognizing it as a result of dynamic, systemic interaction between the two, in a bi-directional model. Valsiner (1994b) emphasizes *intellectual interdependence* as the foundation of the co-construction process. This interdependence is essentially determined by the dynamic relationship between the individual's subjectivity and intersubjective space and is facilitated by communicative actions (Linell, 2009). The process of co-construction is a dialogical one, language functioning as the primary means of mediation.

This research builds on the conceptualization of learning as a collaborative process of knowledge co-construction, characterized by dynamic interdependence on an intellectual and social-relational level. Accordingly, it is by social interaction that individuals align their existing ideas and expertise to create new meaning and understanding (Greeno, 2006). It is also through interaction between participants and resources that knowledge comes into use and is materialized. From this perspective, knowledge emerges as an interactional accomplishment based on social interaction, the joint construction of knowledge materialized into shared knowledge objects ("frozen" knowledge), and their interconnection.

It is a process that unfolds in time (Krange, 2007), and it is shaped by individuals' knowledge, active participation, and the intersubjectivity created during interaction. To employ these ideas in the empirical work, this dissertation proposes a framework that uses four theoretical-analytical constructs. These constructs are as follows:

a) *productive interactions* are considered communicative exchanges (or epistemic actions[1]) leading to participants co-constructing and elaborating on their knowledge,

b) *shared knowledge objects* are viewed as the materialization, externalization or the "freezing" of knowledge at a certain moment in time,

c) *shared epistemic agency* is the expression of the active participation, the capacity to enable deliberate, joint, knowledge-driven activities,

d) *interaction trajectories* are considered coherent sequences of (productive) interaction, which unfold in a sequential manner.

Empirical work

This dissertation comprises empirical research studies of students learning through interaction and joint work on shared knowledge objects, (e.g., research reports, didactic materials, instructional designs). In the application of the above conceptualizations into pedagogical scenarios, I particularly emphasized the following aspects: solving complex, open-ended problems; engaging in joint construction (or co-construction) of knowledge as part of the solution; materializing theoretical and practical knowledge into shared-knowledge objects; active participation in social interaction; and employing (technological) tools to enhance and support collaboration.

The empirical work is presented in four separate studies[2]. These studies were conducted in a university and an applied science university in the Netherlands, with the participating students enrolled in the bachelor's and master's programs in educational sciences (Studies 1, 2, and 3), respectively, in a teacher-education program (Study 4). I employed a design-based research methodology (Brown, 1992; Collins, Joseph, & Bielaczyc, 2004) combined with a multiple case-research approach (Yin, 2003). The former allowed the exploration and application of new ideas and progressive refinement of the

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[1] The term *epistemic* is used here in reference to *knowledge* and *understanding* (from Gk. *epistēmē)* within the confined space of learning science and settings. It does not attend to broader meanings of the term, as conveyed by the sociology of knowledge (Knorr-Cettina, 2007).

[2] This dissertation project was embedded in a larger research and development project, the Knowledge Practices Laboratory, funded by the Sixth European Framework Programme. The way this thesis's work was connected to this project is elaborated upon in Chapter. 4 Methods.

design; it also allowed for the investigation of this design across different courses and domain subjects. The latter provided the means to examine students' collaborative project work in-depth. While the course themes and curricula varied, the design features were similar across courses, with the initial iterations providing input for elaboration and improvements of the subsequent ones. In the first, explorative stage, the research design involved minor adjustments to the course setup (Study 1); at later stages, the courses were practically re-designed in collaboration with the teachers who taught the courses (Studies 2, 3 and 4). Technological support for collaboration was used in all iterations and consisted of an online repository system in the first three studies and an online application supporting collaborative work in the fourth study. The data collection and analysis procedures emerged from assumptions underlying the qualitative paradigm. Complex and emerging phenomena that require in-depth analysis are better examined when access to rich data sets and analytic methods attending this complexity are available. Hence, a set of varied data types was collected ranging from interaction data to knowledge objects, which was examined using qualitative analytic methods.

1.1 Aims

First, this research aims to add to the conceptualization that views learning as a process of knowledge co-construction (Valsiner, 1994b; 1996), by elaborating on the notions of co-construction of shared knowledge objects and shared epistemic agency. The second aim is to provide a deeper insight into the process of co-construction, by analyzing empirically collaborative learning activities in which students address open-ended and complex problems, engage in interaction with peers and resources and in sustained and joint efforts to construct knowledge objects. This in-depth analysis addresses the lack of empirical investigation of how the epistemic aspects of the interaction unfold, how knowledge emerges, how it is regarded and discussed, and how it is materialized into knowledge objects through collaborative work. Third, this project intends to make a methodological contribution. The complexity of the investigated process requires a suitable research design and analysis approach. The four theoretical constructs introduced above serve the development of an analytic framework that considers each investigated aspect, i.e., productive interaction and its relational aspects, knowledge object co-construction, shared epistemic agency, but also their interconnections. Finally, as a contribution to educational

practice, this dissertation discusses the empirical findings in relation to it. To address these aims, this research focuses on

> *the examination of learning in higher education, conceptualized as a process of knowledge co-construction, which involves social interaction and the joint elaboration of knowledge objects.*

This research was conducted by means of four empirical studies; each study placed one of the aforementioned aspects in the foreground of the investigation, but all studies took into consideration the interconnections among the aspects that are part of this process. The four studies and their focuses are listed below.

1. Study 1 concerned the aspect of active participation operationalized as *shared epistemic agency.* This study examined two groups of students working collaboratively on design projects, with the focus on understanding how students participate actively in the interaction, how they position themselves in the collaborative space, and how this positioning and active participation affects the knowledge co-construction process. The context was a 10-week undergraduate course in Educational and Instructional Design.
2. Study 2 addressed the aspect of *productive interactions*. It focused on understanding the types of interactions considered productive from the perspective of the knowledge co-construction process and on how these interactions unfold in a trajectory-like manner during one semester. The study was conducted in an undergraduate Bachelor Thesis 20-week course, with student groups working on collaborative research projects.
3. Study 3 examined the *social-relational aspects* of the interaction of students collaborating in research projects. In this case, the analyses focused on how students dealt with the social and relational aspects of their group interactions and how these influenced or contributed to the co-construction process. The setting was the same university course as in Study 2.
4. Study 4 addressed the way *shared knowledge objects* emerge from interactions, how they are developed, and how they mediate the unfolding interaction. In this study, the emphasis was placed on the co-construction process and the interconnection between the interaction and the developing knowledge objects. These aspects were investigated in the context of three 20-week courses, with teacher-students working on collaborative projects on various topics.

1.2 Outline of this dissertation

This dissertation accounts for the theoretical, empirical, and methodological work conducted in this research project. The dissertation is organized into two parts.

The *Extended abstract* presents a detailed account of the theoretical framework underlying the theoretical perspectives this research builds upon, a review of relevant research, and an explanatory account of the methodological choices and their implementation. References to the original studies are made throughout the extended abstract. The second chapter, *Theoretical perspectives,* outlines the theories that informed the theoretical framework. Therein, I present a conceptualization of learning as a process of knowledge co-construction within the context of the sociocultural perspective. I also apply the theoretical perspectives on the four framing constructs and give these constructs a place in the research. Chapter 3, *Review of relevant research,* presents and discusses, first, relevant research on learning in higher education. The following sections discuss studies that illustrate concepts and models of learning through knowledge building, knowledge creation, and small group interaction and three pedagogical models, namely, problem-solving, project work, and progressive inquiry-based learning. The latter studies were conducted mostly in secondary education, and the review aims at constructing a more accurate picture of the research on collaborative learning, which is not provided by the studies in higher education settings. In the fourth chapter*, Methods*, I discuss and argue for the methodological choices made in this research project. Next, I explain the context of the research, the empirical settings, and the research design, followed by a presentation of the data collection and analytical methods. I end this chapter by discussing the way methodological quality was addressed in this dissertation and I reflect on research ethics. Chapter 5, *Summary of studies*, contains summaries of the four empirical studies that are part of this dissertation. The section ends with the sixth chapter, *Discussion*. In this chapter, I elaborate on the theoretical, methodological, and empirical contributions of this research project and discuss the implications of this work for educational practice and future research.

In the second part of this dissertation, *The empirical studies,* the four studies conducted in higher education settings are presented separately and introduce the empirical work in the style of scientific publications, that is, three article manuscripts and a book chapter. The final discussion concerns the overarching framework and the empirical

findings and elaborates on the empirical, theoretical, and methodological contributions made by this research project.

Study 1.

Damşa, C.I , Kirschner, P. A., Andriessen, J. E. B., Erkens, G., & Sins, P. H. M. (2010). Shared epistemic agency: An empirical study of an emergent construct. *Journal of the Learning Sciences, 19(2),* 143–186.

Study 2.

Damşa, C. I (submitted). *Multi-layered nature of small-group learning: productive interactions in object-oriented collaboration.*

Study 3.

Damşa, C., Ludvigsen, S.R., & Andriessen, J.E.B. (2013). Knowledge co-construction – epistemic consensus or relational assent? In M. Baker, J. Andriessen & S. Jaarvela (Eds.) *Affective learning together. Social and relational dimensions of collaborative learning,* EARLI series 'New Perspectives on Learning and Instruction' (pp. 97-119). Oxford, UK: Routlegde.

Study 4.

Damşa, C. I., & Ludvigsen, S. R. (submitted). *The collaborative construction of what? Learning through interaction and co-construction of knowledge objects in teacher education.*

2 Theoretical perspectives

The theoretical and empirical work in this dissertation builds on theoretical ideas emerging from the sociocultural stance (Vygotsky, 1978), and especially the sociogenetic view (Valsiner, 1996; Valsiner & Van der Veer, 2000). The theoretical elaborations I employ rely primarily on the sociocultural premises regarding learning and development, and on the sociogenetic idea that identity and knowledge emerge and develop through a process of co-construction. This co-construction is assumed to take place in the context of an active and dynamic relationship between the social and the individual. Knowledge is viewed as socially constructed through interaction with the social, cultural or physical environment, and in the context of a process that spans over time and space. These premises are complemented by some elaborations on the notion of active participation and social interaction within the socio-cognitive perspective, distributed cognition and American pragmatism.

To start with, I explore an essential postulate in this thesis, i.e., that knowledge is constructed through the active participation of the learners. I then discuss the central premises underlying the sociocultural perspective and elaborations thereof. Next, I elaborate on four framing constructs that build on these main theoretical ideas and, finally, I summarize and explain how these constructs are employed in the context of this research.

2.1 Learning re-conceptualized as knowledge co-construction

The main assumption this theoretical framework rests upon is that of knowledge being constructed. Within the learning sciences, the discussion about what knowledge is to be learned, or how we acquire it, builds upon longstanding debates between various scientific paradigms. The primary philosophies of knowledge emphasize a definite, undeviating nature, while more recent models stress its reliance on particular situations and its dynamic interference with humanity, human thought, or human action (Hacking, 1999). The common denominator for the latter is the focus on a constructed reality. Hence,

meaning and knowledge are always a human/social construction. By taking the sociocultural approach as a point of departure, I adopt a stance that acknowledges the philosophical debate regarding nature of knowledge as a social construct, but which focuses especially on processes concerning learning and development.

My theoretical positioning is grounded in the three main premises of the socio-cultural approach, as identified by Wertsch (1991): 1) individual development originates in social sources, whether cultural or historical, 2) human action, on both social and individual planes, is mediated by tools or signs, and 3) the process spans over time and space. Using these assumptions as a point of departure, the learning process, conceptualized as a social process of knowledge co-construction, can be approached at three levels: sociogenetic, ontogenetic, and microgenetic (Ludvigsen, 2009; Valsiner & Van der Veer, 2000). At the sociogenetic level, the focus is on the social institutions' organization of knowledge (domains), historical norms and values, and individuals' interaction with, and appropriation of such values. The ontogenetic level is concerned with the lifelong development of the individual. At the microgenetic level, the focus is on the moment-to-moment actions and social interaction among individuals (Ludvigsen, 2009). The microgenetic level unifies, in a generic sense, characteristic features of the learning process. This allows the identification of sequences of actions that illustrate these processes of interaction and knowledge construction.

Building on an integration of these premises, and elaboration hereof, I identify four theoretical assumptions with regard to learning. These are: a) at a microgenetic level, learning is a process of co-construction of knowledge; knowledge is not given or taken in passively by the subjects, but constructed actively; b) the co-construction of knowledge is an inherently social process, taking place through social interaction and interaction with others and the environment; c) this social interaction is mediated by language, and by objects or artifacts; d) the co-construction process is situated, historically, culturally and physically. Each of these assumptions is discussed in more detail in the following subsections, with the note that they are depicted separately only for analytic purposes.

2.1.1 The co-construction process

One of the main tenets of the sociocultural approach is that an individual's development and identity emerge from a (social) construction process (see Wertsch, 1998). Several texts from this tradition discuss the concepts of identity and knowledge co-construction in an interchangeable manner. With reference to this, Valsiner (1994b)

mentions that the ultimate purpose of construction is a "personal culture," (p. 52) which subsequently leads to development. The process of achieving this includes the co-construction of knowledge. The *co-construction* view takes a position of "inclusive separation" (Valsiner, 1996, p 72.), which overcomes the dualism of person and society by recognizing it as a result of systemic interactions between the person and the society. Drawing upon this reconciling position, I attend to three aspects that are of major relevance for a sensible conceptualization.

The first aspect concerns the *mechanisms of construction*; that is, knowledge is not merely verbally transmitted, but must be constructed and reconstructed by the learner. The notion of internalization is used to explain the way the social and cultural message is received, understood, "personalized," or reconstructed. Since this view starts from the position that learning and development are rooted in social practices, the process is supposed to start in the intersubjective, external setting. According to Stahl (2010), internalization begins as an aspect of collaborative interaction, and it successively transforms into a phenomenon of its own. For this first stage to happen, language or other mediating (semiotic) means are needed to "freeze" the meaning of the internalized event (John-Steier & Mahn, 1996, p. 196.). This internalization results in a process that triggers development or results in cognitive artifacts, which are an "internalized form of culturally developed artifacts" (Stahl, 2003, p. 7). One aspect that Vygotsky (1978) has not dealt with in a clear, explicit fashion is that of externalization. Through externalization, the results of the internal transformations of the social input (into thought, cognitive artifact, etc.) are communicated to others, who then receive and transform such messages in their personal way; it places the internalized structures back into the interpersonal space.

Second, related to this succession of internalization/externalization processes is the notion of the *interdependence* between the social intersubjective world/culture and the individual subjective one. Vygostky's (1978) ideas have been criticized by some as being rather unidirectional (Resnick, 1996), in the sense that they render the recipients of the cultural transmission or socialization as rather passive in the process. The co-construction view (Valsiner 1994a, 1994b, 1996) addresses both these aspects as part of the argument that this process of transmission is bidirectional. Accordingly, the individual is in an active process of relating to the environment (physical, social, and cultural), and the construction of knowledge is an outcome of that process. Building upon various generic constructive stances, this view states that the individual receives and actively transforms the semiotically encoded information from/about the world into internalized personal knowledge. This

incoming information can stem from various sources (e.g., the environment, peers); therefore, the process of reconstruction can be highly divergent. The individuals' choice during this ongoing transaction is to keep or to change goal orientation or strategy, which can lead to "episodic convergence" (Valsiner, 1994b, p. 59). That can become collective goal orientation and a visible developing construction or a diverging goal orientation and a diffuse co-construction process. However, once the internalization had taken place, the person had constructed cultural novelty in the form of personal sense, and this becomes externalized (in various forms, such as actions, artifacts, and values). It thus enters the process of communication with other individuals who are part of the social system (Valsiner, 1996).

Wertsch (1991) insists on the dynamic character of this process, by which individuals involved in shared contexts influence and guide each others' development via semiotic means. Valsiner (1994b) refers to this dynamic character as *mutual interdependence,* which is strongly determined by the intersubjective nature of the process, the way this process is mediated by various means—especially by language, and by the active participation of the individuals involved. In reference to the process of idea construction, Valsiner and Van der Veer use the term *intellectual interdependence,* which "entails a process of construction of ideas (made possible through person's internalizations and externalization), which is aimed at a selected direction in the communicative process with other person" (2000, p. 11).

Finally, the aspect of *active participation* is a feature of the co-construction process. Pragmatist proponents have keenly supported the idea that knowledge construction is an active process; to paraphrase Dewey (1960) "the learner is an actor" whom, through active participation, affects the process itself and the knowledge obtained. The socio-cultural approach emphasizes that the active process of knowledge construction is carried out in/by groups and communities, not strictly by individuals. In his bidirectional transmission model, Valsiner emphasizes the aspect of the goal-oriented individual, who "acts within meaningfully structured environment, interactively with the purposive impacts from other persons" (1996, p. 78). These reoccurring exchanges lead to modifications of the structures of knowledge involved. This selection process leads gradually to the retainment of some form of structured knowledge (Valsiner & Van der Veer, 2000). The goal orientation directs these processes and funnels the active role attributed to the person who is appropriating the world. Snow (2001) emphasizes, with reference to human agency, the active, willful

character of actors and asserts that they neither respond exclusively to internal directions nor are passive receivers of structural/social messages and constraints.

2.1.2 Social interaction

Humans exist and develop in *intellectual interdependence* and *social interaction*, and they co-construct their knowledge through this interaction (Linell, 2009; Valsiner & Van der Veer, 2000). This viewpoint involves the belief that (social) interaction is a prerequisite for the way knowledge is constructed and used. When describing this social aspect, I distinguish, primarily for analytic purposes, two facets of the phenomenon. One is the environment that the individual operates in, with its physical, cultural, historical, and relational features. The other is the *interaction* within this environment, which commonly takes place on a regular basis at a micro-social level (Valsiner, 1996) in groups that the individual is part of. The sociocultural approach claims that knowledge is embedded in interaction and, moreover, that the individual processes and structures can be traced to their interaction with others.

In Valsiner's view (1994b), the active individual transforms the "collective-cultural" meaning into a "personal-cultural" (p. 56) meaning, but at the same time, this individual contributes to the reconstruction of the collective culture. Vygostky suggested that social experiences can shape the interpretative processes available to individuals. According to his view, "all higher psychological functions are internalized relationships of the social kind" (1978, p. 57). Thus, knowledge (or meaning) fundamentally exists in the external, intersubjective world (Stahl, 2003). In this "interpsychological" context, the individual comes in contact with meaning by participating in joint activities and by using various means of mediation, such as language. One aspect emphasized by pragmatists is that the individual has "systematic determination of knowledge," meaning that the individual has a degree of control and judgment over his or her social input (Colapietro, 2006). This perspective, however, downplays the unidirectionality of the social input and influence and emphasizes the interdependence between the individual and the social environment, as well as the mutuality of their relationship (Valsiner & Van der Veer, 2000).

There are two aspects that are important from the perspective of this bidirectional stance: one refers to the intellectual interdependence and how it plays out in an interactional setting, while the other refers to the means by which sharing (of meanings) and communicative (inter)action takes place. In relation to the former, Rommetveit (1992) asserts that the social communication process starts from an assumption of shared

understanding, moves toward overcoming mutual misunderstanding, and results into joint construction and novel understanding. The bidirectional model also purports that the first socially co-constructed image is that of *sharing* in interpersonal contexts (Valsiner, 1996). The human environment, or its physical, social, and cultural features, is given meaning by symbolizing activities, and sharing is at the basis of avoiding misunderstanding in this joint effort of meaning co-construction. However, while Valsiner (1996) believes that a form of individual subjectivity needs to be presumed in order to make sense of the intersubjective space and content, he conceives the latter as "constantly leading to creating, maintaining, and changing of persons' sense-backgrounds of the (foreground) dialogical activity" (p. 75). There is a mutual interdependence between the two that involves a dynamic relationship. Wertsch (1991) considers this dynamic sense making the result of a redefinition process, which is in itself co-constructive because the individual acts from the presumption of the other actors' orientation (preferably a convergent one), monitors the actions of the others, modifies his/her own intentions, and acts in accordance.

The second aspect is the *means* by which the interaction takes place, how it can be made visible or traceable. The sociocultural proponents have elaborated upon this idea, stating that the type of interactional achievement that contributes to co-construction is realized in moment-to-moment interactions by taking turns expressing *communicative action* (Linell, 2009). At this point, communication becomes important in that it makes sharing possible, with language serving as a powerful means that allows communicative action to emerge and contribute to an interactional accomplishment (Linell, 1998). Meanings are fluid and inconsistent, according to Vygotsky (1978), and words/language transform the meaning's potential into "frozen" meaning at one specific instance of the interaction process. The dialogical nature of this process is a reflection at the linguistic level of the aforementioned interdependence (Linell, 2009; Bakhtin, 1981). This very prominent role of the language/word is played out during social interactions through the "voices" of participants in the dialogue (Bakhtin, 1981). This view of dialogical construction reiterates the idea that meaning arises through exposure and involvement in the intersubjective space. Bakhtin (1981) elaborates on the aspect of dialogicality—the word is the carrier of an individual's voice in this dialogical process and reaches its potential only in dialogue:

> The word in language is half someone else's. It becomes *one's own* only when the speaker populates it with his own intentions [...], it exists in other people's concrete contexts, serving other people's intentions; it is from there that one must take the word, and make it one's own. (Bakhtin, 1981, p. 293)

As Wertsch (1991) frames this, the individual creates "hybrid constructions" (p. 59) based on different voices by internalizing the meaning, transforming it into a newly constructed meaning, and externalizing it in a form that expresses the individual's ideas and intentions. Wertsch's position accounts both for the dynamic character of the process, and for the idea of externalization, in which meaning is frozen and offered back as input to the co-construction process.

2.1.3 Mediation

One of the main premises of the sociocultural approach—and a main assumption underling this theoretical framework—refers to human action as *mediated* (Vygotsky, 1978; Wertsch, 1991). To start with, Linell (2009) makes a distinction between *semiotic* mediation (cognitive or interpersonal processes being supported by language means and other symbol systems) and artifact-based mediation (which references modern technology). Vygostky's interpretation states that human action, on both individual and social planes, is mediated by tools and signs, which he refers to as semiotics. These semiotic means include, for example, language, various systems of counting, symbol systems, writing, schemes, diagrams, or maps (Vygotsky, 1978). It is obvious that not only language/symbols-related mediating means are included in this group. However, regardless of terminological labels, the main idea is that mediating means can serve both as tools that facilitate the co-construction of knowledge and as the means that are internalized to aid such future activities. Language was considered by Vygotsky as the main means of meditation because of its contribution to the construction of meaning at both the individual and social levels (see section 2.1.2). Wertsch (1991, 1998) emphasizes, in relation Vygotsky's notion of mediation, that the inclusion of signs or language "fundamentally transforms the action," which would take another course without them (1991, p. 32).

However, the concept of mediational means goes beyond the idea of language and signs and physical or material artifacts to also include psychological, intellectual tools (Säljö, 2004). All means of meditation collect knowledge and experience through the years. They represent resources for the activity (Linell, 2009) and are products of cultural, historical, and social processes that are accessed by individuals through active engagement in the practice of their community (Cole & Engeström, 1993). These means mediate not only the internalization of the cultural message by the individual, but also the social interaction that characterizes this intersubjective process.

Other theoretical approaches also refer to conceptual, cognitive, or internal artifacts that have a meditational role (Bereiter, 2002; Stahl, 2003). As posed by Van Aalst (2009), this view goes beyond the idea that (social) interaction is crucial by acknowledging the objects and artifacts and by emphasizing that understanding and knowing are mediated by the objects that are created and shared by a community. Discussing cognitive artifacts, such as intellectual products, gestures, and ideas, Stahl (2003) refers to how these actually contribute to the externalization (in socio-cultural terms) of individual meaning into the observable, intersubjective world. Stahl captures the dynamics of this meditational intersubjective process of meaning co-construction and attempts to transcend the dualist split by integrating the conceptual and the physical:

> In this way, through consistent, intentional use by a group of people engaged in activity together, something – a gesture, a sound, a shaped physical object – becomes a meaningful artifact. Such artifacts intimately combine meaning and physical existence. Through its use in a collaborative activity, an object is meaningful ... . (2003, p. 6)

From this viewpoint, the meditational means, whether semiotic, intellectual, or cognitive, can have multiple values: they can represent an outcome of the activity and can have a mediating role. Taking this idea one step further, various authors have maintained that the objects that are being constructed can also become the objects of inquiry (Paavola & Hakkarainen, 2005; Wertsch, 1991). This multiple value becomes visible and important during the co-construction process. For objects to be constructed, elaborated, and developed, particular types of interaction must take place; this interaction is then influenced by the way the object evolves and develops.

2.1.4 Situated action

When discussing the assumption regarding the situated nature of learning and knowledge co-construction, two aspects are of relevance. The sociocultural perspective makes references to both, namely, that learning and development are situated in a physical and cultural space, but also in a *historical space* (Bodrova & Leong, 1996). According to Linell (2009), "meaning is dialogically constituted … but this dialogical construction takes place with reference to the world and against the background of the world" (p. 25). The idea of learning as an activity situated in a particular context or environment has also been acknowledged by the other theoretical approaches. A particularly common tenet is the idea of the environment being the context where knowledge is situated. Knowledge and action have contextual meaning, and every (cognitive) act is a specific response to circumstances

(Greeno, 2006; Hutchins, 1995; Suchman, 2007). In essence, these theories all purport that learning and knowledge are embedded in the physical (e.g., objects, artifacts, and tools) and socio-cultural environment (e.g., peers, procedures, rules, and traditions) and that the knowledge involved should be contextualized and connected to an individual's experience, knowledge, and world (Gee, 2004). The presence and availability of various resources and tools are emphasized, as well as the ways that learners make use of and capitalize on these (Linell, 2009). In this sense, the situativeness is expressed in the idea that actions construing learning are shaped by situational factors, by interactions among participants, by features and characteristics of the environment, and by interaction with this environment (Greeno, 2006; Suchman, 2007).

2.2 Framing constructs

The idea of framing constructs has emerged as a strategy for connecting the theoretical insights previously discussed to the processes observed and analyzed. These framing constructs represent a transitional level situated between the abstract theoretical assumptions and the analytic concepts I have employed as tools to explore the empirical data. In the following section, I present the four constructs that I have used to elaborate on the idea of learning as a mediated process of active construction of knowledge through interaction. The conceptualizations rests mainly upon sociocultural assumptions, but some of the constructs are also elaborated using input based on other theoretical traditions.

Two constructs, *productive interaction* and *shared epistemic agency,* are based on sociocultural views of the social interaction being central to learning and activity, but sociocognitive ideas also contribute to their elaboration. The notion of *knowledge object* draws upon existing ideas within different (theoretical) perspectives, such as the sociocultural, sociocognitive, and the sociology of knowledge. The notion of *interaction trajectories* is taken up following conceptualizations inspired by the sociocultural stance by Furberg and Ludvigsen (2008) and Ludvigsen, Rasmussen, Krange, Moen, and Middleton (2010). In this section, these constructs are presented based on the conceptualizations in the literature. In a later section (2.4), I discuss how these constructs apply to this research.

2.2.1 Productive interactions

The sociocultural stance emphasizes the interdependence of social and individual processes in the co-construction of knowledge (Valsiner, 1994b; 1996; Valsiner & Van der

Veer, 2000). Accordingly, it is in social interaction that individuals align their existing ideas, concepts, expertise to create new understanding and meaning, and through interaction between participants and resources that knowledge comes into use (Greeno, 1998; Greeno, 2006; Wertsch, 1998). From this perspective, knowledge emerges as an interactional accomplishment based on a combination of individual contributions, collective processing, and mediational resources involved.

Studies of interaction used differing terminology, built on diverging assumptions, or adopted different analytic stances, but the majority addresses the same phenomenon. Productive interactions are mostly described at the microgenetic level of knowledge construction. This level comprises interaction between individuals or between individuals and their environment, or the interplay of individual, interpersonal, and social-cultural aspects simultaneously (Ludvigsen, 2009). Broadly conceived, productive interaction in collaborative learning refers to knowledge construction within the context of a knowledge domain, entailing (joint) actions directed toward shared goals and increased understanding of concepts (Littleton & Light, 1999; Ludvigsen, 2009; Rasmussen, 2005). Miyake (1986) based her account of constructive interaction on the assumption that interaction with peers supports learners' better understanding of concepts and ideas and coined the notion of constructive interaction as an element of the pedagogical design - learners talking to each other while attempting to understand specific phenomena. Roschelle (1992) considered conversational interaction as constructive when it enables students to construct increasingly sophisticated approximations to scientific concepts, through gradual refinement of ambiguous, figurative, partial meanings. Baker (1999) developed an account of constructive interactions and identified two aspects of productivity (or constructiveness). The first involves the productive transformations that lead to the co-construction of meaning, understanding, solutions or knowledge. More specifically, in these interactions, "new meanings or knowledge are co-elaborated, and/or one that fulfils some specific (constructive) function with respect to cooperative activity" (p. 179). This places the emphasis on the communicative aspects and how *interaction leads to knowledge or understanding* through the addition of new knowledge or understanding instead of confusion. The second aspect refers to interaction being constructive to the extent that it contributes to a *shared goal or cooperative activity,* through action that go beyond individual contributions and serve a common purpose. Barron (2003) emphasized the importance of productive collaboration beyond the accomplishment aspect and the characteristics of interactions that lead to differentially productive joint efforts. Mercer

(2004) and Mercer and Wegerif (1999) elaborated on the concept of exploratory talk, referring to a communicative process for reasoning through talk. Accordingly, such talk occurs when

> ...partners engage critically but constructively with each other's ideas. Relevant information is offered for joint consideration. […] Agreement is sought as a basis for joint progress. Knowledge is made publicly accountable and reasoning is visible in the talk. (Mercer, 2004, p.16).

Furthermore, it recognizes peers' rights to participate and contribute toward the shared goal, activity, or outcome. To conclude, although varying in approach and basic assumptions, these studies contribute to a conceptualization of the notion of productive interactions, by depicting it as a key aspect of co-construction of knowledge, meaning, and understanding.

2.2.2 Knowledge objects

There have been several attempts to define the concept of *knowledge object,* but there are no clear cut, unambiguous, and undisputable definitions. Objects are referred to by Carlile (2002) as a collection of artifacts individuals work with, i.e. create, measure, and manipulate. From a cultural-historical perspective, the object anchors the activity system (Engeström, 1987; Leont'ev, 1978), which means that activity (whether learning or otherwise) is oriented toward an object that motivates and guides the activity. The object defines the activity and becomes the "sense-maker" (Kaptelinin, 2005, p. 12), which gives meaning to this activity and the values involved in the activity.

According to the initial ideas of the activity theory, the material object is meant to address and answer needs that determine the motives of a certain activity (Leont'ev, 1978). Some studies (Engeström & Sanino, 2010; Kaptelinin, 2005) are concerned with the dual nature of the object. According to Russell (1997), the object has both projective and objective value, meaning that it represents both the goal to be pursued and the material outcome to be achieved through the activity. Roth and Lee (2004) view this as an inner contradiction, as the object is considered to be both of a material and ideational nature; thus, it can be both a *material object* and the *object of thought*. Kapitelinin (2005) explains the dual nature of the concept through the combined meaning of the original terms that the currently used term "object" is based on. These are *object* and *predmet* (Russian), and the meaning refers to the realization of a material reality, respectively, the object of thought.

The former holds product features, while the latter refers mostly to process features (Jahreie, 2010).

From the constructivist perspective, the focus is placed on *epistemic objects* (Knorr-Cetina, 1997, 2001). Rheinberger (1997) defines knowledge objects as being the same with research objects or epistemic things. These are "material entities or processes – physical structures, chemical reactions, biological functions – that constitute the objects of inquiry" (Rheinberger, 1997, p. 28). He distinguishes technological objects (i.e., ready-to-use, clearly defined, and finished objects with an instrumental role) from the epistemic objects, which are question-generating and complex and have the potential to open lines for inquiry and research. Knorr-Cetina (2001) emphasizes the difference between *objects as instruments*, which are objects that are ready to use, a means to an end, and always available, and *knowledge objects*, which are problematic and open to transformation and further exploration.

Traditionally, a distinction has been made between the notions of *object* and *artifact*, with objects referring to the objective of activity and artifacts to the tools that mediate the achievement of these objectives (Ramduny-Ellis et al., 2005). But these terms have been frequently used interchangeably, and insight into how the notion of artifact captures aspects related to knowledge-driven work is important.

From the perspective that the knowledge artifacts embody of the type of activity they mediate, maybe the most general include material artifacts (e.g., a pen), abstract or intangible artifacts (e.g., software or reports), and processes (e.g., manufacturing processes) (Shariq, 1998). Wartofsky (1979) identifies cognitive artifacts as playing an important role in epistemic activity in general, and learning in particular, and as a means for "creating and acquiring knowledge" (p. xv). The cultural-historical perspective interprets artifacts as *tools* that mediate the achievement of objectives of activity (Stetsenko, 2005). Here, the artifacts play an instrumental role, have tool-like characteristics, and are used to create new artifacts (Ilyenkov, 1977). Bereiter's (2002) elaboration on the notion of *conceptual artifacts* is introduced in relation to how knowledge work in general is taking place, how knowledge is produced, and the idea of knowledge building—as a form of knowledge production and learning in collaboration (Scardamalia & Bereiter, 2003).

With regard to the nature of these artifacts, Bereiter builds on Popper's idea of the three worlds, which labels conceptual artifacts as components of the third world. This world encompasses entities such as problems, theories, ideas, concepts, conjectures, interpretations, proofs, criticisms, and the like. From this perspective, an idea, concept, or

theory is real (Bereiter, 2002). Similar to Ilyenkov's view (1977), these artifacts are conceptual in the sense of being abstract and nonmaterial in nature, having simultaneously mediating roles. Paavola and Hakkarainen (2005) emphasize Bereiter's statement that human work focuses increasingly on conceptual artifacts rather than physical things, which characterizes knowledge work. Furthermore, Bereiter also considers that artifacts play a seminal role in the advancement of knowledge, in which they have multiple values: they are instrumental (i.e., used to create other artifacts), they are historical (e.g., embody knowledge created in time), and they can be the outcome of knowledge work (e.g., can be shared, articulated, and extended by shared efforts and by mobilizing collective cognitive resources).

This summary of the conceptualizations of the two notions is not intended to be exhaustive or to reconcile the discussion regarding the meaning and use of these notions. For consistency, in this study, I use "knowledge object" as a generic term. A main aspect to draw upon when elaborating on these conceptualizations is the open character of the knowledge objects, which makes them more processes and projections rather than definitive things. Their defining features are this changing, unfolding character (Knorr-Cetina, 2001) and their incomplete, continuously evolving nature (Ewenstein & Whyte, 2009). Miettinen and Virkkunen (2005) refer to epistemic or knowledge objects as rather open-ended projections that are oriented toward something that does not yet exist or to something that is not known for sure; they are therefore generators of new conceptions and solutions. As a consequence, work with these objects is a continuous process of transforming an object from its current state into a required end state. The complexity of this construct lies in its dynamic position in relation to the interactional process, which can allot the object the role of an outcome of the co-construction, but also that of mediating tool or object of inquiry in the process.

Finally, an important distinction needs to be pointed out in relation to the present study. It emerges from a sociocultural perspective and concerns the relationship between the generalized and the *situational object* (Jahreie, 2010). The generalized objects of activity are historically developed and represent an answer to societal needs (e.g., assessment systems in the educational institutions), while the situational objects are manifestations of the generalized object but are procedurally and discursively constructed (e.g., a report produced by a group of students). These objects are concrete and are constructed by participants during a flow of various actions. The interaction of learners, in this case, is only

understandable in relation to this situated knowledge object that they construct together (Jahreie, 2010).

2.2.3 Interaction trajectories

A timescale perspective is needed when attempting to elucidate the development of both the knowledge object and the way the interaction unfolds (Ludvigsen et al., 2010). Interaction is thus seen as ongoing process of co-production, which, as Suchman argues, "cannot be stipulated in advance, but requires [...] a presence and a projected future" (2003, p. 78). The concept of *interaction trajectories* (Furberg & Ludvigsen, 2008; Krange, 2007) encompasses this idea of interaction and knowledge construction unfolding in time in a sequential fashion. The interaction and the related co-construction of knowledge objects are depicted as moment-to-moment events. These processes involve both the interaction and related action at a specific moment in time, but they also stretch over a longer time span. Sarmiento-Klapper (2009) states that in longitudinal interactions, temporal and sequential resources are central to constituting activity as continuous. Krange (2007) emphasizes that a trajectory perspective creates possibilities for determining how these momentary interaction elements build into continuity, how the interaction process evolves over time, and how participants capitalize on, first, each others' contribution to the joint effort and, second, on the various resources available. Theoretically, this concept creates the framework for explaining the co-construction process from a micro-level static perspective, but also expands this view to a more dynamic one that captures progress within the given time boundaries (Furberg & Ludvigsen, 2008).

2.2.4 Shared epistemic agency

This notion draws upon sociocognitive ideas, as well as knowledge philosophical and sociological stances. It adds to the sociocultural perspectives employed in this dissertation by elaborating on a concept that is relevant to the phenomenon examined, but it is not treated explicitly within the sociocultural framework. Etymologically, the term "epistemic" refers to knowledge, and epistemic agency involves human beings having control of their course of actions and being able to determine how to apply their will in concrete acts related to knowledge (Reed, 2001). Individuals possess the potential to distance themselves from the existing, known patterns of activity and to find new ways to express their ideas; agency involves examining alternative trajectories for future acts. Socio-cognitive theory (Bandura, 2001) emphasizes intentionality as a core aspect of human

agency, which implies purposefulness, acting based on clear intentions, determining the course of action, and regulating the activity by reflective means. Scardamalia (2002) defines it as a meta-cognitive ability related to goal setting, motivation, evaluation, and long-range planning. Participants in this type of project relate their personal ideas with one another, monitor advancement of collective activities, and overcome challenges emerging in the process, activities which she relates to epistemic agency.

Emirbayer and Mische (1998) consider agency to be characterized by experience-based social participation, involving acts of negotiation on the course of future actions. Accordingly, epistemic agency does not reside within the individual's mind, but rather emerges through participation in collective activities (Holland, Lachicotte, Skinner, & Cain, 1998; Schwartz & Okita, 2004). Martin (2007) maintains that the achievement of common goals and productive participation with others requires more than individual strategizing, and Palonen and Hakkarainen (2000) add that epistemic agency is the concept that reveals students' understanding of the fact that it is not only the teacher initiating inquiry or activities of knowledge construction, but that the students themselves can be the ones who initiate, conduct, and steer this process. The assumption I elaborate upon (Study 1) is that agency in collaborative contexts involves a social element that is enhanced during group work. The notion of sharedness in agency presupposes intersubjectivity (Matusov, 2001) and interaction between participants. Although collaborative tasks are performed, this does not necessarily indicate that the group is an established community with customary ways of working. Edwards emphasizes that it allows individuals "to work with others in order to expand the object that one is working on" (2001, p. 7) and that, in general, it places the focus on the joint action and the impact on those who engage in it. In a joint action, a wider range of concepts or resources are likely to be deployed on the (shared) object than it would in the case of individual action. I argue that it is the shared object that is the reason and the focus of the collaborative activities and which brings the group members together, functioning both as a process catalyst and an outcome to strive toward.

To conclude, these constructs offer the possibility of transforming general theoretical ideas into more specific conceptual elaborations that depict some particular aspects of the investigated processes in a targeted and detailed manner. In summary, the concept of productive interaction encompasses the notion of the dialogical interaction, which contributes to creating shared understanding, and involves the various aspects of knowledge content and the way this is expressed in the interaction. The interaction trajectory expresses the temporality of this process, which is constructed based on sequences of moment-to-

moment interactions. The shared knowledge objects reflect the idea of the knowledge content (within various domains) and how that is materialized through joint work. Finally, the shared epistemic agency refers to the deliberate, strategic way of acting jointly to materialize knowledge into objects.

2.3 Integration – an applied theoretical framework

This dissertation project seeks to reach a deeper understanding of the process of learning conceived as knowledge co-construction and to add further elaboration to this conceptualization. From a sociocultural viewpoint, this process and the related phenomena can be approached at different levels, such as sociogenetic, ontogenetic, and microgenetic. The microgenetic level unifies, in a generic sense, several emblematic features identified as defining for learning (Ludvigsen, 2009). Within a determined temporality, this allows identifying and accounting for sequences that illustrate these complex processes of interaction and knowledge construction. Starting from these premises, I assemble a theoretical framework based on an integration of the four constructs, i.e., productive interaction, interaction trajectories, shared knowledge objects and shared epistemic agency. The key aspects of this framework are discussed and illustrated below.

The *productive interactions* are the expression of the social character of learning in the knowledge construction process I conceive these as communicative exchanges leading to participants' co-constructing and elaborating on ideas and knowledge objects as shared outcomes of collaborative group work. They involve sequences of collaborative actions around shared objects or moving from one state toward another in a direction that leads to the advancement of these objects. In this context, each case and context defines the "productiveness" of interactions in epistemic terms, rather than some universal criteria. In addition, I conceive *interaction trajectories* as coherent sequences of productive interactions, displayed analytically as collections of episodes. These take into account not only the (epistemic) content of the interaction, but also the temporality of the interactional process with its sequentially organized actions. This implies that investigating productive interactions involves tackling both the *epistemic* aspects of the interdependence and the *social* and *relational* aspects. Also, it means that the moment-to-moment interactions are organized in sequences that create a time-based trajectory. In other words, the productivity of the interactions I investigate is expressed in rich epistemic content and in the way that the interaction sequences build on each other.

In this dissertation, knowledge objects are viewed as a means of attaining knowledge or something else, but also, more importantly, as part of the content of inquiry. I adopt and use the concept of *knowledge object* and conceive objects as an externalization of knowledge, "freezing" knowledge at certain moments in time. The objects embody knowledge that is not in the mind, but rather is externalized in something (such as ideas or actions) that is accessible to the whole group and can be used to produce new knowledge. As an analytic stance, I adopt the distinction between generalized objects of activity, which are historically developed, and *situational* objects (Jahreie, 2010), which are discursively constructed in the interaction of the learners. This position situates the shared knowledge objects in the center of the interaction process, either as mediating entities or as objects of inquiry, and not simply at the end of it, as end outcomes. It views the knowledge objects as rather open-ended projections oriented toward something that is not known for sure and, as a consequence, are generators of new conceptions and solutions.

Finally, I regard the construct of *shared epistemic agency* as the capacity to enable a deliberate, joint, object-oriented interaction. This type of agency expresses different qualities of the knowledge co-construction process. The epistemic aspect refers to the active involvement of the group with knowledge and its materialization into knowledge objects. The aspect of sharedness implies that agency is not the expression of each individual member's activities or pursuits, but is rather the expression of joint efforts at the group level. Furthermore, I conceive shared epistemic agency as an emerging, recursive capacity that manifests itself and unfolds during the interaction. The emphasis is on how sharedness and the joint action emerge from the combination of individual positions and input and how interaction and knowledge object co-construction are driven by this intellectual interdependence.

3 Review of relevant research

In this chapter, I present and reflect on research in the field of learning in higher education and relevant studies of collaborative learning. In the first section, a examination of review studies indicates that research on learning processes in higher education conducted from emerging theoretical perspectives are not necessarily abundant. This review attempts to identify relevant directions and studies of learning in higher education that focus on collaborative learning processes, particularly, and include knowledge as an important aspect of this process. A second set of studies was examined in order to provide insights into models of learning through knowledge building, knowledge creation, problem-solving, or progressive inquiry, and implementation of ideas regarding learning in interaction, especially in small group settings. The latter set of studies was conducted primarily in secondary education and provides an extended insight into aspects of collaborative learning that is not provided by studies in higher education settings. Therefore, I opted for a selection of the research on ideas and models most relevant to this dissertation, instead of focusing only on research within the field of higher education. In addition, the tradition of investigating collaboration in the last two decades was built especially on theoretical perspectives rooted in the socio-cognitive rather than socio-cultural ideas. Thus, I am looking primarily into the former, as it contains a solid and extensive empirical body of work on this theme. Given the wide range and the high number of studies of collaboration, an exhaustive overview of this research is beyond the scope of this dissertation.

3.1 Learning in higher education: research trends

This review section attempts to provide a general overview of the research trends and themes in undergraduate learning research. The main sources are review studies by Tight (2007; 2012), Haggis (2003), and Nerland (2012). Together, these reviews provide a general view of this research, based on a content analysis of articles published in leading journals in the higher education research in the last three decades and a cross-section

analysis of publications in 2010. Given the aim, scope, and small sample of studies, this review is not intended to be exhaustive or to cover all of the themes of higher education research.

The analyzed literature brought four main aspects to the fore. First, most common arenas for studies on student learning are the disciplinary domains, such as engineering, computer science, or medical studies. While research on learning at other education levels (secondary school, for instance) is organized and elaborated based on general conceptual approaches to learning, research in higher education is divided to a greater extent according to knowledge domains. According to Nerland (2012) and Tight (2012), much of the research on student learning is published in the disciplinary literature. Perhaps as a consequence, higher education-specific journals publish an overwhelming majority of studies on aspects other than student learning. The review conducted by Tight (2007), based on a comparative analysis of 406 articles from 17 international journals, showed that only 5% of the studies had a focus on aspects directly related to learning processes. It appears that within the disciplines there is a more explicit interest in the learning processes, although they are approached and investigated from a disciplinary perspective.

A second matter that requires attention in this discussion concerns the themes on student learning research as they emerge based on studies published in higher education journals. Tight (2007) identified two themes that are directly relevant to this dissertation: teaching and learning, and knowledge. The studies covering this research add up to 10.5% of the research reviewed. According to Haggis (2003), only two of the six themes she identified have a direct focus and take into consideration learning processes, namely, approaches to learning and curricular innovation. With regard to the notion of knowledge, Tight's study specifically makes it clear that this aspect is insufficiently addressed in the higher education arena, particularly from the learning sciences perspective.

A third aspect that stands out is that research on student learning is dominated by particular theoretical trends (Haggis, 2003; Nerland, 2012). In her review study, Haggis (2003) reached the conclusion that a) each of the studies reviewed is difficult to categorize as belonging to only one theoretical perspective, and b) research on student learning appears not to build on theoretical perspectives emerging in recent years. Accordingly, these studies draw upon rather traditional theoretical perspectives, such as cognitive psychology, and continue to do so currently. Also, these conceptual choices have led to a majority of studies taking an individual position and focusing on cognitive aspects of learning from this individual perspective. Examples are: students' perceptions and experiences with learning

(Marton & Säljö, 1976), epistemic beliefs (Schommers-Aikins, Duell, & Barker, 2003; Muis & Sinatra, 2006), and self-directed learning and critical reflection (Entwistle & Peterson, 2005). Nerland (2012) also makes the point that one of these orientations was considered especially influential. The phenomenographic approach, stemming from individual cognition perspectives, led to the development of both a theoretical framework regarding learning, i.e., deep, surface, and strategic (Marton & Saljo, 1976) and a very distinct methodology based on questionnaires and interviews. This dominated student learning research for decades, and represented the basis for major higher education policy and curriculum-related decisions. In the last decade, however, more varied theoretical perspectives have been employed (from sociocognitive, sociocultural or social-epistemological) and served the investigation of learning in higher education, also in relation to professional learning (e.g., Bucciarelli, 2003; Muukkonen, Lakkala, Kaistinen, & Nyman, 2010; Slevin, 2008; Stankovic, 2009). Findings from some of these studies are discussed in the following sections, based on relevance (see Sections 3.3.2 and 3.3.3).

Finally, one aspect that seems to concern research on student learning in recent years in connection with the ongoing developments in the knowledge society refers to the necessity of organizing learning in higher education to support students to develop "epistemic fluency" (Goodyear & Zenios, 2007). The Boyer Report (1998) indicates research-based learning as a strategy to prepare students to enter knowledge-driven professional work. In the European context, the same needs emerge, but for additional reasons, i.e., the massification of higher education (Maassen & Stensaker, 2011). In essence, this research takes learning processes into consideration by focusing on: materializing research skills into the curriculum (Zimbardi & Myatt, 2012); an understanding, among curriculum makers, of the types engagement (Levy & Petrulis, 2012) and research activities students are enrolled in (Turner, Wuetherick, & Healey, 2008); or understanding within disciplines of students' contributions to research and knowledge production (Brint et al., 2012; Robertson, 2007). Nerland (2012) also pointed at a line of reasoning that builds on the sociology of knowledge, in which the process of knowledge production is viewed as a dynamic relationship between epistemic aspects, various resources, and different contexts. However, the emphasis is rather more on the general level of epistemic cultures and their mechanisms, and empirical studies of learning, including social interaction, are rather scarce in undergraduate learning research.

This brief overview of research trends indicates that research on learning in higher education is spread over disciplinary domains, and that often relevant results do not

disseminate across domains. Furthermore, it seems that in the last decades this research has not followed the theoretical perspectives emerging within the learning sciences, as did other learning research. These emerging theoretical directions seem to activate new ideas with regard to research on learning in higher education that invoke exploration. In response to this, new research must address aspects that characterize learning from these perspectives, such as the sociocultural approach, and take into account conceptual developments in the professional field.

3.2 Research on learning models

The previous review section showed that learning conceptualized as a process in which knowledge is constructed through (social) interaction has not been frequently a topic of research within the field of learning in higher education. This led to a need to ascertain whether this, or comparable, conceptualizations of learning were employed and investigated by research studies at other education levels. A review of such research serves a number of goals. First, it examines models and conceptualizations of learning that include the idea of collaboration and knowledge creation/construction/building.[3] Second, it attempts to provide an analysis of a cross-section sample of studies on collaborative groups. Finally, it has the potential to indicate how this dissertation can contribute to further elaboration of the current conceptualizations of learning and provide empirical substantiation on its behalf.

I hereby analyze and discuss: a) two approaches to learning, i.e., knowledge building and knowledge creation; b) empirical studies of collaborative and small-group learning; and, c) briefly, three pedagogical models, i.e., problem-based learning, inquiry-based learning, and project-based learning. The distinction between the different categories of studies is due to the nature of their conceptualizations of learning. In the two approaches, learning is conceptualized from a theoretical viewpoint, and the theoretical framework that depicts the learning phenomenon is formalized to a certain degree. The set of studies on collaboration builds on ideas of learning in and through social interaction, originating in various theoretical perspectives (e.g., sociocognition, a sociocultural approach, and socio-constructivist views), and investigates these in empirical settings. In the pedagogical models, the emphasis is on the application of theoretical principles to pedagogical design,

[3] These are terms used to denominate theoretical models of learning in collaboration.

and their implementation in practice. In addition, technology is a featured element in the majority of the studies discussed in the following sections.

3.2.1 Knowledge-building approach

The knowledge-building (KB) approach has emerged from cognitive studies of literacy, intentional learning, and creative expertise (Bereiter, 2002; Scardamalia & Bereiter, 1991; Scardamalia & Bereiter, 2003). It argues that prevalent epistemology and mainstream theories of learning are generally too individualistic, with learning perceived as an accumulation of ready-made information to the human mind. This kind of learning should be replaced by deliberate activities for building knowledge together. Thus, knowledge-building is defined as the "production and continual improvement of ideas of value to a community" (Scardamalia & Bereiter, 2003, p. 1371). It is characteristic of knowledge communities (e.g., scientific, business, artistic) to produce conceptual artifacts such as ideas, theories, or designs. These can be shared, articulated, extended and improved through the community's discourse and use of its cognitive resources. The central aim of knowledge communities is to advance their knowledge, by collaboratively developing new ideas, which then become available for subsequent use and further elaboration. In addition, such communities must uphold cognitive responsibility for the pursuit of the knowledge-building processes (Scardamalia, 2002).

An examination of the KB related research studies, both conceptual and empirical, led to a number of conclusions. Within the scope of three decades, the knowledge-building approach has led to a considerable body of research studies, mainly aimed at contributing to the development and implementation of the model and its supporting technology.[4] Scardamalia (2002) developed 12 principles that translate knowledge-building ideas into a set of pedagogical guidelines—as part of a principle-based rather than procedure-based approach (see Zhang, Hong, Scardamalia, Teo, & Morley, 2011). Thematically, the studies using knowledge building as a frame of reference address more than one of these themes, a combination of research foci being often the case (e.g., the use of Knowledge Forum in a learning activity that employs a number of the design principles). I examined, specifically, studies that focused upon the following: learning situations in which idea advancement and

[4] The Computer-Supported Intentional Learning Environment (CSILE) and the Knowledge Forum (KF) (Scardamalia & Bereiter, 1994).

improvement were central, both in classical and online settings; learners' active participation; and social aspects of the KB process.

In a number of studies of graduate and high school students' knowledge-building activities, KB principles and electronic portfolios were employed to analyze the nature of these processes and social aspects of the KB inquiry. Chan, Lee, and van Aalst (2001) analyzed how notes contributed to a problem-centered KB process in the geography domain, and attempted to understand and assess knowledge building from an individual and collective perspective, using portfolios. Principles referring to collaborative efforts and progressive problem-solving were used. Related to the former, actions were identified, such as reading notes by other participants, identifying problems, and integrating and summarizing views that they then shared with the community. For solving problems, students identified confusions and gaps in knowledge, refined definitions, and documented others' impact on their own perspectives. While these results indicate action complying with the KB ideas, it is interesting to note that all of the activities identified were of an individual nature. Collaborative inquiry actions were identified only with regard to students' reading, selecting, or summarizing others' notes. In other studies, wherein students' performance was also assessed using notes and portfolios, van Aalst and Chan (2007) and Lee, Chan, and van Aalst (2006) found that students were able to discuss, integrate, and synthesize others' notes, and there was better engagement in in-depth inquiry, but little to no evidence of idea follow-up or idea advancement was noted. The problematic matter of socially built knowledge was identified here too, with just one student going beyond simply replying to others' notes. A study focusing specifically on the principle of epistemic agency (Erkunt, 2010) used Social Network Theory to identify how college students engage with their epistemic goals and in collective knowledge construction. The findings point to aspects that are of major importance for how students participate in the process, the role of epistemic artifacts, and the role of the community.

A number of studies (Hong & Sullivan, 2009; Hong, 2011; Zhang, Hong, Scardamalia, Theo, & Morley, 2011) attempted to demonstrate that an idea-centered collaboration benefits learning and students' view of collaboration. This notion emphasizes ideas as fundamental knowledge units or conceptual artifacts, which need to be created, improved, and transformed, during a process that can take place within or outside predefined groups. Such studies showed that idea-centered designs foster knowledge construction rather than knowledge acquisition (Hong, Scardamalia, & Zhang, 2010; Hong & Sullivan, 2009). Hong's (2011) study identified an improved view of collaboration

registered in students' self-reflections, but made little mention of the beneficial effects of this strategy for idea advancement. The study by Zhang et al. (2011) showed more specifically that a more flexible group model allowed students to come into contact with diverse ideas, monitor gaps in the community space, formulate new inquiry goals, and develop coherent accounts. However, the study emphasizes that while this design strongly facilitates knowledge sharing, there was less idea advancement and elaboration, which happened often in smaller group settings. Zhang and Messina (2010) expanded the notion of idea-centered collaboration to what they describe as collaborative productivity. This adds to the former characteristics of a creative community and a capacity for self-organization (information flow, loops fueling idea generation, selection and development, distributed control). This study of fourth-grade students showed positive results concerning the advancement of knowledge. Previous ideas were used as stepping-stones for new problems and goals, ideas were developed through peer-uptake and incremental refinement, critical idea selection was part of the process, etc. The aspect of self-organization was less promising, with the teacher playing a prominent role in the process.

Another set of studies examined was one describing the role of conceptual artifacts in the KB process. A number of studies analyzed notes produced by students in the KF. Notes can be viewed as "an embodiment of a single idea" but also as problems or scaffolds (Scardamalia, 2002, p. 7), and are intended to serve the collaborative inquiry process. Studies that follow the idea of notes as artifacts showed that the notes triggered reflection regarding collective problem-solving (Hewitt, 2002). Ideas expressed in these notes support a higher level of scientific thinking (Hakkarainen, 1998); they foster engagement in higher-level thinking and the development of the students' epistemological awareness of the process (Hakkarainen & Sintonen, 2002). In the same tradition, Van Aalst and Chan (2007) and Lee, Chan, and Van Aalst (2006) investigated how digital portfolios scaffold the collaborative inquiry of high school students using KF technology. The findings point to the formative value of the portfolios, which represented not only knowledge products, but the materialization of students' developing ideas and a form of scaffolding that helped students recognize and make sense of productive discourse. However, the collaborative aspect of KB were again represented only by the analysis of peer discourse and not by active involvement in creating it.

The research analyzed here provides insights into models and efforts that attempt to foster knowledge building mostly in larger communities, such as classrooms. Of distinctive interest for my research are especially aspects concerning idea production and advancement.

However, studies of knowledge building appear to focus mainly on individual contributions and behavior in the context of a collective activity, and do not investigate and theorize on the social aspects of the collaborative process.

3.2.2 Knowledge creation metaphor

The knowledge creation metaphor (Paavola & Hakkarainen, 2005) elaborates on a view of learning that draws upon the knowledge-building model. While the KB model emphasizes ideas and idea improvement as central to collective knowledge advancement, the knowledge creation metaphor takes a more specific focus on collaborative work on knowledge objects, as a practice that leads to the creation of knowledge through incremental work, revisions, and joint efforts. This conception of learning elaborates on, among others, ideas from Engeström's (1987) expansive learning model, which discussed the objects in depth as an important aspect of learning. One of the main arguments in the elaboration is that conceptual artifacts fulfill their envisioned purposes when they are made explicit and translated to concrete knowledge objects (texts, models, etc.). The objects created and shared by the community serve learning in that they are, at a point in time, objects of the inquiry, but once finalized they can mediate knowing and understanding by embodying the community's ideas and knowledge.

The conceptualization of learning through knowledge creation is closely related to the knowledge building approach. I will not engage in this discussion (van Aalst, 2009), and I will treat the knowledge creation metaphor as it was originally conceived by its authors. This involves interactions, generation of ideas, and their embodiment into knowledge objects that serve various roles (see discussion in Chapter 2, Section 2.3.2). The review of empirical studies revealed that the body of research using the knowledge creation metaphor as a conceptual framework is rather limited, with the majority of the studies being conducted within the framework of the KP-Lab project. In addition, some studies in organizational settings drawing upon the expansive learning model bring forward the idea (also expressed by the knowledge creation metaphor) of knowledge objects as mediators for knowledge-oriented activities.

Studies of collaborative learning in higher education have attempted to identify characteristic aspects of the knowledge creation process and the knowledge object as both object of inquiry and scaffold for the inquiry process. Examples of knowledge objects may include theories, plans, protocols, frameworks, and designs. In a study on the role of technology mediation and tutoring in students' knowledge production in inquiry-based

learning, Mukkonen, Lakkala, and Hakkarainen (2005) built on the assumption that the progressive inquiry process benefits from a shared representation, which can be either a visual one or a textual artifact (e.g., learning logs). To understand how the scale of various types of scaffolds related to the nature of the knowledge produced by students, the authors analyzed the content of students' productions. The findings showed that technological scaffolding supported problem setting, building on each others' ideas, and monitoring joint idea advancement. In the same trend, Muukkonen and Lakkala (2009) examined the development of undergraduate students' meta-skills, assuming that advancing shared objects by means of collaborative inquiry contributes to the development of higher-level skills. In relation to the shared object aspect, groups devised common knowledge objects, which they used as guidance for their inquiry questions. Also, groups that appeared to be more aware of their strategies elaborated more on their common knowledge object, and groups that focused more on the object-oriented aspects of inquiry were more self-critical about the process.

A number of studies pointed to the role of knowledge objects in the processes of learning and competence building involved in the construction of products in private companies. The study by Miettinen, Lehenkari, and Tuunainen (2008) illustrates instances of the object as both an element that drives the collaborative knowledge production process and its outcome. The main conclusion of this study refers to the complementarity of object-specific resources, and how knowledge objects bring together the ideas, resources, and competences needed to create this new product. In this case, the focus is on the knowledge object as outcome and object of inquiry. MacPherson, Kofinas, Jones, and Thorpe (2010) focused on knowledge objects as mediating elements of collective learning, and their contribution in shaping learning trajectories in the context of organizational transformations in small firms that undergo restructuring. The study showed that strategic renewals and developing a new modus operandi require accepted artifacts (e.g., concept maps, training courses, and operating systems) and the practices around them, in order for these objects to trigger the desired transformations.

To sum up, these studies point to aspects of high relevance for the understanding of collaborative learning in which different types of knowledge objects or artifacts are involved. In organizational contexts, the objects are viewed most frequently either as a mediating element of various activities or processes (whether as tools or as triggers for transformation), or as an outcome of the latter. As opposed to organizational research, studies conducted in educational settings establish the link between the objects and the learning process in a more direct manner. However, in both settings, little attention is

focused on how these objects come to life and how they develop as part of the unfolding interaction and activities.

3.2.3 Research on small-group learning

The purpose of this section is to acknowledge research on small-group learning that proves of relevance for this dissertation. In the last decades, studies of collaboration approached the phenomenon from a social-cognitive or social-cultural viewpoint, which emphasizes the social aspects and interaction in various ways. Extensive attention was allocated to investigating non-epistemic aspects of collaboration, the relationship between individual and group performance, or procedural aspects of the collaborative process (see Arnseth & Ludvigsen, 2006; Jeong & Hmelo-Silver, 2010, for overviews). In terms of thematic orientation, an interesting development was that some notions introduced initially within the cognitive tradition were explored, elaborated, and expanded by perspectives that placed social interaction in the foreground; an example is the notion of joint problem space. The notion was re-conceptualized for the idea that knowledge is a social construct, which occurs when learners solve problems through a "coordinated production of talk and action" (Roschelle, 1992, p. 254). The Cognition and Technology Group at Vanderbilt (1997) elaborated the notion further using the label "anchored instruction," which conceives learning from a distributed cognition perspective. Some of these studies (Roschelle, 1992; Teasley & Roschelle, 1993) had a focus on collaborative problem-solving through conversational interaction and use of technological support.

Within the context of investigating problem-solving in small groups, Barron (2000, 2003) introduced the idea of content and relational spaces. The content space refers mainly to epistemic aspects, expressed in how learners deal with the content of their learning and the knowledge domain. Within small-group learning research, studies of joint problem space, virtual collaborative math learning, and disciplinary engagement address this aspect directly or through related topics. The interaction space is referred to as the intersubjective, social, and relational one in a group's collaboration. By this, Barron emphasized the complexity of the collaborative process and set the course for other studies that attempted to consider both the epistemic and social-relational aspects as interrelated, and not mutually exclusive. Barron and colleagues conducted a series of studies on small-group collaboration that attempted to gain deeper understanding in both the collaborative solving of mathematical problems (see the Cognition and Technology Group at Vanderbilt, 1997), and the way the groups deal with the social and relational aspects of the collaboration. Barron

(2000, 2003) and Barron and Sears (2002) focused on understanding the characteristics of interactions that lead to differentially productive joint efforts. Aspects influencing the productivity of the interaction were identified more at the relational and meta-cognitive level than otherwise. Groups that were considered more productive in their collaboration coordinated and monitored more individual contributions to the joint work, and dealt with issues of power and role status as well as engagement issues. Engle and Conant (2002), in a study of productive disciplinary engagement, attempted to characterize the productivity of students' engagement during collaborative tasks. The engagement was considered productive when progress was noticed in students' knowledge (use of more advanced arguments, emergence of more elaborated questions, etc.). The aspect of positioning appears to be of importance. It relates to Barron's observation of the epistemic processes students display, while tracking and evaluating others (2003). One aspect that stands out in the conclusions of these studies is the active role learners are expected to take on during the process.

More recent studies (Krange, 2007; Sarmiento-Klapper, 2009) considered the temporal and sequential orientation of the interaction. Sarmiento-Klapper (2009) attempted to re-conceptualize the dimensions of the collaborative space and make explicit the temporality of the interaction, which lies in bridging the discontinuities emerging over multiple episodes of interaction. This stance is motivated by the complexity of the process, given the fact that it is distributed across multiple communities and dispersed over time, e.g., long-term projects and multiple interaction moments. Based on an analysis of a small group's discussion about a problem-solving task, this study shows that the temporal or sequential dimension is also essential for understanding the content and relational dimensions of the interaction. One problem indicated is the discontinuity between interaction moments; thus, bridging episodes of interaction is important to maintain continuity of the discourse, both in epistemic and relational terms. The sequential relationship of the utterances is important to establish the elements of interactions that are past, present, and future situated. Interestingly, Krange (2007), in a study of secondary school students' disciplinary interaction, not only arrived at the same conclusion, but even used the same notions to indicate the importance of the temporal aspect. In the context of groups solving a problem concerning genome sequencing, the concept of participation trajectories was introduced as one aspect of the interaction indicating temporality (see also Furberg & Ludvigsen, 2008). Krange focused on analyzing bridging at the content level within the span of the same interaction episode. Her conclusion was that the way students

engaged in participation trajectories over time influenced both their content-related interaction and their interpersonal relations.

Another relevant line of research consists of studies of computer-supported, collaborative, virtual math learning. The main aim is to understand how students solve problems together by building knowledge through discursive interaction. These studies emerged from the notion of group cognition (Stahl, 2006), and were conducted by Stahl and collaborators (see Stahl, 2009). This notion attends to intersubjectivity in the context of learning in collaborative settings. As stated by Stahl (2009), this conceptualization emerges as a reaction to reductionist views of learning, which despite the social orientation, "still maintain a psychological focus on the individual mind in their empirical studies" (p. 556). Accordingly, processes of building knowledge or collaborative problem-solving cannot be reduced to a sequence of contributions from individual minds. Essentially, intersubjectivity is here constructed through the group discourse. Stahl (2006, 2009) emphasizes the necessity and importance of an in-depth analysis and understanding of learning at the level of the group, and makes a comprehensive case for the study of discursive interaction as the main engine behind the collaborative construction of knowledge. The empirical work underlines the importance of the small group as unit of analysis and its substantial contribution with regard to analytic methodologies and design for small-group learning.

The most relevant empirical studies were conducted in the Virtual Math Teams (VMT) project or affiliated contexts. The findings contribute to an argument that re-conceptualizes collaborative problem-solving. A number of the studies dealt with the notion of *proposal* and how that influences or contributes to the groups' work. Proposals can lead to group actions aimed at clarification of deictic (linguistic) references, then to the discussion of a topic that eventually becomes shared by the entire group (Stahl, 2009). Sarmiento-Klapper's (2009) analyses showed how the proposal can function as a conceptual bridge (in time or between teams), and contributes to the sequential creation of a joint problem space; this space allows for further discussion of shared content across a longer time span. The way groups dealt with conflicting proposals (Toledo, 2009) unveils aspects of negotiation, and points to disagreement and tension as eliciting productive discourse. Stahl (2009) maintains that proposals contribute to a group's object orientation, with mathematical objects being the topics that are negotiated and co-constructed throughout the temporality of the discourse based on different individual contributions. In addition, proposals were considered to introduce a temporal structure by triggering various responses, uptakes, elaborations, or even new proposals (Çakir, Xhafa, & Zhou, 2009; Fuks &

Pimentel, 2009; Wee & Looi, 2009). Stahl also introduced the idea of mathematical object. The object can range from a mathematical sign (Medina, Suthers, Vatrapu, 2009), to an idea generated through a proposal (Fuks & Pimentel, 2009), to a visualization created by technological means (Çakir, Xhafa, & Zhou, 2009; Charles & Shumar, 2009). These objects are more tangible than a problem, and are created, maintained, and transmitted through discourse. In essence, the problem-solving process is a process of handling these objects, by adjusting and modifying and by adding content.

To sum up, these studies are important because of their detailed accounts of interaction and their accurate depictions of the processes taking place. However, a comprehensive approach that takes into account the complexity of the process, its dimensions (epistemic, social-relational, and temporal), and their dynamics, is necessary. The studies discussed above depict some of these aspects, but further in-depth empirical studies are needed to gain insights into how these dimensions are interconnected, how the intersubjective space is created and used, and how that leads in time to particular actions and outcomes.

3.3 Pedagogical models

3.3.1 Problem-based learning

Problem-based learning is an instructional, learner-centered approach in which students learn by conducting research, integrating theory and practice, and applying knowledge and skills to generate a solution (Hmelo-Silver, 2004; Savory, 2006). This instructional approach was elaborated within medical education learning. It is opposed to teaching isolated domain content through lecturing methods and emphasizes self-directed experiential learning around the investigation and resolution of ill-structured, authentic problems (Hmelo-Silver, 2004; Savory, 2006). Mandatory elements of a problem-based learning situation are: ill-structured open-ended problems, usually identified and defined by the tutor; space for free inquiry; self-directed activity and engagement from participating learners; a collaborative setting; and a tutor who facilitates the process and models the reasoning (see Hmelo-Silver, 2004; Hung, Jonassen, & Liu, 2008; Savory, 2006). The roles of the problem as trigger for inquiry, of the tutor as facilitator, and of the collaborative setting as an arena of distributed knowledge and resources are essential (Hmelo-Silver & Barrows, 2006; Hmelo-Silver, 2004).

Most of the recent studies on problem-based learning were conducted within medical education, many focusing on the efficiency of the method in comparison to traditional instruction methods (see Hung, Jonassen, & Liu, 2008; Strobel & van Barneveld, 2009), and some focusing on the mechanisms of the problem-solving process itself (Hmelo-Silver, 2003; Hmelo-Silver & Barrows, 2008). The latter studies focused on interactional processes, with knowledge artifacts (e.g., visual representations of ideas, concepts, and phenomena; concept maps; flow charts) as mediating elements. In two mixed-methods studies of medical students' technology-mediated collaborative learning about clinical trials, Hmelo-Silver (2003) analyzed how technology mediates the interaction, and how a student-generated representation not only mediates but also triggers and sustains the collaborative construction of knowledge. The findings show that, while the prompt to generate a representation of the problem was given by the teacher, once students represented the knowledge that had been discussed in the group, they created, took ownership, and employed this representation in an optimal manner. Hmelo-Silver and Barrows (2008) analyzed a problem-based learning activity with a focus on how second-year medical students and their tutor engaged in knowledge building. The study conceived the causal explanations produced as conceptual artifacts, and also paid attention to how various artifacts, e.g., drawings, mediated the discourse. The findings show that students engaged in the knowledge-building discourse by reacting to and modifying each others' ideas, negotiating the emerging ideas, and using drawing as a tool to mediate their discourse and increase understanding of the problem. The detailed analyses also identified particular discourse moves that were associated with the knowledge-building discourse, but only incidentally. While the study also points to the students sharing responsibility and making collective efforts to enhance the group's understanding, it seems this was often triggered by the facilitator's questions.

3.3.2 Project-based learning

The project-based learning approach is a model stemming from the situated cognition idea, and was developed by Kraijck and Blumfeld (2006). The core ideas are to engage students in pursuing projects that involve the real-world activities of experts, with a clear, shared goal. Learners are usually provided with specifications for a desired end-product, and the guidance is more oriented toward particular procedural aspects. The assumption is that students achieve a better understanding of knowledge and materials when they actively construct their understanding through involvement in projects. The outcomes

are better defined in this case than in the problem-based learning model. Engagement and management of the process are important elements of the activity.

The project-based learning model has been employed in various contexts. In higher education, in recent years, carrying out customer projects is emerging as a practice, especially in business, engineering, and design studies (e.g., Denton & McDonagh, 2005; Seitamaa-Hakkarainen, Lahti, & Hakkarainen, 2005). Prior findings have suggested that interdisciplinary or multi-professional learning is argued to amplify relational, mediated, transformative, and situated dimensions of learning and creativity (Latucca, 2002). There is, however, a need for more clarity about how employing the model with the additional elements of the external customer requirements contributes more engagement, more advanced skills, and deeper inquiry. In relation to measuring learning gains, Bucciarelli (2003) criticized educational practices for reducing knowledge to static, distributable entities, where problem-solving usually takes place in a linear, unambiguous, and de-contextualized process. On the other hand, reflections based on research findings (Muukkonen & Lakkala, 2009) point to the distinct features of highly challenging situations for students when engaged in such distributed projects. They need to manage and generate their own activities in teams, which may be especially difficult when also having to deal with a customer. In Stankovic's study (2009), students experienced that accountability and time management are important and difficult to achieve. Furthermore, undertaking a complex process of collaborative design is likely to be accompanied by feelings of ambiguity and uncertainty among the participants (Dym et al., 2005). From the point of view of learning approaches that especially emphasize knowledge building, creation, or construction, and attempt to support processes involving these, this model has to withstand questions regarding its focus on procedures and rather clearly established steps and outcomes, which allegedly leave less space for inquiry and original contributions.

3.3.3 Inquiry-based learning

The inquiry-based model is considered a pedagogical model that stimulates learning of "content, strategies and self-directed learning skills through collaboratively solving problems, reflecting on their experiences, and engaging in self-directed inquiry" (Hmelo-Silver, Duncan, & Chinn, 2007, p. 100). From an epistemic perspective, inquiry is characterized by a question-driven attitude and process of understanding, and relies on constructing evidence-based arguments (Hmelo-Silver, 2004). The aim of the inquiry is to explain the investigated phenomena through a deepening question-explanation process, in

which participants share their expertise and build new knowledge collaboratively. One variant applying the inquiry-based learning principle is the progressive inquiry model (Hakkarainen, 2003), which builds primarily on the interrogative aspect of scientific inquiry (Hakkarainen & Sintonen, 2002), the knowledge building approach (Scardamalia & Bereiter, 2003), and concepts of distributed expertise in communities of learners (Lave & Wenger, 1991). It represents an instance of how inquiry-based learning is translated into small-group learning situations, and emphasizes creating knowledge artifacts as part of the inquiry process and product. The model specifies particular epistemological processes characterizing the way a community goes through inquiry, in collaborative terms, and the cyclic succession of the steps involved. The core features of the cyclic succession of steps typical to this model (Muukkonen-Van der Meer, 2010) are the following: the process builds on the expertise distributed among the community members; it anchors into the central principles of the domain; the problems and the questions are generated by learners themselves; learners use their background knowledge to create explanations; the explanations produced are analyzed and assessed critically; learners are encouraged to engage in deepening knowledge; general questions are elaborated into subordinate questions; and the knowledge produced is shared with the community, to serve the purpose of further elaborations.

In principle, most empirical studies of progressive inquiry were aimed at investigating the deeper processing of scientific knowledge and how students make sense of concepts (Hakkarainen, 2003; Veermans & Lallimo, 2007), the self-regulation of inquiry and students' engagement (Mukkonen, Lakkala, & Hakkarainen, 2003), and how the inquiry process can be scaffolded in such a way that it enhances students' learning (*M*uukkonen, Lakkala,& Hakkarainen, 2005). Fewer studies considered the knowledge creative part of the process. In a study of undergraduate students' project work, Mukkonen, Lakkala, Kaistinen, and Nyman (2010) looked in depth at the type of inquiry associated with collaborative work in small project groups. The type of inquiry identified, in addition to project-related work, was labeled as epistemic (see also Muukkonen & Lakkala, 2009), emphasizing advancement in understanding, collaborative design, and versioning of shared objects. While this type of inquiry was present, the authors concluded that the pragmatic aspects of project work prevailed due mainly to students' perception of project work and the rather indistinct type of scaffolding of inquiry work. Two other studies by Muukkonen and colleagues (Muukkonen & Lakkala, 2009; Muukkonen, Lakkala, & Paavola, 2011) focused to a greater degree on inquiry processes that involved the creation of shared knowledge

objects. The analyzed skills appeared to be characteristic of knowledge creation and the creation and advancement of shared objects. Differences between the analyzed groups indicated that the knowledge-creative inquiry proved difficult for the students, and that only one group performed epistemic actions: monitoring and redirecting the inquiry discourse toward the shared object; a higher level of awareness of the collective goals and activities; and critical reflection on products and their own actions. The second study, too, showed variation in how the participating groups managed the inquiry directed at creating the shared objects. The inquiry model appeared to support the object advancement, but both participants and researcher concluded that more support and clarity at the level of epistemic work are needed.

The discussion of these pedagogical models serves both review and methodological purposes. Primarily, the conceptualizations of learning posed by these models allowed an understanding of the process as applied in concrete settings. These insights supported decisions especially regarding the pedagogical designs used in this dissertation. More specifically, the ideas of students working on ill-structured, open-ended problems, which are solved in collaboration and in the context of self-directed activities, build on the problem-based model. Solving these problems through questioning, searching for information, researching and testing alternatives, discussing solutions with peers, and adjusting and revising results, draws upon input from the progressive inquiry model. A project set-up involving certain steps, process regulation by the group itself, a facilitating role of the teacher, and involvement of external customers are features characteristic of the distributed project-based model. All of these features are combined in a design that is intended to stimulate and support groups of students to engage in an inquiry-like process, which requires active engagement and participation, and which aims at co-constructing knowledge that is materialized into shared knowledge objects. The centrality of these objects conveys to this scenario a different specific and degree of novelty, beyond the simple combination of features from the three models above.

4 Methods

In this chapter, I present the research approach and methods employed, as well as the empirical settings, for the four studies. The complexity of learning conceived as a process of collaborative construction of knowledge requires methodologies that permit in-depth investigation and provide substantial input for interpretation, thereby justifying the implementation of design-based research and the use of case study methods. In this chapter, this justification is discussed, along with the decision to base the data collection and data analysis on assumptions underlying the qualitative paradigm. Next, I present the context, settings, and pedagogical design employed in the empirical work, which was conducted in five higher education courses. Within the context of the case studies, various data types were collected, ranging from interaction data to knowledge objects. These data were primarily analyzed using qualitative analytic procedures; i.e., interaction analysis and qualitative content analysis. The rationale behind the analytic procedure and the construction of the instruments is explained based on the general methodological approach used in this dissertation. Finally, I account for the quality of the research by discussing the quality of the methods and procedures as well as aspects of research ethics.

4.1 Methodological approach

The choice for the mainly qualitative research methodology was determined by the complexity of the processes investigated and the need for an analytic approach that allowed in-depth examination of these processes. Most studies on collaboration employ quantitative measures focus on the relationships between different variables and take a normative stance regarding the performance of individuals in collaboration settings. As opposed to studies that attempt to make generalizations based on the classic criteria, in-depth studies of specific types of collaborative learning are of seminal importance. The approach adopted for exploring new the co-construction process required the implementation of iterative, smaller scale studies to understand how particular ideas work in the reality of learning practice.

Lastly, detailed and in-depth analyses of interaction and the interconnected aspects investigated in this dissertation (e.g., knowledge objects and interaction trajectories) were employed to understand how these play out in practice.

4.1.1 Design-based research

Achieving the aims of this dissertation required the design and implementation of pedagogical ideas and models that support collaborative learning through the co-construction of knowledge objects across time and space. For this purpose, an expansive version of the design-based research method (DBR) was employed (Brown, 1992). DBR involves educational researchers going into the field to conduct their investigations as opposed to studies carried out in laboratory settings (Sandoval & Bell, 2004). It contains methodological principles for designing and examining learning settings that are presumed effective but are often overlooked or not examined in-depth, especially when summative aspects prevail in research studies (Wang & Hannafin, 2005). This methodology focuses on examining educational practices by iteratively designing interventions or pilots, examining their appropriateness, identifying constrains and limitations, and redesigning the future iterative cycles. This is one of the core ideas of DBR, which combines its iterative character with the capacity to modify the intervention when it requires improvement. DBR is not only useful for formative research based on theoretical principles (Collins, Joseph, & Bielazyc, 2004), but can also be used to combine the theory-driven design of learning with empirical research, leading to an understanding of how these applied models work in educational practice (Sandoval & Bell, 2004).

While design-based research is an appropriate approach for this dissertation, given the use of sociocultural ideas as the starting point for this investigation, it is important to discuss how the design-based research has been employed,. Critics of DBR have pointed to some weaknesses of the method, such as rather a vague unit of analysis, a predefined intervention strategy, and acceptance of a variable-oriented approach (Engeström, 2008). Krange and Ludvigsen (2009) add that the institutional level (including curriculum, norms, and standards) or the way that learning processes are organized and unfold over time and across spaces are important as well. They claim that understanding the knowledge construction that takes place through interaction necessitates a design that spans time and space as part of a historical line of development and of various institutional levels. Sandoval and Bell (2004) point out that little is known about how to coordinate across levels or how to involve key variable in the interpretation and understanding of the process. I adhere here

with the viewpoint of Krange and Ludvigsen (2009) in that the design-based research method, as developed and employed in the decade after Brown's (1992) innovative research agenda, restricts to some extent the design and the study of learning to the classroom setting.

The research design used in this dissertation has attempted to overcome this limitation. In accordance with the sociocultural stance, the focus of study is the interaction/action revolving around knowledge objects and mediated by tools, as well as how it unfolds over time (Valsiner & Van der Veer, 2000; Wertsch, 1991). Therefore, the designing of the learning scenarios (see section 4.2.1) involved aspects of context, mediation, temporality, and space. Learning activities were considered as occurring in a sequential fashion and emerging in subsequent instructional and interaction moments, which needed to be embedded as part of a trajectory. By using the design concept of a distributed project work, learning was considered to occur in various settings and contexts. The institutional aspect also received attention in the design process, which was organized based on information regarding the place, role, and curriculum of the educational unit (course); the existing instructional and evaluation strategies; institutional norms; and the teachers' views. In fact, it went beyond simply acknowledging the institutional aspects by involving teachers in the design process.

Another important characteristic of DBR is the progressive refinement of the design; i.e., the iterative nature of the development and implementation of the learning model envisioned. Design ideas and solutions are strongly based on prior research and theory, and the iterative approach allows one to adjust and tailor these solutions to the learning situation to gradually improve the design and to feedback into the theory. In the case of this dissertation, the iterative approach offered an appropriate solution, since it allowed for emerging and developing design ideas to evolve throughout several iterations. The framing concepts elaborated upon in the theoretical framework (Chapter 2, section 2.2) provided the starting point for the design process. These ideas needed to be translated into pedagogical design principles, which required a sequence of iterations that led to their refinement. Additionally, the iterative nature of the methods allowed for an empirical investigation of how ideas for a new learning model work in practice. Designing learning for knowledge co-construction based on sociocultural ideas and related notions involved investigating learning situations that have not been focused on in similar research. This meant exploration of new ground, sometimes making mistakes that needed to be corrected during the process, and the adjustment of design details between the iterations. All these aspects had further implications for the way the empirical investigation was set-up, for the

analytic procedures and the interpretation of the data, and how they contributed to the following iteration and theoretical elaboration.

4.1.2 Case study

The design-based research approach was used as an overarching methodological framework. Within this framework, the iterations of design and empirical studies were carried out as case studies (Yin, 2008). Although case study research has a rather long history, the way the case study is conceived as a research method is not completely straightforward. According to Yin, a case study is "an empirical inquiry that investigates a contemporary phenomenon within its real-life context" (2003, p. 13). According to Johansson (2003), it may be a relatively bounded object or a process, it may be theoretical, empirical, or both. At a minimum, a case is a phenomenon that is specific to time and space. In case study research, the problems examined are typically open-ended, allowing for the investigation of complex (social) phenomena and for the characteristics of authentic events; it can be iterative in nature and is used to develop theories for poorly defined phenomena.

Case studies also allow exploration of a bounded system, case, or particular event over time through detailed examination and in-depth analysis (Creswell, 2007). They offer the opportunity for multiple perspective analysis. Yin (2003) describes a number of characteristics that are critical when deciding to use case study methodology. Case study inquiry copes with the technically distinctive situation in which there are more variables of interest than the data indicate; relies on multiple sources of evidence (e.g., documentation, interviews, and artifacts), with the data needing to converge in a triangulating fashion; and benefits from the prior development of theoretical propositions to guide data collection and analysis.

In this study, the design-based research approach and the use of scenarios allowed for a description of how the theoretical ideas were translated into a pedagogical model, how these were refined, how they evolved throughout the iterations, and how they contributed to theory development. In addition, the case study design can explain aspects of the research design related to data collection and analytic procedures and how these were applied in order to capture the complexity of the collaborative process. This dissertation's focus on multilayered processes and activities created the need to examine how the envisioned design worked both at the intricate level of small group interaction and across the various contexts of different courses, institutions, and subject domains. For this purpose, a multiple case approach was employed (see Yin, 2003), which is particularly relevant to the examination of

an environment where the boundaries between the phenomenon of interest and context are not clearly evident. It also allows one to identify and investigate phenomena that appear similar across specific contexts. In this dissertation, I used the multiple case approach by capitalizing on the sequentiality of the design iterations. The designing and interpreting of cases in the later iterations were based on the understanding created through the previous cases.

4.2 Empirical context and research design

This dissertation project was partly connected to a larger research and development project, the Knowledge Practices Laboratory (KP-Lab), funded by the 7th European Framework Program (www.kp-lab.org). Participants included 22 institutions, university departments, institutes of technology education, and software development companies across Europe. The aim of the project was two-fold: (1) to design learning settings for higher education and professional contexts for enhancing and supporting learning in collaboration and through joint work on knowledge objects and (2) to develop and implement online applications that support these learning processes. In my dissertation, I have employed some of the main theoretical ideas elaborated upon in the project. In terms of methodology, the choices I made in terms of design, piloting, and implementation, as well as the use of technology, were independent, but they synchronized time-wise with the KP-Lab iterations. The information regarding technology implementation and the data collected and analyzed in this dissertation were also used for reporting purposes in the KP-Lab project. In the sections that follow, I will focus on the particular methods and features employed in the four case studies investigated in this dissertation.

4.2.1 Pedagogical scenario and iterative co-design

This research employed *pedagogical scenarios* as the unit of design. The scenario approached served the translation of theoretical ideas, formulated as design principles, into the pedagogical contexts. A scenario can roughly be defined as a purposeful description of instructional and learning activities taking place in a certain context (Rolland et al., 1998; Wasson, 2007). The pedagogical model described in these scenarios, varying between courses and iterations depending on the subject domain, was devised from the sociocultural ideas of learning, the knowledge-creation metaphor and the three pedagogical models discussed in sections 3.3. These sources led to a set of design ideas and principles that were

implemented during successive iterations and were gradually refined according to the DBR methodology. The following ideas and principles represent the core of this model:

- *Open-ended, complex problems*: instead of lectures and individual assignments, the learning process is organized as a collaborative activity aimed at solving complex and ill-structured problems that requires inquiring actions and generating knowledge as basis for potential solutions.
- Learning through *interaction*: the learning process builds on the sociocultural assumption that learning and development are social processes and that social interaction is the best avenue for the co-construction and advancement of knowledge.
- Focus on *shared knowledge objects*: knowledge objects materialize the knowledge co-constructed during the process; they can also play a mediating role through which they trigger and direct the interaction.
- *Sustained and longstanding* pursuit of knowledge advancement: the co-construction of knowledge is sequential and takes place across long spans of time.
- *Eliciting agency*: the participants' active engagement and collective responsibility for their own learning is important for participation in a longstanding collaboration;
- Engaging in *distributed projects*: this engagement allows the process to be built on the knowledge situated at different sites, both within the institutionalized context of the course and outside of it.
- *Flexible technology mediation*: this mediation scaffolds collaboration and collective knowledge construction.
- *Teachers' role*: throughout the learning process, the teachers' role is to provide support on an as-needed basis.

Each design iteration roughly followed the same phases (see Edelson, 2002): (1) problem identification, through discussion with participants from the field (i.e., teachers or educational program leaders); (2) problem description, based on problems and context analysis; (3) (re-)design of the pedagogical scenario, based on elaboration and refinement of design principles (and technology requirements, in the case of the KP-Lab work); (4) implementation through translation into the educational practices; and (5) evaluation of the model, from both a research and an educational practice perspective.

In the design process, the learning and instructional settings, the direct beneficiaries of the learning model, teachers, developers of technology, and researchers are bound together in a process that requires active participation and long-lasting engagement (Barab

& Squire, 2004). The DBR method offers a solid basis for creating a viable model that takes into account not only theoretical prescriptions, but also participants' views. The success of any research-based model depends on the participants' understanding and enactment of the scenario, materials, and approaches. In the case of this dissertation, the new and complex learning model required a complete buy-in of the participating teachers. I accomplished this through co-design (Penuell, Roschelle, & Shechtman, 2007), where designs were developed in close collaboration between the researchers and the participants. This is a team-based process in which teachers and researchers work together to design an educational innovation, realize the design in one or more prototypes, and evaluate each prototype's value. In this dissertation, the teachers participating in the research were involved in the design process to a varying extent.

4.2.2 General description of iterations

The development of the scenarios took place in iterative cycles. Through these iterations, based on theoretical insights, findings from the previous iterations, and negotiations among the participants involved in the process, the design principles and ideas were refined and improved. The three iterations included in this dissertation are described below, as well as in Table 1 in combination with information concerning the settings and participants in the empirical studies.

Iteration 1. This iteration had an explorative nature since it was primarily aimed at examining the existing learning practices. The existing pedagogical design used in the educational and instructional design course in which Study 1 was implemented was adjusted only to a small degree. Namely, the adjustments involved the following: the task was open-ended, complex, and ill-structured; the collaborative process was introduced as a concept, but no specific support was provided in this direction; the existing technology, as provided by the institution, was a course management system that provided rather limited support for collaboration; lectures were combined with small group collaborative projects; and the teacher had a coaching role.

Iteration 2. In this iteration, the scenario of a research course was refined based on the findings of the first iteration and the problem analysis conducted within this course. In reference to the first iteration, the following aspects were emphasized: the distributed project notion was introduced and external clients were invited to present problems and situations that could become potential research problems; groups had the opportunity to analyze the problems and discuss them with the clients before the research problems were

formulated; the teacher initially had a mediating role between the groups and the client and then transitioned into a coaching role; the same type of technological support was provided as in the first iteration, but each group had a "collaboration" folder at their disposal for uploading materials; and at the end of the course, each group presented their final research report to the client and their peers.

Iteration 3. The third iteration lasted for two semesters and took place in a teacher training institution. Extensive attention was paid to introducing teachers and students to the concepts of object-oriented collaboration and online technology since feedback from the previous iterations indicated these as important. The scenario was adjusted and refined, and in addition to the features from the previous iterations, the following aspects were added: a pilot study was set-up through the period of the first semester with a limited number of students; teachers were organized into a project design team, which met with the two researchers biweekly to discuss, redesign, and adjust the pedagogical scenarios; workshops that introduced the object-oriented collaboration, distributed project work ideas, presented the new technology, and provided hands-on training sessions with the technology were organized for teachers and students; and the first meeting of each course included brainstorming sessions in which students presented and discussed topics or problems collected from their internship places. In this iteration, after the pilot phase, the scenario was implemented at a larger scale in the second semester (in three courses) following the same procedure.

In all studies, I developed the design structure; in the third iteration, this development was done in collaboration with another researcher, who focused on the teachers' activities. The initial iteration was more explorative, and the co-design involved consultations with the teachers but no intensive collaboration regarding the design work. In the second iteration, I started the project by recruiting participants, presented the research project to all the participants involved, and mediated the activities. The teacher provided the two clients and contributed to the design. In the third iteration, the participating teachers filled design roles equal to those of the researchers. In addition, students' input and critical reflections regarding the design and use of the technology were taken into consideration during subsequent iterations.

4.2.3 Settings and participants

The empirical investigation in this dissertation was set-up and conducted within the context of five higher education courses. Of the studies discussed here, Studies 1, 2, and 3

took place in a university program, while Study 4 was conducted at an applied sciences university; both of these institutions were located in the Netherlands. All participants were students enrolled in the study programs at these institutions. In Studies 1, 2, and 3, the students participated on voluntary basis, following a request for participation by the researcher. In Study 4, the institution decided which courses (and the students enrolled) would be involved in the research project. After being informed about the purpose and content of the project, the procedures, and the data requested, all students were asked to sign an informed consent (Appendix 1), and only those who consented in writing were part of the data collection. Table 1 presents an overview of the iteration, settings, and participants.

Study 1 (first iteration) was set-up in the Educational and Instructional Design course, within the Educational Science bachelor program at the university. This was a 10-week course offered during the second program year. The aim of the course was to familiarize students with the major theories and methods of instructional design and to provide them with a context in which to apply this knowledge. The course included a collaborative design project, lectures about design theories and methodology every second week, and face-to-face, on as-needed basis, coaching sessions with the teacher. The design project required groups to create an instructional design product for (by preference) an external client and a group justification report. I followed four groups of students collaborating on their instructional design projects, and for the purpose of Study 1 I analyzed in-depth data from two contrasting groups (see Study 1 in Part II of this dissertation).

Studies 2 and *3* were devised based on the second iteration, in the context of the *Bachelor Thesis* course, a research course in the same Educational Science bachelor program. This is a 20-week course offered in the third and final year of the program. The aim of the course is to support students in integrating and applying previously acquired scientific research knowledge and skills, by setting-up, conducting and reporting on a research study. Students were also required to regularly write short reflection texts on their performance and experiences with doing research. There were 120 students enrolled in the course, with a team of teachers coordinating the activities and coaching the groups. Fourteen of these students signed-up based on a call for participation in which I presented the purpose, context and procedure of the study, and the topics brought in by two external client institutions. They formed five groups, by signing up for research topics brought in by two companies for educational consultancy.

Table 1: *Overview of iterations, settings and participants*

Study	Type of study	Research focus	Course title(s)/ Course focus	Duration (weeks)	Participants (N)	Groups (N)	Techn-ology
1	Explora-tory	Shared epistemic agency in interaction and co-construction of knowledge objects	Educational and Instructional design (EDI) / *Development of instructional materials*	10	19 students *(1 teacher)*	4	Black-board®
2	Design based-research	Productive interaction in object-oriented collaboration	Bachelor Thesis/ *Conducting research and reporting in research articles*	20	14 students *(1 teacher)*	5	Black-board®
3		Social-affective aspects of the co-construction process					
4	Design based-research	Epistemic aspects of interaction - development of shared knowledge objects	Learning situations for pupils with disabilities & learning difficulties (PS12)/ *Instructional material*	15	15 students *(2 teachers)*	4	KPE
				15	13 students *(2 teachers)*	3	KPE
			Designing and assessing evaluation instruments (PS11)/ *Analysis and evaluation of instruments*	15	8 students *(2 teachers)*	2	KPE
			Coaching and learning in intercultural contexts (PS5) / *Information material*	15	37 students *(3 teachers)*	10	KPE

In these first two iterations, the *technological support* for collaboration was provided by Blackboard®, an online course management system. The system provided support both for managing the course and making course documents available, but also for within-group collaboration. Course curriculum, objectives and guidelines were posted by the teacher in the virtual course environment, in specific online folders–*Course Documents*, and announcements could be placed in the *Announcements* space. A Discussion *Board* was available for posting and discussing matters relevant to all the participants in the course. For the collaborative work of the groups, separate virtual spaces were created for each group. This space had a *File Exchange* functionality, which allowed group members to upload, download and exchange documents, materials and report versions. A *Chat* functionality was available for synchronous communication. Groups also had access to regular email.

Students were encouraged to exchange ideas, provide feedback, annotate and elaborate on each other's draft.

The third iteration (Study 4) consisted of a one-year study, organized in a teacher training institution at a university of applied sciences in the Netherlands, and included three courses in the bachelor program. This institution offers educational programs for pre- and in-service teachers for secondary vocational education, trainers, and specialists in the green sector. The curriculum is based on courses called Professional Situations (PS), wherein students attended lectures for part of the study time and were conducted individual project in work environments for the remaining time. Three different PS's were included in this research study: 'PS5 - Coaching and learning in intercultural contexts', 'PS11 - Designing and assessing evaluation instruments' and 'PS12 - Learning situations for learners with disabilities or learning difficulties'. At the start of this project, learning in the PSs was organized around a combination of lectures and seminars given by the teachers, and individual student projects or assignments. Throughout the entire project period, a group of eight teachers and 73 mixed-age students, enrolled in the three PSs, participated in the study. In the first phase of the study (*pilot phase*), four groups of 15 students enrolled in PS12 and two teachers participated. Eight teachers and the two researchers, myself included, participated in the same period in project meetings. In the second phase (*implementation phase*), the project meetings were followed up, and 58 students enrolled in 19 groups participated. Figure 1 shows a depiction of activities taking place during this study. The groups of students participating in the study were required to develop and report on knowledge objects, varying based on the subject domain: e.g., didactic or instructional material, study material for teachers, guidelines for applying new teaching or assessment methods, etc. All the projects targeted problems identified by students at their internship institutions (schools, educational institutions, etc.), which represented the external clients in this iteration. These institutions were involved through providing information in the analysis phase and feedback on the final products. Six students were not included for further examination, since their data sets were incomplete.

Figure 1. Types of activities in Study 4

In this study, the web-based application designed and developed in the KP-Lab project was piloted and implemented as the sole technology supporting the collaborative work of the student groups. The Knowledge Practices Environment (KPE) is a web 2.0 application that provides virtual collaboration space, including facilities for organizing collaboration, interacting with each other and working on knowledge objects. The KPE was organized as a set of shared spaces, which are collective workplaces for student groups. Different courses and all materials produced by groups are encapsulated in shared spaces as shown in Figure 2 (left). KPE was mainly used for planning, organizing and structuring object-oriented activities. Each shared space encompasses a workplace for students, which presents them with three views: a process view (a view that supports planning and organizing the process), a content view (which allows creating, sharing and collaboratively editing versions – document, wiki pages, notes, etc.) and a community view (which enable managing the communication within the group). During both the pilot and the full-scale

studies each group of students worked in its own shared space. The tools employed specifically to support collaborative creation of knowledge objects were document versioning and wiki for collaborative text production (Figure 2. right). KPE was mainly used for planning, organizing and structuring object-oriented activities.

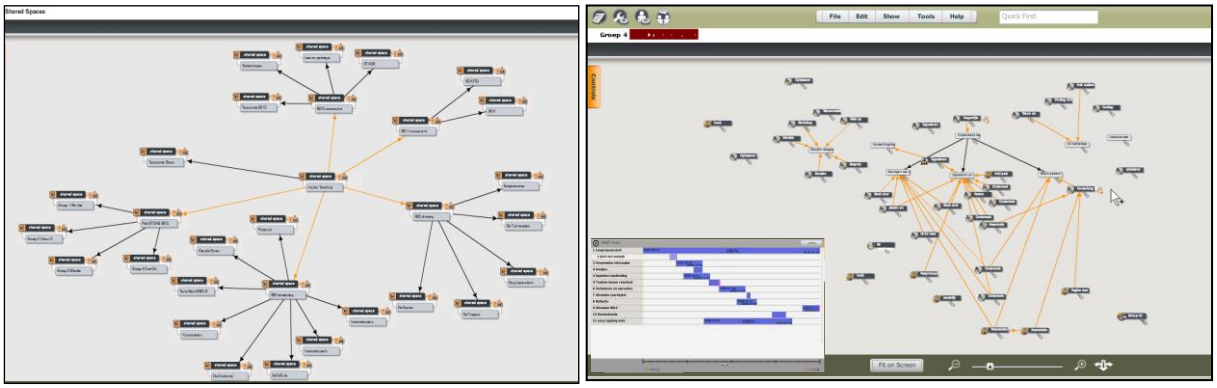

Figure 2: *Shared spaces in the KPE*

4.3 Data-collection

Designing a data collection strategy in a way that will capture the complexity of the collaboration process in focus is a challenging task. While designing instruments for data collection before the actual collection activities begin is valued by some research approaches, other researchers suggest that it is not possible to specify all the details of the process in advance because of the emergent nature of the processes under investigation and the importance of the context (Patton, 2002; Engeström, 2008). The DBR method also offers the opportunity to adjust the scope of the sources of evidence in order to better capture the complexity of the phenomenon and of the intervention. The essence of case study methodology is the combination on different levels of theories, techniques, methods, and strategies (Johansson, 2003). It also allows just one or several cases to be studied by means of an indiscriminate set of methods and procedures. The combination of multiple data sources and the accumulation of evidence through different iterations were the main strategies for capturing the complexity involved in this study (Creswell, 2007; Yin, 2003).

4.3.1 Procedure

The data collection activities were intertwined with the introduction of a new design at each of the investigative sites. Based on a protocol that was also intended to ensure the validity of the research, a number of steps were followed when each study was set-up. In

essence, this protocol referred to both the actions to be performed by the researcher and to ethical guidelines. The latter were important due to the fact that I was present at the site not only to organize and conduct research, but also to introduce a new learning model (Studies 2 and 3) and new technology (Study 4), and to assist both teachers and students in findings their way within this new situation. That led to an active role depending on the needs of the participants. Labeled as participant observations (Cobb et al., 2003), this type of observation allows researchers to be more involved in the activities and enables possibilities for perceiving and designing the activities from an insider's perspective (Yin, 2003). My presence at the research sites ranged from 4 hours each week in Study 1 to 3 days a week in Study 4.

In addition to following the general guidelines of data collection procedures, participants were given an explanation of the rationale for providing data each time they were requested to do so. Students and teachers were asked for a great deal of involvement in terms of time and effort, and I therefore believed that they were entitled to understanding the purpose of the research activities they were being asked to participate in; and that I should create a natural environment in which participants could go about their learning activities as naturally as possible.

4.3.2 Description of the data

It is important to mention the multilayered nature of the learning process as conceived here and how the data can reflect that. The main focus of this dissertation was to observe and analyze knowledge co-construction processes at the microgenetic level (see Ludvigsen, 2009). However, because of the multilayered aspect of the process, it is also possible to situate the analysis in the (sociogenetic) context of educational and institutional practices and on a trajectory that emphasizes the temporality of this process. The data collected, in terms of the nature and distribution across the length of the study units, were intended to facilitate zooming in and out across these layers. Following this reasoning, some sources were used to generate the *core data*. This were the recordings of interactions within the groups and the knowledge objects or artifacts produced by each group. These data were the focus of the analysis process and were subject to in-depth analyses and interpretations. These sources were complemented with *secondary data*: observations, group interviews at the end of the collaboration period, individual pre- and post-reflective questionnaires or reports, group e-mails, and log data from the online environment. These data sources were employed based on the rationale that related information can shed more light on processes

and participants' experiences. Finally, course documentation and information about the institutional context was collected as background data.

In addition, collecting different types of data contributed to creating a comprehensive view of the process. Particular types of data reflect particular facets of the process. Therefore, I collected data that reflected what the participants *did* during their involvement in knowledge co-construction; for example, objects (observations of) activities. Also, I collected data reflecting what participants *said* about the activities they were involved in, either during or after (e.g., discussions, e-mails, interviews, and questionnaires). Finally, some data provided a *structural* and more synthesized view of the activities (activity logs). Table 1 below provides an overview of the data collected in this research.

Table 2*: Overview of collected data*

Data types	Data sources	Description	Study 1	Study 2 & 3	Study 4	Status of the data
Interaction data	Video-recordings of group discussions	78 hours in total, capturing groups' discussions and activity during the whole project period.		x	x	Core data
	Audio-recordings of group discussions	184 hours in total, capturing groups' discussions and activity during the whole project period.	x	x	x	
	E-mail corres-pondence	E-mails sent by group members in conjunction with their projects	x	x	x	Supplementary data
Knowledge objects	Object drafts and final object	Versions of the group products, and final objects	x	x	x	Core data
	KPE data: Drafts and final objects	Materials uploaded in groups' virtual spaces			x	Core data
Reflection data	Semi-structured interviews	Semi-structured interviews with group students	x	x	x	Supplementary data
	Reflective questionnaires/ Reports	Individual open-ended questions applied at the beginning and at the end of the project		x	x	Supplementary data
Documen-tation	Meeting minutes	Each group's meetings notes	x	x	x	Supplementary data
	KPE data: Log material	Data generated by the system regarding individual activities			x	Supplementary data
	Participant observation of activities	Researcher's field notes		x	x	Supplementary data
	Design documents	Knowledge objects produced by the teacher team			x	Background information
	Course documents	Materials on aims, methods, assessment criteria	x	x	x	

Interaction data

The interaction data were gathered for the purpose of creating in-depth depictions of the interaction in small groups and across time. While moment-to-moment interaction does not represent the whole spectrum of activities that constitute object-oriented collaboration,

the details of the interaction are crucial for the reconstruction of this process. They represent the building blocks of this process, and hence, these data are needed to enable analysis. The largest body of interaction data was represented by recordings of the group members' face-to-face discussions, either at or away from the university site depending where the group members met. All group discussions were audio-recorded, and selected groups' meetings were also video-recorded. Each group received an audio-recording device, a demonstration, and verbal and written instructions on how to record their discussions when these took place in the absence of the researcher. Date, time, and the names of the persons present were to be recorded at the beginning of each discussion session. For the video-recordings, I prepared all the recording devices and videotaped the group meetings.

The e-mail correspondence of the groups was collected in Studies 2, 3, and 4. The rationale behind collecting these data was that some of the interactions took place through this correspondence. Also, whether it is only related to regulative aspects, such as managing or organizing project work, or concerns epistemic aspects, e-mail correspondence is temporally structured and allows for a documented way of reconstructing the timeline of the interaction trajectory. Students were asked to add my e-mail address as a CC recipient to all the e-mails they sent to each other or to the teacher in conjunction to the collaborative projects. This resulted in a large database of e-mail correspondence. Each group had one member in charge of the data collection material. This member was responsible for the audio-recording equipment and ensured that if e-mails were forgotten, they would be sent to me at some point in the project.

Finally, I collected my observations of the student groups and of the course activities. I recorded activities when they were deemed important; e.g., the discussions with the clients in Studies 2 and 3 and the brainstorming sessions in Study 4 in which the whole class of students contributed problems and participated in the discussion. The entire set of interaction data was organized per group and chronologically.

Knowledge objects: final products and iterations

The focus was on the knowledge objects constructed within the groups, including all their versions and iterations. The main strategy was to invite students to upload all their drafts and notes in the common virtual space (Blackboard@ or KPE), preferably at the time these drafts were created. In addition, I collected the attachments from the groups' e-mails, which also included various drafts. In Study 1, I collected only the final versions and versions of the knowledge products at fixed moments in time, which I chose based upon

project deadlines set by the teacher. In Studies 2, 3 and 4, I collected all the versions and drafts of the knowledge objects, as well as their final versions. In addition, I collected all the meeting minutes of the group discussions. I organized these materials chronologically in a database. I regularly asked groups permission to compare my database with the materials that they had produced up to that point in order to keep this database updated.

Self-reflective data

The operational aim of collecting these data was to gain material that would provide an insight into the students' experiences with learning in collaboration, as well as their knowledge of and experiences with the use of various (online) technologies for learning. In the end questionnaire, they were asked to share how this learning model and new technology (i.e., KPE) worked for them. The individual reflective questionnaires were presented to the students both at the beginning and at the end of the process. These data were only used reporting on technology use in the KP-Lab project.

Group interviews were conducted at the end of the collaborative projects. All group members participated, and each interview lasted about 45 minutes. In Study 4, an interviewing strategy that used features of stimulated recall was used (Lyle, 2003). The groups were presented with visual representations of their analyzed activities[5] and asked for explanations of these actions or reasons why these actions were pursued. Students were invited to add comments and information they deemed important with regard to the project.

Course documents

To be able to depict the nature of the institutional norms and the characteristics of the context in which these learning processes were organized and took place, I collected data that documented such aspects. In conjunction with the final knowledge objects, I also collected the assessment results for each group product. In Studies 1, 2, and 3, an assessment instrument was created based on the official course requirements and input from the researchers. In Study 4, a new assessment instrument was designed by the teacher team to specifically assess the collaborative co-construction process and its outcomes. The course documents were collected in all four studies and all course curricula materials. Additionally, discussions with the teachers about their views of learning, instructional approaches, and course management techniques completed this set of data.

[5] The representations were generated by the analytic tools embedded in KPE (see Richter et al., 2013).

4.4 Analysis methods and procedure

The choice of analytic methods and procedures was determined by the nature of the phenomenon investigated, the purpose of the investigation, and the type of data gathered. The learning processes designed and studied were complex, rich, sometimes ill-structured, embedded in the institutional context, and had temporal aspects deemed as important. To attend to this complexity, I applied a sociocultural perspective to analyze the participants' interactions and their co-construction of knowledge. This perspective involves three interrelated layers: (1) participants' evolving (individual) understanding of concepts and their use; (2) their social interaction; and (3) the social organization of knowledge in institutional settings (Ludvigsen, 2009). It is important to recognize that acknowledging these three layers serves an analytic function as they are deeply interwoven. To gain a better understanding of these layers, I refer to Linell's (2009) dimensions of interaction: I, you, the object (it), and the sociocultural setting (we). The 'I' dimension involves the individual's development, and it can be related to the layer denominating individual understanding. The 'you' and 'we' dimensions can be associated with the interactional layer, which involves more than one individual participant. 'You' represents the other participants involved in the interaction, which can be more than one individual; in that case, the 'I' and 'you' positions will be alternated during the interaction. 'We' refers to the potential to create knowledge in an interactional setting, with a given sociocultural basis to draw upon. The 'it' concerns the object of the interaction. In interaction, participants coordinate and negotiate *what* to talk about (the content) and *how* to act for achieving it.

Qualitative analysis is another powerful means, with the potential of providing both the appropriate tools for in-depth examination and the input for generating tentative, but explanatory, theories about the investigated phenomenon. In this study, qualitative methods allowed to unveil this richness of the interaction process and to take into account the contextual aspects. Also, these methods are considered valuable to study educational phenomena in novel fields. The data gathered lend themselves to in-depth analysis through such methods since they capture various facets of the collaborative process.

The overall analytic process can be characterized as combining inductive and deductive strategies, with an emphasis on the inductive approach. According to Jordan and Henderson (1995), analyzing data should not be based on predetermined categories; rather, these should emerge through the analytical work. Linell (2009) made this more explicit by

stating that evidence that learning is happening should be sought through understanding the ways in which people engage in collaboration.

Nevertheless, given the substantial body of research on collaboration and dialogical interaction, I also considered it important to build upon this existing knowledge base. Hence, I combined a bottom-up approach that involved relying heavily on the data, with a more top-down approach, in which I used ideas from seminal studies to shape the analysis instruments (see section 4.4.2 below). Furthermore, while I did not have the ambition to use quantifications, I employed descriptive statistics to count some of the interactional data. The main reason for this was to provide an overall view of the actions performed and to be able to create a sequential overview of the interaction moments and their contents (Putambekar, 2013). In the following sections, I present and discuss the way the data were prepared for analysis. Next, I present the analytic methods and procedures, and discuss a number of analytic concepts and the analysis instruments used. Note that in the empirical studies, analytic methods were used in a combined manner. It is only for clarity that I present these methods in separate sections.

4.4.1 Preparation of the data and analytic procedure

The methodological challenges of employing and applying qualitative analytic methods, specifically interaction analysis, and steps in the data analysis have been addressed by Sawyer (2013) and Derry et al. (2010). The main challenges these authors identified when dealing with rich data sets include segmentation and selection of the material. In the following section, I discuss some of these aspects as part of the steps followed to prepare the data for analysis, which roughly follow the procedure described by Sawyer (2013). The data collection process described above yielded a large data set, which required a great deal of *structuring, organizing,* and *documenting,* which was the *first step* in the procedure. This phase started with the logging the content of the recordings (Jordan & Henderson, 1995).

All collected materials were organized at two levels: per group, in a "group database," which included separated folders for each data type (recordings, e-mails, knowledge objects, meetings minutes, questionnaires and interviews, and documentation), and per each mini-database, in which all materials were organized in chronological order and tagged with the date and, when possible, time of the recording and the participants' names. The main aim was to create a clear overview rather than to reduce the amount of data. I used the field notes and the meeting notes to contextualize and construct the sequential structure of the data.

The *second step* consisted of two activities. First, I performed a *rough examination and exploration of the material* by scanning the textual material and by sampling the recorded material. The meeting minutes and field notes were read in detail, and the groups' recordings and group interview protocols were examined through rough viewings of the material. This preliminary examination helped me to identify data that had a potential to contribute to the investigation in this dissertation by displaying relevant sections, general patterns of interaction or knowledge co-construction, and practices that illustrated the complexity and difficulty of the process (i.e., contrasting groups). Second, based on this examination and on my observations during the field trials, I *selected* data from certain groups to analyze in detail.

Following the selection of groups described above, all face-to-face (audio- and video-recorded) group discussions were *transcribed verbatim* as a *third step* in the preparation procedure. A set of transcription conventions was used, which was also used for the presentation of the analyzed excerpts (see section 4.5.1). The focus of the transcription was verbal (communicative) actions, but nonverbal actions relevant to the discussion and the focus of the respective study were also documented; e.g., when participants took notes or typed during the discussion.

The *fourth step* was the *segmentation* of the selected interaction data (transcripts and e-mails) and the related objects. In the course of multiple readings of the transcribed and the other related data, finer levels of detail in the participants' interactions appeared. This approach followed a recursive process that allowed themes in the data to be identified. In other words, I looked for instances that were typical and made these themes that could be used to select and categorize data (Silverman, 2001). Through the examination described above and through a selective use of theoretical insights, I identified themes that related to the nature of the participants' interaction over time; data reduction was the ultimate goal in this phase. The themes signified what was made representative by the participants, but were also viewed from the perspective of theoretical insights selected through review. This examination provided input for the construction of the categories of the qualitative content analysis instrument used and refined in the following iterations (see section 4.4.2).

Following these steps, an *analysis* of the selected excerpts and related data (objects and interview recordings) was conducted depending on the focus of each empirical study. It was conducted by means of interaction analysis and qualitative content analysis. Some descriptive statistics measures were applied in Studies 2 and 4. As a side note, the analytic process started out (as described under the second step) as an open exploration of the

groups' interactions and knowledge objects and ended as a more focused analysis of interaction instances and the related objects. I used the first field trial to explore what was characteristic to the process. This inductive identification of themes for further investigation during the first two rounds of analysis made the following round of fieldwork and analysis more focused.

Finally, in terms of *presenting* the data, I used (as much as possible) a consistent set of terminology. This strategy was applied to the main terms used in relation to the data throughout the studies in this dissertation, as follows:

- *Project period*: this term was used to designate the length of the collaborative projects of the participant groups, varying from 10 to 20 weeks.
- *Session*: this term was normally used for the groups' face-to-face meetings. Such sessions varied from 1 hour to whole-day meetings.
- *Excerpt*: this term was used to represent the transcribed version of the participants' talk and activities.
- *Episode*: this term was used to describe a discrete analytic entity or interaction where participants oriented themselves towards a topic, task, or problem.

4.4.2 Qualitative content analysis

A need arose to create an overview of how the interactional moments could be combined to constitute a complete representation of the interactional process. For this purpose, qualitative content analysis (Mayring, 2000) was used to categorize the interactional data. I adopted the method because of the opportunity it creates to establish links between the original "raw" data and the researcher's theoretical concepts. Usually, in this analytic approach, textual data are segmented and coded following some predefined rules and according to some similar properties. These codes emerge based both on preliminary theoretical ideas and aspects emerging from the data itself. Ultimately, this analysis led to data reduction and identification of key moments in interaction that were inviting for more in-depth analyses.

The way I employed qualitative content analysis followed the conception mentioned above, in which I constructed an analysis instrument based on two sources. One was the theoretical material from knowledge-building studies and other studies of collaborative groups. The review of these studies (Study 1) generated an overview of ideas that inspired the construction of analytic categories. Mainly, the search for categorizations followed the two dimensions identified as important in collaborative processes: the epistemic

(knowledge-related) dimension and the regulative (process-related) one. Based on the review findings, a number of categories were identified. The other source was the data set in Study 1. Data identified as relevant were subject to categorization rounds using an emergent coding technique (Stemler, 2001). This strategy was applied to various sections of the selected interaction data of two collaborating groups. The unit analysis was not each individual utterance, but rather what was identified as mediated action moments in the interactions (Wertsch, 1998). Based on recurrent coding, the set of categories was adjusted and further refined.

Table 3: *Instrument for qualitative content analysis*

Dimensions	**Categories (of actions)**	**Actions**	**Description**
Epistemic	*1) Creating awareness*	Identifying focus	Naming the topic, subject, concept, discipline etc., that represent the project focus
		Stating problems	Naming difficulties that impede the group from finding a solution to the problem they are solving or from elaborating on the solution they are working on
		Identifying lack of knowledge	Identifying gaps and missing knowledge in relation to various aspects of the problem or of the solution
	2) Sharing knowledge	Sharing information (from sources)	Informing other members about sources of information
		Sharing knowledge from sources	Informing other members about the content of information sources and their possible use
	3) Creating shared understanding	Creating explanations to concepts or ideas	Explaining concepts or ideas using definitions and knowledge from sources
		Structuring new concepts/ ideas	Organizing concepts or ideas the group is discussing
		Problematizing	Questioning understanding and explanations of concepts/ideas
		(Re)framing problem/focus	Reformulating focus or problem
	4) Generative collaborative actions	Generating new ideas	Bringing in ideas that can contribute to solving the problem or elaborating the solution
		Negotiating new ideas	Constructing arguments in favor of the ideas brought in or challenging other group members to do so
		Idea up-take	Building up on own other members' argument in order to provide explanations and elaborations
		(Co-)elaborating concepts/ideas	Formulate explanations, arguments, illustrations, or provide examples for the ideas discussed
		(Constructive) use of feedback	Use feedback provided by other group members or the teacher to elaborate on ideas
Regulative	*5) Regulative actions*	Planning: define goals and create joint plans	Formulating goals for the group project activities, and creating a plan of activities together
		Coordinating process	Organizing activities within the group, dividing tasks, and assigning responsibilities
		Monitoring process and object progress	Checking on the status of tasks that must be fulfilled and others' contributions
		Reflecting on individual and collective actions	Discussing about the progress of the group work and members' participation
Other		Other types of statements	Engaging in social talk unrelated to the task

The segmentation and coding procedures were conducted using ATLAS.ti (Muhr & Friese, 2004). Interrater agreement measures were calculated using sample coding by an independent researcher. The resulting instrument (Table 3) was further refined using data from Study 2, with a 0.90 Cohen's Kappa interrater agreement. This was also employed in Study 4.

Lastly, to examine the content and elaboration of the knowledge objects, a set of categories indicating the integrative complexity of elaboration was used in Study 4. The purpose of this analysis was to establish how the knowledge discussed in the interaction was elaborated in the knowledge object content. The instrument we devised was based on the categories of integrative complexity (Cummings, Schlosser, & Arrow, 1996) with revisions inspired by the knowledge development theory measures described by Chernobilsky, DaCosta, and Hmelo-Silver (2004). The following four categories for determining the degree of elaboration were employed: (0) the idea or concept was *not taken up* in the subsequent discussions and object iterations; (1) *no integrative complexity* content was constructed, and information was (literally) taken over from one or more sources, without generating any new ideas (comparable to *telling* by Bereiter & Scardamalia, 1987); (2) *moderate integrative complexity*, different perspectives were expressed based on information sources and one's own insights but without new conceptualizations and sophisticated connections between concepts and ideas (*elaborated telling*); and (3) *high integrative complexity* specified a dynamic relation between perspectives, including integration of source-based knowledge and information and one's own ideas and interpretations, which can lead to new conceptualizations (*transforming*).

4.4.3 Interaction analysis

The purpose of the analysis was to use the interaction between the participants the starting point for exploring *their* participation in the interaction and *their* conception of knowledge and knowledge objects under co-construction. I employed interaction analysis to attend to these aspects. Interaction analysis, rooted in ethnomethodology, conversation analysis, and discourse analysis, is defined as an interdisciplinary method that "investigates human activities such as talk, nonverbal interaction, and the use of artifacts and technologies, identifying routine practices and problems and the resources for their solution" (Jordan & Henderson, 1995, p. 39).

To start with, interaction analysis bases theorizing about knowledge and practices in the naturally occurring everyday interactions and in time and space. It focuses on the nature

and details of the verbal (dialogical) interactions between participants in collaborative work, which allows interaction to be situated in the authentic context of its occurrence. Furthermore, not only does it unveil moment-to-moment interaction, but it also allows following the way these moments build on each other in time. Second, and important from a sociocultural viewpoint, interaction analysis takes into account not only verbal talk, as talk during an interaction, but also participants' engagement with objects and artifacts. This enriches the interpretations since an interaction and the processes related to it (such as the co-construction of ideas, artifacts, and objects) are influenced by the mediating tools and objects involved (see Wertsch, 1991). Third, interaction analysis combines micro-level analysis with the use of an ethnographic type of data, which constitutes the basis for providing "thick descriptions" of activities (Geertz, 1993, p.15). This facilitates the understanding of how micro-level activities are part of locally situated contexts and institutional practices (Linell, 2009). Finally, interaction analysis can function as a flexible analytic framework that allows one to tackle both the content (as in knowledge) and the linguistic aspects of the interaction. For this study, I used the method in such a way that it captured the knowledge content of the interaction in *epistemic* terms (Studies 1, 2, and 4), but also the language mediated the interaction or contributed to it (see especially Study 3).

Interaction analysis was used in such a way that it allowed the combining of analyses and interpretations with other methods, namely, qualitative content analysis (see section 4.5.2). Once relevant episodes of interaction were identified through the content analysis, and these were taken up for further analysis. Also, to depict the phenomenon occurring in the data as accurately as possible, I employed a two-step analytic approach, consisting of the *first-* and *second*-level analysis (Linell, 2009). The *first order* analysis involved mapping what the participants did during their interactions without making interpretations from an analytic perspective. This analysis was done by describing students' actions as well as identifying the type of actions and how they fit in the larger scheme of the interaction process. The *second order* analysis served the purpose of systematically interpreting the participants' (verbal) actions from the point of view of the aims of the study and from the theoretical perspectives. For each excerpt analyzed, the interpretation was summarized and discussed in a separate section. This approach prevented biased interpretations from interfering with the participants' actions.

In order to capture the specifics of each interaction aspect in the separate studies, I used different strategies for generating the interpretations. In Studies 1, 2, and 4, the interaction analyses built on the qualitative analysis that depicted the knowledge co-

construction process in terms of epistemic and regulative actions. This was used as starting point to examine different facets of the knowledge co-construction process in-depth, such as the agentic aspect and how students pursued that knowledge collaboratively, in Study 1; the productive aspects and the multilayered nature of the process, in Study 2; and the co-constructive aspect, or how objects emerged and evolved through the interaction, in Study 4.

In Study 3, I used a different interaction analytic strategy by using *empirically sensitive concepts* (Hammersley & Atkinson, 1995), such as orientation, elaboration, and confirmation. The concept of *orientation* denominated what students were discussing, whether the talk was about the concepts belonging to the knowledge domain or whether they were navigating the social-regulative aspects of the interaction. The concept of *elaboration* depicted the way participants followed up on their orientation. In other words, how they acted and interacted: they elaborated on concepts, ideas, statements, or stances using linguistic devices (i.e., describe, clarify, justify, or explain). The concept of *confirmation* was primarily reflected in how group members reacted to ideas, points of view, arguments, or suggestions for action put forward by other members. Since this study focused on social-relational aspects of interaction, the notion of *disagreement* was also used to determine which elements expressed differences in the participants' ideas, statements, or contributions and how the participants dealt with these differences at the empirical level.

Finally, the notion of *interaction trajectories* (Krange, 2007) was also employed as analytic support. I used this concept for detailing the temporality of interaction, with the underlying rationale that participants' knowledge constructions can be accessed by looking at how things change over time. This concept contributes to expanding a moment-to-moment analysis by taking into account continuity and change in their interactions. Also, and of importance to this study, it creates the opportunity to explore whether and how knowledge object are picked up, interpreted, modified, and elaborated. In practice, that meant that the analyzed sequences were selected in order to reconstruct a sequential course of events. I conducted analyses of chronological extracts in these three studies, with each study focusing on different facets of the trajectory: changes in the students' positioning during interaction (Study 1), the follow up of ideas and concepts throughout the project period (Study 2), and the trajectory of knowledge objects in conjunction with the interaction process (Study 4).

4.4.4 Descriptive statistics

Given the mainly qualitative analytic approach employed, the aims of the investigation, and the small samples, only basic descriptive statistics were used to apply quantitative measures. I used descriptive statistics in Study 3 and 4 to describe the overall structure and volume of contributions of the participants in the interaction and the frequency of re-occurring themes in the interactional content. The occurrence of the interaction categories in each group's interaction data was the main target for this analysis. In addition, counting measures were used for the occurrence of concepts.

4.5 Ensuring methodological quality

The type of qualitative research conducted in this dissertation, which employed intensive data gathering and in-depth analyses that is interpretive in nature. It is important that the analyses and findings are credible and compelling. Credibility is often defined by the degree of rigor and quality that can be identified in the methodology employed (Lincoln & Guba, 1985). In general, my efforts to safeguard the quality of the research were directed toward the following: ensuring methodological coherence, taking care that the sampling was appropriate, collecting and analyzing data concurrently, and making theory development possible (see Morse et al., 2002). In the following, I discuss in more detail the means used to ensure methodological quality from the point of view of reliability and validity, followed by some reflections on the generalization potential and the ethics related to this research.

4.5.1 Reliability

In qualitative research, regardless of the terminology, it is generally agreed that the reliability of findings depends on the likely recurrence of the original data, or "potential replication" (Peräkylä, 2004), and how the data are interpreted (Silverman, 2001). Reliability in this sense can be safeguarded in two different ways (Ritchie & Lewis, 2003). The first concerns the need to ensure that the research is robust by carrying out checks on the quality of the data and its interpretations. The second refers to the necessity to convince the reader of the trustworthiness of the research by providing thorough information about the process.

Fieldwork is one aspect that belongs to the former aspect. In this research, the fieldwork was organized and conducted in a thorough, consistent, and transparent manner. For this purpose, I selected and documented the choices for the data-collection methods.

Also, I created a set of guidelines (section 4.3.1), which I followed in all empirical studies when organizing and conducting the data collection. This ensured that: the settings and participants were all treated in the same manner; the procedure was consistent across studies; and that participants were provided with space to provide the information they considered important in relation to the investigated topic.

Regarding working with the data, I used strategies that allowed organizing and documenting the data set; transcribing based on standardized rules; checking for biases in the analytic procedure through various methods (Ritchie & Lewis, 2003). Pursuing this strategy contributed to the analysis being carried out systematically, and increased the transparency of the procedure. In Section 4.4.1 above, I described the steps followed when dealing with the qualitative data. Organizing and documenting the data set in a structured and consistent manner was both a necessity, given the large amount and variety of data sources, and a strategic choice, the latter because of the need to create a clear overview of the types of data, amount, sources, etc., that made it possible for other researchers to access and understand the nature of the material. Next, the verbatim transcription of interaction data was conducted according to standardized transcript conventions (Table 4). Such transcription strategy provides a more clear understanding of the depicted interaction and activity, and it adds to the trustworthiness of the data. Furthermore, the real data (excerpts) are included in the presented analyses, which makes it possible for the reader to follow the interpretations in close relation to the data.

Reliability was also addressed at the level of analysis. Checking for the reliability of the coding scheme by calculating inter-rater agreement coefficients was a way to increase the accuracy of the instrument. In addition, the analysis process took place in a structured manner, following a number of steps (see section 4.4.1), in accordance to a stepwise replication strategy (Lincoln & Guba, 1985).

Table 4: *Transcript conventions*

[…]	: Utterances removed from the original dialog
… utterance	: Start of quoted excerpt
utterance… utterance	: Short pause in speech
utterance….	: End of quoted excerpt. The original group discussion continues.
[text]	: Author's comments in the original text.
(*text in italics*)	: Sections in the excerpts related to coded actions.

Also, I analyzed different types of data in order to gain insight into and create an understanding of one aspect of the co-construction process to strengthen the interpretations. An example is the construction of the sequential interaction trajectory of the groups, based on meeting minutes, emails, my field notes, and group discussion recordings. Finally, the analysis of the interactional data was not conducted in isolation. While an analysis account of the excerpts was first developed independently, it was always followed by discussions about both the data and the interpretations with other researchers in research and project meetings.

4.5.2 Validity

In qualitative studies, validity is considered more in terms of: selection and use of appropriate data-collection and analytic strategies, in order to come up with valid conclusions (corresponding to the construct validity); how data are interpreted and whether analytic claims made about data and interpretations can be regarded as convincing (internal validity); how the chain of evidence is constructed in regard to the investigated phenomenon and the generalization potential of these interpretations (ecological or external validity) (Ritchie & Lewis, 2003). In order to meet the validity criteria, a multitude of strategic choices have to be made. Techniques that supply these strategies were identified (Whittemore, Chase, & Mandle, 2001; Meadow & Morse, 2001) at a practical level that applied to various aspects of this research.

When making research design considerations, I ensured the thorough development of a self-conscious research design. This involved, among other things, ensuring sample adequacy. In organizing the field work, first of all, I carefully considered the selection of the participants, and selected the most appropriate type of sampling for the purpose and design of this research, a combination of convenience and a purposive sample (Patton, 2002), Another technique used was the combination of data and methods. Data were collected from various sources. Decisions concerning data types followed the rationale that a complex phenomenon such as the co-construction of knowledge objects requires a set of methods that captures this complexity. Considering that such a phenomenon involves several participants, that the process spans over long periods of times, and that it is influenced by institutional aspects, methods were selected in an attempt to capture information from different sources. The same reasoning was applied when using a combination of analytic methods, each having the potential to unveil different facets of the process and what actually occurred in natural settings (Silverman, 2001).

Validity criteria were taken into consideration when generating data. A technique used in this regard was that of articulating data collection decisions, as explained above. Further, prolonged engagement allowed searching for "convergence among multiple and different sources of information to form themes or categories in a study" (Creswell & Miller, 2000, p. 126). Data were examined over multiple groups, in different settings, and over time. The multiple groups and interaction episodes provided an opportunity for examination of the similarities of the findings across the groups. In addition, persistent observation was employed, which allows for recognizing central issues and characteristics, and articulating an understanding of these factors. Providing verbatim transcriptions (as discussed in the previous section) was a technique used for all of the analyzed group discussions and intended to increase the accuracy of the interpretations by staying very close to the raw data.

At the analytic level, articulating the decisions regarding analysis was also utilized in various circumstances such as research and project meetings, discussions with peers, or interim reports. In addition, I used various forms of peer debriefing and expert checking. This activity can involve an experienced peer or peers exploring aspects of the inquiry and of the data (see Creswell & Miller, 2000). The process of seeking feedback and perspective helps prevents researcher bias and ensures that alternate plausible explanations are considered. Given that these studies were also part of the broader investigation within the KP-Lab project, data sessions using data provided by different project partners were organized several times during the project period. Data were presented and discussed with peer researchers, and common analysis procedures and instruments were developed based on multiple sets of data. Also, as mentioned in the discussion on reliability, the material was discussed and detailed feedback was provided in a number of meetings of the research group at the University of Oslo and at the National Graduate School of Educational Research (NATED), in which colleagues and peers provided feedback on the analytic procedures and other aspects of the design.

In the presentation of the research and the data, I provided evidence that supported the interpretations in a visible manner. On the occasions of reporting for the KP-Lab project, and in response to reviewers of submitted manuscripts, I addressed the matter of "comprehensive data treatment" (Silverman, 2005). This concerns the issue of presenting data excerpts and their analyses and interpretations in order to illustrate and discuss distinctive interaction patterns or co-construction strategies by the participants. While such presentation of the evidence seems the appropriate approach, it raised questions with regard

to the representativity of this data and the substantiality of the interpretations. To address this issue, for Study 1, I expanded the evidence set for the submitted manuscript by providing additional interaction data and by contextualizing through "thick descriptions" (Geertz, 1993) based on supplementary data. Given that this procedure worked well, I also applied this strategy to the other studies. Importantly, I also relied on theoretical postulations of the socialcultural perspective and the knowledge creation metaphor. I made use of this opportunity by employing theoretical lenses to identify themes in interaction, to support reiteration of co-construction practices, and for cumulative explanations of object-oriented activities.

4.5.3 Generalization

In the traditional sense, generalization refers to the possibility of transferring the findings from a study on a population beyond the sample and the context of the research itself (Ritchie & Lewis, 2003; Silverman, 2001). Generalization of findings based on qualitative research involves different aspects, given that each setting is in some sense unique. In this dissertation, interest in the micro-level aspects of the knowledge co-construction process required working with small samples and very specific research designs, which does not provide a basis for statistical generalizations. Nevertheless, the findings presented here provided a basis for generalization connected with the analytic strategies.

The generalization allowed by this dissertation is of an analytical nature. According to Kvale and Brinkman (2009), analytical generalization involves judgments with regard to how findings can be indicative of what might occur in another situation, and are based on analyzing similarities and differences between situations. The potential for generalization of these findings is substantiated by being explicit about the logic of inquiry (Derry et al., 2010). One way of grounding the process of generalizing from these findings is to ensure that the criteria for the quality of the research are met. For this purpose, I provided thorough descriptions of the fieldwork procedures, the methods used, and the analytical strategies. Based on this, valid interpretations of the data were sustained. Also, the findings are based on investigation of the phenomenon in three different settings. The procedures and the research design employed were identical, the differences in the latter consisting only in the refinement and improvements brought across the iterations. To be more specific, the way the quality criteria were attended to makes it possible to attempt generalizations with regard to the type of epistemic actions that contribute to a productive interaction, the way

interaction unfolds when work on knowledge objects is pursued, and how knowledge is materialized through sustained and iterative actions. The analytical generalizations are discussed at a more general level in the final section of each of the three articles and of this extended abstract (Chapter 6), and are based on relating the findings to the theoretical point of departure and a review of research.

4.5.4 Research ethics

The research in this dissertation followed the research ethics guidelines for social science, as formulated by the Norwegian Social Science Data Services (NSD). I collected my entire set of data at sites in the Netherlands and in the context of the KP-Lab project, and the ethics of the procedure were also backed by strict guidelines characteristic of EU projects. I applied and received approval from NSD for the data-collection strategies used in this project.

The main ethical concerns in relation to this dissertation were in regard to participants' privacy and involvement in the research. My strategy with regard to involving participants in the studies was based on a complete and open information flow approach. At every research site I informed the participants by means of a presentation about the aims, theoretical ideas, methods of the research project, and what was expected of the participants. Once participants agreed to participate, either on an individual basis or through their institution, they were all requested to sign an informed consent form that stated the same aspects we had discussed, the data types that would be collected, and participants' commitment to the project (see Appendix 1). Only individuals who agreed to and signed this form participated in the studies. During the data collection, group members were informed every time the recording devices were switched on and off. During transcription, the data were anonymized and all participants' names were replaced with pseudonyms. The data were stored securely on devices only accessible to the researcher. Video material was presented only in closed research or project meetings. In addition, during the entire period of the field trials and afterwards, participants could pose questions and comments regarding the data collection particularly and the project in general. I made sure they received clear answers and that their participation in the research continued to be on a voluntary basis.

5 Summary of studies

In this chapter, I present a summary of the four empirical studies conducted in the context of this dissertation. Each of these studies examined a set of aspects described also in the applied theoretical framework. But the relationship and interconnection of these aspects was constantly taken into consideration across studies. In chapter 6, the findings of these studies are discussed in an integrative manner, with an emphasis on their interconnection.

The first aspect refers to the *types of interaction*s during the knowledge co-construction process. It is assumed that co-constructing knowledge requires specific types of interaction, that is, *productive interaction*. Study 2 focused mainly on conceptualizing and illustrating productive interaction in students' object-oriented collaboration. In addition, Studies 1 and 4 depicted productive interaction in relation to the co-elaboration of knowledge objects and to shared epistemic agency. The second aspect concerns the *co-construction* and *co-elaboration of shared knowledge objects*. The investigation in Study 4 focused on how the shared knowledge objects emerged from interaction, how they were developed, and how they were part of the interaction. In addition, in Study 2 the interconnection between the interaction and the developing knowledge objects was examined and illustrated. The third aspect encompassed *characteristics* of the knowledge co-construction process. The first was the active and deliberate participation in the joint construction of knowledge objects, depicted by the notion of *shared epistemic agency*, and was investigated in Study 1 and 2. The second was represented by the *social-relational aspects* of the interaction. In Study 3, the analyses focused on how students dealt with these social and relational aspects of their group interaction and how these influence or contribute to the process.

Study 1.

Damşa, C. I., Kirschner, P. A., Andriessen, J. E. B., Erkens, G., Sins, P. H. M. (2010). Shared epistemic agency - An empirical study of an emergent construct. *Journal of the Learning Sciences, 19(2),* 143 – 186.

This article reports on an explorative qualitative study of the construct of *shared epistemic agency*. The aims of the study were to provide a conceptualization of the notion of shared epistemic agency and to illustrate this conceptualization with empirical data.

Various studies of collaboration indicated that simply bringing people in groups and assigning them tasks are not sufficient conditions for collective knowledge advancement (Barron, 2003; Perkins, 2003). Scardamalia (2002) introduced the notion of epistemic agency as an aspect sustaining collective knowledge advancement and students taking responsibility for their learning. While considered key to this collective effort, the notion was neither clearly defined nor comprehensively investigated. Empirical studies (Palonen & Hakkarainen, 2000; Russel, 2002; van Aalst & Chan, 2007) approached it from the perspective of the individual learners involved in collective activities. In this study, we proposed a new construct, shared epistemic agency (SEA), which attempted to depict more precisely the nature of agency as it is expressed in collaborative activities of knowledge creation (Paavola & Hakkarainen, 2005). The conceptualization of SEA built on the idea that co-construction of new knowledge necessitates particular engagement in the process, and interaction with peers and emerging knowledge (objects). Sharedness (Akkerman et al., 2007) is central to the SEA construct, emphasizing the productiveness of interaction and collectively organized action. We conceived SEA as a capacity that enables groups to deliberately engage in and perform sustainable collaboration that results in the creation of new knowledge, materialized in shared knowledge objects.

In this qualitative study, we attempted to capture and explain the shared epistemic agency construct in two ways: a) by creating a preliminary conceptualization based on existing theoretical and empirical studies, and b) by illustrating its characteristics through empirical analyses, and refine the preliminary conceptualization based on the findings. The participants were seven students attending the course Educational and Instructional Design (EID) at a large university. During the 10-week course, students used major theories and methods of instructional design to work on collaborative design projects. The technological support for collaboration was provided by a Blackboard® system. We followed the two groups during the 10 weeks and collected interaction data, the groups' knowledge objects

(design material, drafts, reports) and reflective group interviews. We analyzed the groups' discussions and interviews through qualitative content analysis and interaction analysis, and the knowledge objects through a document content analysis.

Two core dimensions of shared epistemic agency were identified, namely, the *epistemic* (knowledge-related) and the *regulative* (process-related) dimensions. The empirical analyses distinguished agentic patterns that consisted of a succession of actions: creating awareness of problems or a lack of knowledge, reflecting on ideas and alternatives for object development trajectories, and engaging in actions that serve the purposes of object creation and advancement. Despite a similarity in intentions, groups demonstrated differences in the way these intentions were translated into action. These results showed that tasks can be finalized successfully by using a division of labor and rigorous regulation of collaborative work (in Group B), but that sharing of knowledge, strategic planning and joint actions of an epistemic nature create a stronger foundation for construction of knowledge (Group A).

To conclude, shared epistemic agency can be described neither as being a distinguishing quality between groups nor as generally characterizing a collaborative process, but as combination of actions emerging when groups are conducting particular collaborative work. This study indicated that agency emerges in different ways and to varying degrees in different groups. In some cases, it emerges naturally, and group members find a way of dealing with what it takes; other groups need guidance and support to discover and pursue object-bound collaboration in an agentic manner.

Study 2.

Damşa, C. I. (submitted). *The multi-layered nature of small-group learning: Productive interactions in object-oriented collaboration*

This article reports on a study of collaborative learning in higher education. It aimed to provide a deeper understanding of *productive interactions* and their interconnection with groups' shared knowledge objects and epistemic agency. The focus was on learning through solving open-ended, complex problems, addressed by collaborative work aimed at co-constructing knowledge objects as solutions.

Broadly conceived, productive interaction represents a key aspect of co-construction of knowledge, meaning, and understanding (Littleton & Light, 1999; Ludvigsen, 2010). Studies by Baker (1999), Barron (2003), Engle & Conant (2002), Mercer (2004), Myiake

(1986) contributed to a depiction of the notion of productive interactions in collaborative settings. These studies identified transformations that lead to co-construction of meaning, understanding, or knowledge, and contributed to a shared goal or cooperative activity (Baker, 1999) or a common relational space (Barron, 2003); and an exchange of ideas at communicative level, involving language as part of a process of 'interthinking' (Mercer, 2004). A conceptualization from sociocultural perspectives proposed, however, that knowledge is constructed as part of the interdependence that involves people interacting with peers, tools or objects (Wertsch, 1991). Defined from this perspective, *productive interactions* are communicative exchanges leading to participants co-constructing and elaborating knowledge objects. I examined interactions considered productive during long-term collaborative research projects, with a focus on: how these interactions unfold, whether they prove productive in relation to the emerging knowledge objects, and learners' active participation (or agency) in this collaborative work.

This article reports on the second iteration of a design-based research project (Collins, Joseph, & Bielaczyc, 2004), which employed a distributed project model (Muukkonen, Lakkala, Kaistinen, & Nyman, 2010). Fourteen undergraduate students, enrolled in Bachelor Thesis, a 20-week course that aimed to support students in integrating and applying previously acquired scientific research knowledge. The curriculum was redesigned with an emphasis on co-construction of shared knowledge objects created as solutions to open-ended problems brought in by two external clients (Sins, Bauters, & Damşa, 2008). Organized in five groups, the students set up and conducted research, and reported the findings in a common article. The technological support for collaboration was provided by a Blackboard® system. The analysis focused on three discrete layers that characterize the complexity of the process during a longer time span. First, *group interaction* was examined using a qualitative content analysis techniques and descriptive statistics. Second, in-depth analysis of interaction was combined with analysis of *knowledge objects* that emerged from it. Quality of the final objects was determined using a standardized assessment instrument. Third, groups' *shared epistemic agency* was disclosed by searching for patterns in the interaction that indicated deliberate, strategic and reflective conduct.

The findings identified various types of productive interactions that occurred during collaborative work, in some groups more than in others. These interactions were considered productive in the sense that they, first, create the ground for co-elaboration and co-construction of new knowledge objects; second, the generative actions identified actually

lead to emergence of new knowledge and progress of the knowledge objects. The different types of actions that make up these productive interactions and their occurrence are, nevertheless, interwoven. Further, the findings showed how discussion among group members triggered problems (and sometimes conflicts) and illustrated knowledge object's potential to elicit more converging, complex interaction at the epistemic level. Here, the notion of shared epistemic agency proved useful for explaining what drives groups to engage in particular types of interactions and how to go about working on the knowledge object. Data showed how the interaction and object development processes can take a different turn because of group members' awareness and engagement with tasks.

This study suggests that productive interaction can be designed and supported. It implied that the task must be of the right nature and complexity, the guidance needs to be adjusted according to group needs, and the assessment should acknowledge both interactional aspects and outcomes as elements of the learning process.

Study 3.

Damşa, C., Ludvigsen, S., & Andriessen, J. (2013). Knowledge co-construction – epistemic consensus or relational assent? In M. Baker, J. Andriessen & S. Jaarvela (Eds.) *Affective Learning Together. Social and relational dimensions of collaborative learning,* EARLI series 'New Perspectives on Learning and Instruction' (pp. 90-119). Routlegde Academic Publishers/Taylor & Francis Group: Oxford, UK.

In this study, we analyzed co-construction of knowledge by participants in a collaborative research project by taking into account the *social-relational aspects* of interaction. The study aimed at deepening understanding about how addressing tensions of relational nature and solving disagreements during collaboration create a basis for interaction that assures epistemic progress.

The idea of meaning making was employed as the foundational concept that provided a basis to investigate specific aspects of the collaborative process. Meaning making is achieved through actions within specific contexts (Linell, 2009) through a stream of experiences, knowledge, and the language activities of learners. However, just organizing and monitoring the collaborative process (Barron, 2003) does not necessarily lead to shared understanding and meaning making. Furthermore, sometimes, the sharing of a learning situation does not entail a full involvement with the content by the participants (Barron, 2003; Engle & Conant, 2002). Hence, how participants construct knowledge together

crucially depends on how they take up the others' ideas and elaborate together (Linell, 2009). To this it adds that challenges, dilemmas, or tensions are important and often lead to complex dynamics that are not only related to the knowledge content of the interaction.

This study applied the sociocultural perspective to understand and examine participants' meaning making and co-construction of knowledge. We employed Linell's (2009) four dimensions of interaction *I, you*, *it* (the object) and *we* (the social-cultural setting) to interpret the social interaction sequences. We analyzed students' talk while they tried to solve a research-related problem and attempted to close knowledge and relational gaps (Graesser, Person & Magliano, 1995). We performed a *first-order* (mapping and describing actions identified in the data) and a *second-order analysis* (interpretation) of discussions of a group of three undergraduate students while they were organizing, conducting and reporting a joint research project, as part of the Bachelor Thesis 20-weeks course[6]. In the latter analysis, we employed *four empirically sensitive concepts*: orientation, elaboration, confirmation and disagreement.

The findings indicated students' different orientations, positions in the interaction and disagreements on how to relate concepts to each other. This involved repeated attempts of the participants to make the others understand and accept their viewpoints, through using a knowledge domain-bound discourse and language. Strategies used to address the knowledge gaps identified were: proposing one's own views and providing arguments, requesting elaboration from the others on new ideas, providing one's own elaboration or inviting the others to adjust or elaborate further. What appears as a condition is that (tacit) discrepancy and disagreements had to be explicated and acknowledged by collaboration partners to be able to cope with conflicting ideas. Furthermore, resolving different orientations and disagreements was beneficial for the functioning of the group, but it did not necessarily lead to a superior understanding of the matter in discussion, or a more advanced conceptualizations. Conscious decisions to overcome communicational or relational breakdowns led to a stricter commitment to the institutional demands than to epistemic elaboration. One can say that the communication was just sufficient to solve the problem, and it showed moderate evidence of shared conceptual understanding, conceptualization, and elaboration. The group reached an effective and operational decision, but not consensus.

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[6] This data analyzed is collected in the same iteration and settings as in *Study 2*. .

It became obvious that the social and relational aspects can contribute to or can impede shared meaning-making and joint elaborations. Viewed as an interaction trajectory, individual students' understandings of the concepts changed over time, even if they did not reach a more fixed or firm understanding. The individual students' understanding was constituted by but not determined by the trajectory of the group (Krange, 2007). Also, this study showed a focus by students on institutional norms as a standard to progress and evaluation. If we want students to better understand how to make their collaboration productive, we need to "enculturate" them about how collaboration might work, and how to deal with crucial aspects when collaborating about specific tasks

Study 4.

Damşa, C. I. & Ludvigsen, S. R. (submitted). *The collaborative construction of what? Learning through interaction and co-construction of knowledge objects in teacher education*

This article presents an empirical study of groups of teacher students, learning through collaborative projects that involve *co-construction of knowledge objects* (e.g., research reports, educational material). The focus of this investigation was on how these objects emerge based on students' interaction and how they were developed through iterative co-elaboration.

Various studies posited that interaction and problems with open-ended character entice students to activate and create knowledge, and to envision solutions to these problems together with peers (Hmelo-Silver & DeSimone, 2013; Muukkonen & Lakkala, 2009). This calls for theoretical and practical knowledge to be materialized into knowledge objects, wherein it becomes transparent for the participants involved (Ludvigsen et al., 2010; Paavola & Hakkarainen, 2005). Still, little is known about how social interaction between learners leads to materialization of knowledge into knowledge objects, and especially, how the iterative process of creating these shared knowledge objects is taking place. Various studies (e.g., Carlile, 2002; Eckert & Boujut, 2003; Ewenstein & White, 2009) discussed how knowledge objects play an important role in human activity, as they structure interaction, generate problems, or provide groups with motives for interacting or outcomes to reach for. The emphasis has been mostly on the role of objects in various types of activities rather than on the way these objects are being created. We adopted and used the concept of *shared knowledge objec*t, and conceived objects as an externalization of

knowledge, or *freezing* of knowledge at certain moment in time, and as part of the co-construction process, instead of only being the outcome of it.

This one-year study was conducted at a university of applied sciences, which prepares pre- and in-service teachers for secondary vocational education. Throughout the entire project period, a group of 8 teachers and 73 mixed-age students, enrolled in three one-semester long courses, participated in the study. We used a design-based research approach and technological support was provided by the Knowledge Practices Environment (KPE), a web 2.0 application, consisting mainly of virtual collaboration spaces. We collected different types of data: interaction data (recordings of group discussion, chat protocols, email correspondence), the knowledge objects (with all their iterations), reflective data (group interviews and questionnaires), and course documents. We used a contrasting groups approach and analyzed in-depth the data set of three student groups. The qualitative analyses followed three lines of investigation, consisting of analysis of: *group interactions*—through qualitative content analysis and interaction analysi*s*, of *concepts and ideas uptake*—through concept mining, and of *object co-construction and development* – through document content analysis.

The findings showed various degrees of idea sharing, how shared objects emerged from the discursive interaction, and co-elaboration of object iterations. The results showed variation in the nature of groups' interaction, different uptake strategies and degrees of elaboration. Interaction of epistemic nature, strategic uptake of concepts, elaborations based on shared insights, and constructive feedback are the most important ingredients for a successful co-construction process. Only one of the three groups attended to this and achieved a high integrative complexity of the knowledge object. In addition, the study identified three trajectories of interaction and object co-construction, with the one displaying strong object orientation allowing for interpretations with regard to how joint work on knowledge objects can contribute to learning.

From an educational practice perspective, it appears desirable that students work towards high levels of elaboration, but it should not be taken for granted that they are always aware of the differences in the elaboration levels. Hence, these findings call for attention to students' understanding of this type of learning and interaction, and to how the pedagogical design can provide more specific scaffolds for students when entering knowledge co-construction processes.

6 Discussion

The research in this dissertation examined learning in higher education, conceived as a process of knowledge co-construction, which requires social interaction and joint elaboration of knowledge objects. On a *theoretical l*evel, this research aimed to elaborate on the sociocultural conceptualization of learning as a process of co-construction, in particular, of knowledge and knowledge objects. This theoretical direction guided the pursuit of the *empirical* aims, which concerned a deeper understanding of the co-construction process, the interaction and the knowledge objects constructed through this interaction, and the characteristics of and the interconnection between aspects. *Methodologically*, I aimed to employ a design approach and to devise analytic instruments that allow to examine and depict the complexity of the co-construction process, with its interconnected aspects and sequential character. Based on the findings, this dissertation also considered identifying implications for the educational practice and making suggestions for further research.

This research adopted a sociocultural stance that conceives of learning as a process of joint construction of knowledge. The analytic focus was on the interaction process, the joint construction and iterative elaboration of knowledge objects, and their interconnection. The main contributions are represented by: empirical substantiation for the conceptualization of learning as a process of knowledge co-construction, that involves interactions and joint work on knowledge objects; expanding the conceptual elaboration of the notion of co-construction of knowledge objects; and a deeper understanding of how these aspects are interconnected and can be interpreted in relation to learning in collaboration.

In the following, I integrate and discuss the main empirical findings in relation to the theoretical ideas and findings brought to the fore in the review of relevant research. I further identify and discuss the methodological and theoretical contribution of this research. Finally, I reflect on the implications of the study and its findings for the field of educational design and practice, and identify directions for future research.

6.1 Empirical contribution

The empirical contribution of this research comes forth based on the extensive investigation of the collaborative activities of students groups, and of the knowledge constructed within this context. The set of findings provided by the four studies shed light, *inter alia*, on students' participation in collaborative work (Study 1) and productive and social-relational aspects of the interaction process (Studies 2 and 3). While these results are interesting, I identify a set of findings that represent a distinctive contribution at the empirical level, regarding the construction of knowledge objects through interaction with peers and resources and the patterns of object-oriented collaboration that lead to the construction of knowledge. The discussion below is organized around these topics, which are first discussed independently. It is, however, important to mention that the identified aspects of interaction and the construction of knowledge or knowledge object characteristics are deeply interconnected, and their discussion in separate sections is mainly for analytical reasons.

6.1.1 Object-oriented collaboration

This research provided an insightful addition to the understanding of interaction in small groups as part of collaborative activities that involve working with complex problems and the construction of knowledge objects. In relation to this contribution, I hereby address two aspects of relevance.

The first concerns the *types of actions* performed by the collaborative groups when engaging in interaction, and the focus here is on the *epistemic actions*. As shown by the findings (especially in Study 3), the role of social-relational actions in the interaction require a nuanced understanding. These findings are in line with various studies of collaboration, which focused on the procedural aspects of collaborative groups (e.g., Barron, 2000; Janssen, Erkens, & Kirschner, 2010) and collaborative project work (e.g., Dym et al., 2005; Muukkonen & Lakkala, 2009; Stankovic, 2009). These studies maintain the stringent necessity of regulating collaboration, both on the social and relational levels, in order for activity to achieve its goals. My findings also show that actions at the social and relational levels are important for organizing interaction and joint work. They appear to facilitate or impede joint elaborations of concepts and ideas and can affect the outcomes and quality of the co-construction process.

The main point of the current findings, however, is that the over-reliance of groups on the social coordination of individual contributions or agreement at relational level does not lead to joint knowledge construction (Study 3). Hence, in my investigation, I searched for actions that have a direct impact of the construction of shared knowledge objects. Building on ideas about dialogical interaction was instrumental, since the types of actions aimed at creating awareness or creating shared understanding are situated in a dialogical space. These were also depicted by studies of argumentation (Baker, 1999; Baker, 2009), problem-solving in small groups (Barron, 2000, 2003; Engle & Conant, 2002), knowledge building (Zhang & Messina, 2010), or dialogical meaning-making (Mercer, 2004; Mercer & Wegerif, 1999). Relatively few studies (see Mukkonen, Lakkala, & Hakkarainen, 2005; Muukkonen & Lakkala, 2009; Van Aalst & Chan, 2007) went beyond analyzing this dialogical space. Muukkonen and colleagues' studies emphasized knowledge objects in relation to inquiry outcomes or the role of technology and tutoring, but they did not engage in an in-depth analysis of the nature of the actions that characterize productive epistemic interaction aimed at constructing knowledge objects.

The analyses in this dissertation unraveled the types of actions that lead to the co-construction of knowledge in detail, at the microgenetic level. The findings identified *epistemic* actions as typical for the co-construction process, and Studies 2 and 4 showed that groups that engaged consistently in interaction at the epistemic level reached a deeper understanding and application of concepts and ideas and created knowledge objects of higher integrative complexity. Based on these results, I argue that the interaction and its productivity at the epistemic level plays an important role in the way students develop an understanding of extant knowledge, co-construct their own knowledge, and then materialize it. I defined "productive interactions" as ones that were conceived as communicative encounters between collaborating individuals and which then led to a shared understanding of concepts and ideas, a co-elaboration of the latter into knowledge objects, and a sustained advancement of these knowledge objects. From this viewpoint, interaction can be productive (in a non-normative manner) when it contributes to advancing and elaborating the knowledge objects being developed. The relevance of the knowledge object for the convergence and productivity of the interaction becomes evident, in this context. Namely, dialogic actions, such as the ones described above, are necessary but not sufficient for developing a knowledge object from an idea to a final, tangible product. The design envisioned created space and support for the participating students to engage in object-bound actions, identified as *generative actions*. This dissertation identified actions of this

type, such as generating ideas, idea uptake, and co-elaboration, as constructive ways of giving and using feedback and the practices of revising and versioning.

The cases of contrasting groups, as presented in Studies 1, 2, and 4, illustrate the assumption that, in order for interaction to be productive and to contribute to the construction of a knowledge object, joint effort is required to pursue epistemic actions. Such actions need to go beyond simply collecting relevant information and assuming that individual processing will suffice or engaging in epistemic discourse but not capitalizing on its outcomes. Some of groups (e.g., Group A in Study 1, Group D in Study 2, or Group A in Study 4) showed how productive interaction can be enacted through sharing, discussing, and negotiating and how knowledge can materialize into a shared object as a result of joint and iterative elaboration. These groups engaged more actively with the knowledge content than other groups did. This resulted in a more grounded co-construction process, and more advanced conceptualizations and elaborations of the knowledge objects. Other groups showed that the potential and resources to engage in productive interaction but limited their actions to productive discourse. These findings also support my stance that productive interaction focuses not only on the joint understanding of knowledge, but on engaging with ideas and concepts to construct new conceptualizations and then translating this knowledge into tangible objects (drafts). The course and content of the interactions determines how objects evolve and develop.

The second aspect to be emphasized concerns the way productive interaction unfolded and how epistemic actions played out during the collaborative process aimed at constructing knowledge objects, as displayed through different *patterns of object-oriented collaboration*. This aspect connects to the centrality of the knowledge objects in the co-construction process, as opposed to merely dialogical interaction. In short, the findings of Studies 1, 2, and 4 showed that, when interaction is taking place with the aim of co-constructing a shared knowledge object, the dynamics differ from those present when collaboration aims at the dialogical exploration of new meanings. The findings indicated particular *patterns of object-oriented collaboration* in relation to the development of the knowledge object. The way these patterns unfold can be depicted and understood in relation the knowledge objects that are being constructed in the respective interaction. Muukkonen-Van der Veer (2010) also considered the sequentiality of the collaborative activities in comparable settings. This dissertation extends the findings of these studies and provides empirical substantiation for how sequences of actions are played out in different groups for

the interconnection between the interaction and the knowledge objects involved, and the varying role of the knowledge object in the co-construction process.

The patterns identified in the present study unfolded around the development of knowledge objects, with the object holding a central or a peripheral position in the co-construction process. A first pattern noted was one characterized by *individual action-based collaboration* and involved a group relying strongly on regulative actions and work based on the division of labor. Such collaboration is characterized by the pursuit of shared goals, but is mainly about individual actions and the construction of shared objects in a superficial manner. The second collaboration pattern is a *discourse-oriented* one. In such a collaboration setting, groups engage in interaction and discursive actions aimed at understanding and elaborating on knowledge, but this knowledge is often not taken up and further elaborated upon adequately. Compliance with institutional norms, time constraints, or logistics can be reasons for students to keep their interactions to a dialogical level and reduce their degree of knowledge elaboration. A third pattern, one of *object-oriented collaboration*, showed students engaging in dialogic interaction and in co-elaborating on the knowledge objects. This type of collaboration is characterized by, in addition to the discursive interaction typical to the second pattern, the materialization of knowledge into concrete object drafts, iterative versioning, the use of feedback and revisions, and the implementation of a joint strategy for the object's advancement and elaboration. Some of these groups challenged the institutional norms and engaged in inquiries that went beyond only meeting the assessment standards (Group A in Study 1 or Group E in Study 2). While the majority of the examined groups finalized their projects, the quality of their work and final objects varied, with the groups that pursued epistemic actions in a more systematic manner earning better assessment scores and devising more sophisticated objects. In the groups that engaged in this type of interaction, the knowledge objects were the central elements of the interaction, which then shaped the group's trajectory and determined particular courses of action (see further discussion on this in the next section). Overall, important indicators of interaction that indicate an object-oriented mindset are:

- New versions of shared objects contain concepts and ideas put forward during interaction;
- More advanced versions and drafts that demonstrate an elaboration on new ideas and deeper understanding; and,
- These versions and final objects contain cumulative and joint contributions made by each of the group members.

6.1.2 Co-construction of knowledge objects

Among the primary aims of this dissertation was to identify and depict the co-construction of shared knowledge objects as a process that provides potential for learning and for participants to address open-ended and complex problems. The characteristics of and the way the interaction takes place are, in an ingrained manner, connected to the knowledge objects that emerge from and which are developed through this interaction. Muukkonen et al. (2005) and Muukkonen and Lakkala (2009) have analyzed some aspects of object-oriented practices, but have not performed an in-depth analysis of the developing knowledge objects. A number of activity theoretical studies (MacPherson et al., 2010; Miettinen, Lehenkari, & Tuunainen, 2008) depicted the role of knowledge objects in various organizational processes and showed that (ready) objects can function as mediating elements in collective activities or learning.

My examination went beyond this merely mediating role of knowledge objects, and focused more on their knowledge content and development through interaction. It examined how the object was developed and how its content and development played a role in the co-construction process. Building upon the socioultural perspective (Vygotsky, 1978; Wertsch, 1991), I purported that complex and open-ended problems create the potential for the joint construction of knowledge and knowledge objects. In this context, knowledge objects are seen as concrete entities (Paavola & Hakkarainen, 2005), in the sense that they materialize the knowledge collected and constructed during the interactions of the collaborating groups. To approach the notion empirically, this research employed the notion of *situational objects* (Jahreie, 2010), and assumed that the knowledge objects constructed by the participating groups are situational in the sense that they become constructed discursively, through joint epistemic input and coordinated interaction in a specific context.

One distinctive contribution of this empirical examination of knowledge object construction is its attempt to follow the knowledge content of these objects. This analysis focused on the *trajectory of the knowledge* from the moment it entered the interaction process (e.g., ideas, concepts) until it was materialized and elaborated into the final objects produced by groups. Few studies have traced knowledge in this way, and those that attempted to (Stahl, 2009) focused on the concepts' trajectories only and did not examine their further elaboration. The results of the present study add to this body of research by showing how ideas and concepts identified as "important" are put forward in the group. This knowledge in its preliminary form was dealt with in different ways, with an array of alternatives that ranged from groups working towards shared understanding and elaborating

through discussions or by them simply leaving the information unprocessed and relying on individuals' understanding and actions. Up to this point, the results corroborate with studies of interaction and the dialogical construction of meaning-making (Atwood, Turnbull, & Carpendale, 2010; Furberg & Ludvigsen, 2008; Myiake, 2007), which converge on the ideas of shared understanding being beneficial for knowledge construction and learning. However, this dissertation's results add to this by disclosing what happens to this knowledge once shared discourse within the group is achieved, at the point when these verbal elaborations have to be "frozen," concretized, and materialized.

This examination was taken further by connecting it to the ways in which emergent knowledge is elaborated. The way groups shaped knowledge and engaged with it for a period of time was, in a sense, also representative of how they positioned themselves when addressing the open-ended problems that triggered their collaborative work. The results show that some of the groups examined here engaged in a systematic analysis of the concepts they worked with, and their elaborations were eventually meager (Group B in Study 4, or the group in Study 3). What seems to distinguish groups that engage in advanced co-elaboration of knowledge, such as Groups A in Studies 1 and 4, is a higher level of awareness of the complexity of the project, a consciously chosen joint strategy regarding the elaboration of the knowledge they gathered or generated, and the advancement of the knowledge object drafts. Furthermore, such groups were observed engaging with knowledge in a more active and profound manner, which involves discussing and negotiating the meanings of concepts, creating explanations, and working through iterations that apply peer feedback and revisions to refine the knowledge content. This requires a strategic approach to project management, something that has been deemed necessary when dealing with complex problems (Stankovic, 2009; Muukkonen, Lakkala, Kaistinen, & Nyman, 2010). More importantly, it also involves engaging with the knowledge in its various forms, transforming it, re-constructing it, and following its evolution and transformations vigilantly.

Finally, the characteristics of the interaction patterns, discussed in the previous section, show that the relationship between the way students shared and materialized their knowledge into objects is a dynamic and important one. This aspect is also connected also to the *role of the knowledge object* in different groups and the interconnection between interaction and knowledge objects as inherent aspects of the co-construction process. The aim, course, and content of the interactions determined how the objects evolved and developed – in Studies 2 and 4 we saw how the content and shape of the objects changed

after the groups had productive interventions. At the same time, the developing objects determine the course of the interaction – in the same studies, we also saw the way that group interaction unfolded after drafts of the objects were discussed and elaborated upon. The objects created by groups passed through these different functions while also shaping the groups' ongoing interactions. The findings also showed how the drafts the groups worked on (Group A in Study 4) were central in their discussions, were used to organize inquiry, shaped the group trajectory, and determined particular courses of action. The lack of clear conceptualizations and knowledge elaboration identified in various intermediate objects led to discussions, searches for additional knowledge, the reformulation of focus, and revisions of drafts. In short, objects led the inquiries and triggered advanced interaction with knowledge. Such a trajectory provides substantiation for the conceptualization of the knowledge object as a sense-maker in an activity and shows its potential for triggering new inquiries in educational settings (Kaptelinin, 2005; Ewenstein & White, 2009). It also illustrated the shared knowledge objects' multiple roles: object of the groups' inquiry, outcomes of the activity, and mediating element in the interaction.

6.1.3 Temporality of the co-construction process

Another aspect of the empirical contribution is highlighted by the examination of the co-construction process by taking into consideration its temporality. Studies of collaborative problem solving (Barron, 2003; Sarmiento-Klapper, 2009; Stahl, 2010) have attempted to analyze temporality in small-group collaboration and showed mainly how dialogical interaction is played out during mathematical problem-solving. To some extent, the results of this research corroborate with the conclusions of the aforementioned studies by depicting and illustrating how interaction unfolded during multiple collaborative sessions, how ideas and concepts were taken up, and how contributions and interventions (re-)directed or changed the course of the interaction. At the level of discursive interaction, the temporality is reconstructed by using linguistic means.

The current results add to this dialogical aspect by showing groups engaging in trajectories that went beyond only discursive interaction, to build on shared elaborations and follow up on iterations. The notion of *interaction trajectories* (Furberg & Ludvigsen, 2008; Krange, 2007) is used to interpret the temporality involved, which takes into consideration the sequentiality of the co-construction process and the way it is interconnected with other aspects of it. In this research, one way in which the productivity of the interaction manifests is through the sequentiality of actions in the interaction that leads to the co-elaboration of

these objects. Given the complexity and length of the projects, organizing and attending to a sequential structure in which knowledge is not only generated and discussed but also taken and followed up, elaborated upon, and refined is of vital importance.

The results show evidence of how groups address this temporality. Some groups were not able to deal exactly with this challenge (Group C in Study 4) of bridging the time gaps in a process spanning a long period of time; they failed to capitalize on the knowledge they had managed to bring into their group space. In Groups A in Study 1 and 4, the sequentiality was played out in a sophisticated manner, wherein the gaps created by the long-term collaboration were bridged both at the discourse level and in the way knowledge was followed up throughout the process. Interestingly, the way this sequentiality was materialized by some groups (Group B in Study 4 or the group in Study 3) contradicted to some extent Sarmiento-Klapper's (2009) position, in that bridging dialogical interaction moments across time is sufficient for engaging in complex problem solving and conceptualizations. Rather, based on the findings, I propose that materializing knowledge, whether in a preliminary or advanced form of elaboration, into situational objects serves the continuity of the process. It also aids the progressive accumulation of conceptualizations and elaborations (see also Muukkonen & Lakkala, 2009) and contributes to the co-construction process by freezing the generated knowledge at particular moments during the process. As stated earlier, the knowledge object drafts have a catalyzing role for groups' interaction, and that is also expressed in how the course of the interaction changes or adjusts in order to become meaningful for the co-construction of these objects. Understanding that the complexity of the process involves this temporal aspect, and viewing it as a series of actions and activities that follow each other in time, can allow groups to organize and pursue the co-construction process in a more effective manner.

6.1.4 Interconnection

The findings illustrate the interconnectedness of the interaction process and the knowledge objects produced in the interactions. The relatively few studies that have considered the empirical examination of both aspects (Muukkonen & Lakkala, 2009; Sarmiento-Klapper, 2009; Toledo; 2009) did not enter the discussion of their relationship in depth. This dissertation study showed that there is a clear need to understand and analyze in depth the constitutive aspects of the knowledge co-construction process, and even more so to grasp the way these are interconnected. Each of these aspects has been addressed in previous sections of this chapter, but their separate discussions posed challenges when

explaining them, since, in the reality of the collaborative work of the groups, they were constantly interwoven. Studies 1 and 4 were especially clear illustrations of the way the key interaction moments led to the emergence and elaboration of knowledge that then materialized in objects and how objects (drafts) triggered interaction moments that are important to the object development.

The empirical examination and discussion of this interconnection also relates to how collaborative learning activities are constituted in the social-historical context (Valsiner & Van der Veer, 2000). The findings also feed into the discussion of the multi-layered nature of the learning process, which involves the relationship between the socio-, micro-, and ontogenesis (Ludvigsen, 2009; Valsiner & Van der Veer, 2000). The sociogenesis is expressed in the characteristics of the institutional aspects (i.e., how the curriculum was organized and what type of resources the students had access to). The concepts the students activate and discuss do not come with a fixed meaning, but rather an historic meaning potential for co-elaboration, which is provided by the pedagogical design. Study 3, especially, showed how students engaged with the curriculum content and positioned themselves towards the institutional norms. While in that study the group chose to comply more to the institutionalized norm and content, in Studies 1 and 4 the groups engaged more deeply with the knowledge content, and some of the groups chose their own epistemic trajectories. In these cases, meaning potential posed from an institutional perspective was re-constructed and realized through interaction at the micro-genetic level, wherein students decided to share, negotiate, and "freeze" knowledge. While not in focus in this research, the ontogenetic layer of the individual students' participation was accounted for in the way the intersubjective space was constructed in the interaction. I consider the individual contributions to the discussions and object elaboration to be a part of the intellectual interdependence (Valsiner, 1994b; Valsiner & Van der Veer, 2000) emerging within each group.

In conclusion, such a multi-layered analysis provides us the opportunity to address the interconnection between the various aspects of the co-construction process in a more diligent manner than is possible with studies analyzing these layers independently.

6.2 Methodological contribution

Investigating learning by conceiving it as a process that involves social interaction and knowledge co-construction is valuable precisely because it provides readings of these

practices via which we can understand them and act in order to guide or improve them. From a naturalistic perspective, this stance is welcomed and encouraged, but the type of gains such research approaches provide entail creative strategies and, often, sophisticated designs. The way I upheld quality control for the methodology employed is described in section 4.5. Here, I discuss three aspects that represent a contribution from a methodological perspective.

One aspect of this contribution is through the combination of two research methods, the design-based research approach and the multiple case study. Design-based research (Brown, 1992; Collins, Joseph, & Bielazyc, 2004) is a method that specifies the design and examination of complex learning situations in authentic environments and allows for the iterative refinement and improvement of these designs. Case studies are, among other things, viewed as addressing small-scale phenomena with a high awareness of and connection to the context while attempting to capture in detail phenomena in their natural modes of occurrence (Yin, 2003). The methodological strategy I adopted in this dissertation resulted in combining intensive studies of particular processes with an iterative approach to a phenomenon that is characterized by sequential organization and emergent processes. The choice to pursue a micro-level analysis of the interaction process and its characteristic features unveiled details that enhanced understanding of the how the process and the participants became engaged with each other and the knowledge objects involved in moment-to-moment activities. The design-based research is based on a set of principles that allows for an overarching design framework that can entail multiple case studies and various iterations. From a research design perspective, iterations offered a way to specify challenges, explore alternative solutions, and refine research aims based on preliminary findings from previous iterations. From an analytic point of view, iterations allowed for developing analytic approaches and instruments that could be refined, adjusted, or improved in the course of the process. The way these methods are combined in this dissertation capitalizes on these principles by employing the refinement of design iterations based on the findings and conclusions drawn from the previous one.

Furthermore, in this research it was important to be sensitive to the empirical material when defining the central issues related to interaction and how knowledge is constructed. This required an analytic approach that would make it possible to do justice to both the knowledge content of the discussion and the size of the data set. Interaction analysis proved useful for the former purpose, but the large data set required an approach that allowed for a structured analysis of the verbal interaction data (group discussions). The

qualitative content analysis provided a way to handle a large set of interaction data without necessarily aiming at quantification. The development of the analysis instrument used for this purpose was described in section 4.4.2.

The methodological contribution made by the development and use of this instrument deserves two remarks. First, the approach used to develop this instrument was a hybrid one. Given the large number of studies that have investigated or theorized aspects of collaboration, I thought it was important to build on this body of knowledge instead attempting to reinvent the wheel. A review of studies in Study 1 allowed a selection of relevant insights, which were then complemented by the empirical findings of the same study. Second, the manner through which the instrument was adjusted during the iterative trajectory also confered specificity to the approach and allowed for an increasingly refined account and analysis of the groups' interactions. A possible limitation in relation to the development of this instrument is that it has not been validated in the classical manner. However, its use was subjected to inter-rater reliability measures, and it served the purposes of this research in an appropriate manner. Improvements to the current instrument could involve validation and application in contexts other than institutionalized learning settings.

Lastly, the analytic strategy used to depict the complexity of the knowledge co-construction process deserves mention from a methodological viewpoint. The way I attempted to deal with this complexity was first to develop an understanding of how it is embodied in the collaborative processes being examined. The first exploration of empirical material clearly showed that the interactional process needs to be addressed in interconnection with other aspects of the co-construction process, and primarily with the knowledge objects involved. This is one of the challenges that received much attention, both during the design and in the analysis of the data. It became clear, as explained in the sections above, that the co-construction process was a complex phenomenon in which interactions and emerging knowledge objects had to be viewed and approached as interdependent aspects. Analyzing one and ignoring the role and development of the other would have provided a weighted image of the process. On the one hand, only analyzing groups' discussions would have provided an account of their discursive interaction, but would have left out the way the knowledge emerging is further used and materialized. On the other hand, analyzing only the knowledge objects would have excluded essential aspects of the process, namely, how knowledge is understood, shared, negotiated, re-constructed, and co-elaborated in interaction. Further, the way the intersubjective space and the shared agency were constructed assigned additional complexity to this process. Finally, the

understanding that temporality (discussed in section 6.1.3) plays an important role in this process led the analytic approach to take into account the sequential organization of the interactions and objects' development. Following the way the interaction sequences unfolded and connected to each other in a trajectory fashion allowed for a partial re-construction of how everyday learning processes take place and how this temporality affects the content and the role of the knowledge involved. To conclude, the analytic approach employed, which attempted to capture how these aspects were interwoven and emerged over longer time spans, proposes a diligent way to examine these complex processes. Further refinement of such an approach has the potential to provide an increasingly dependable and detailed view of how knowledge co-construction happens in authentic learning settings and to contribute to elaborated conceptualizations and pedagogical design solutions.

6.3 Theoretical reflections

The conceptualization of the co-construction process emerged from core socio-cultural assumptions, which allowed for an understanding of collaborative learning in its complexity, that is, treating as much as possible all its inherent relations. The socialcultural approach conceives the learning process as a co-construction process that is inherently social, taking place through social interaction, mediated by language or objects, and situated institutionally and socially (e.g., Valsiner, 1994a, 1996; Werstch, 1991). The individual learners and the social environment are not seen as two separate entities, but by definition as interrelated. The individual is involved in a continuous social process, frequently engaging in interaction, relying on cultural or historical tools and artifacts, or creating these, which also further enables social interaction. My approach to the learning phenomenon emphasized the co-construction aspects and how social interaction and knowledge objects are interwoven in this process. I employed the sociocultural stance as the foundation and core source for my conceptualizations, but I corroborated it with a number of concepts coined by other approaches that emphasize the social element of learning. Examples are the notion of epistemic agency, which was put forward in the sociocognitive tradition (Scardamalia, 2002), or the idea of productive interaction, which builds on notions elaborated upon within different traditions, such as the sociocultural and the situated cognition approaches. The empirical findings contributed to furthering the understanding of these aspects in a theoretical sense, and some of them are discussed below.

The main aims of this dissertation were to clarify and further elaborate on the nature of interaction and the way knowledge objects can be part of, are constructed and enhance this interactional process. A large body of research contributed to the development of a, if not unified at least rich, conceptualization of dialogical interaction. The main studies within the field of learning sciences address dialogical interaction from various theoretical perspectives. To exemplify, from the sociocognitive and social-constructivist perspectives, collaboration and the interactional process were investigated and theorized in the classroom context and were characterized in terms of content/task-oriented, process/procedure-oriented actions, spaces of interaction (e.g., Barron, 2000, 2003; Roschelle, 1992), or linguistically facilitated reasoning (Mercer, 2004). In the last decade, however, more attention has been given to the knowledge involved in interactions and the role it plays in the process. The notion of a knowledge object was particularly addressed in a number of theoretical studies (Bereiter, 2002; Carlile, 2002; Wartofsky, 1979). These objects are conceptualized primarily from the perspective of professional knowledge practice, as entities, whether abstract or material, which can constitute objects of inquiry, are question generating, complex, and have the potential to open lines for research.

My conceptualization of the notion is rooted in sociocultural stances, which refer to objects as tools and mediating elements in the interaction. However, the findings in this dissertation provide a basis for conceptualizing the object in a broader manner. Knowledge objects, in their initial and final versions, are proven to embody the knowledge constructed in the intersubjective space and to materialize collective knowledge. In that sense, objects are outcomes of inquiry. However, the findings in this dissertation allow for an expanding of the conceptualization of knowledge objects as mediators of interaction in the sociocultural tradition (Wertsch, 1991) and as objects of inquiry. In the former, objects showed potential for supporting actions that impact the course, content, and dynamics of interaction. In the latter, objects, as conceptual or material artifacts, could be placed in the center of the inquiry, triggered questions and problems, and yet spurred the groups to action towards finding solutions. Furthermore, developing objects offers the opportunity for a group to practice joint elaborations and to sharpen their conceptualizations by writing them down. To conclude, while the idea regarding the hybrid and versatile nature of the knowledge object had been proposed, few empirical studies have yielded results that support this idea. In that sense, I propose that a deepening conceptualization of the role and position of shared knowledge objects in interaction is the most compelling contribution of this dissertation.

Finally, the *shared epistemic agency* construct proved useful for explaining what drives groups to engage in particular types of interactions and to go about working on the knowledge object. The rationale for coining a new construct was the fact that the theoretical and empirical studies reviewed did not make a strong case for how agency is expressed at the collective level in the context of knowledge-related activities without relying profusely on individual members' agency. My core premise was that shared epistemic agency is characterized by a capacity that enables groups to deliberately engage in sustained interaction, which leads to the co-construction of new knowledge and its materialization into a shared knowledge object. The sociocultural approach attempts to account for the position and role of both the individual voices in the interaction and how they contribute to the intellectual interdependence (Valsiner, 1994b; 1996) that characterizes the co-construction process. The way I view and elaborate on the notion of sharedness contributes to this conceptualization and its substantiation. Hence, I also engaged in this investigation with the aim to conceptualize a construct that illustrates both the collaborative quest to construct knowledge and the intersubjective aspects of this process, with the latter coined by the idea of *sharedness*. I elaborated on this construct by building on the notion of epistemic agency, as coined by Scardamalia (2002) and the ideas of sharedness, as depicted above. I conceived the notion of epistemic agency as a parallel to the way Pickering (1985) depicted conceptual agency, which he sees as a rather difficult, invisible ability that enables people to express their will and intention to embody their knowledge within a disciplinary, often constraining, context. Building on Scardamalia's (2002) account of epistemic agency, empirical studies (e.g., Charles & Shumar, 2009; Palonen & Hakkarainen, 2000; Schwartz & Okita, 2004) attempted to show how learners engage in such conduct in the context of collective knowledge work. These studies, however, did not advance the understanding with regard to how the aspect of sharedness is embedded in this collective agentic conduct. The empirical findings provided substantiation and contributed to expanding the conceptualization of the epistemic and shared aspects by showing how agency manifests at the epistemic level, in relation to the knowledge objects being developed, and how sharedness is built through interaction. These results demonstrated that the shared knowledge object forms a common focal point for students and creates the premises for joint actions. Also, that interaction and object development can take remarkable turns because of group members' awareness and engagement with the joint activities and with the knowledge objects. I argue here that agency can be a group production when expressed in the context of working on shared objects of activity. It can play a role in the way groups' agency manifests itself, such as by

acting from a more cooperative perspective (with individual contributions added together) or a more intersubjective one. Intellectual interdependence (Valsiner, 1994b) is constituted through individual learners bringing into the group space his or her own subjectivity, but with the knowledge being co-constructed through a dynamic exchange that shapes the intersubjective space. This makes obvious the complementary and inexorable nature not only of the individual subjectivities, but also the importance of how this interdependence allows for co-constructing knowledge.

6.4 Practical implications

The findings of this dissertation showed how sustained and joint engagement in solving open-ended problems and interaction focused on epistemic aspects have the potential to bring about learners' involvement in complex knowledge work and to stimulate learning. From a more specific pedagogical viewpoint, the findings support the identification of suggestions for organizing learning and instruction wherein knowledge co-construction is a central feature. However, the experiences during the design and the implementation of the pedagogical scenarios indicated that making such learning models and activities a common practice for learning in higher education might not be the easiest task. Designing, setting up, and evaluating such learning situations requires a fair degree of modeling and support, at least for the initial phases of the process and especially in cases of students who are supposed to have no experience with this type of learning activity.

A first suggestion builds closely on the findings of the empirical studies with regard to epistemic actions that lead to generating knowledge and advancing knowledge objects. Such suggestions are directed toward design efforts, which should emphasize the importance of the content knowledge and how it is embedded in the context of the envisioned activities. As shown by these current findings and other studies on collaborative work with knowledge (Muukkonen-Van der Veer, 2010), organizing and facilitating interaction in which the knowledge is the center of the inquiry are both important and challenging. When designing for collaboration, the fact that division of labor does not always lead to committed engagement and in-depth understanding of knowledge must be kept in mind. Such designs should emphasize work that requires: constant encounters to discuss and share ideas and information; situations that call for the re-construction and generation of (new) knowledge, not only adaptations from existing sources; or iterative

writing strategies and the use of feedback rounds, which can facilitate further refinement and elaborations of this knowledge.

A second commission that arises is to inform and facilitate understanding among students with regard to the nature of the learning activities envisioned. An introduction to this type of learning could take the form of a workshop or opening activity of a course. In Study 4 of this dissertation, such *introductory sessions* were organized in both iterations and were appreciated by both students and teachers as having high informative value and impact. Two forms of modeling can be recommended based on the experiences with these sessions and can serve to set up the learning practices that spell out the orchestration of joint efforts in relation to joint practices (Muukkonen-Van der Veer, 2010). *Structural* and *procedural modeling* is aimed at explaining and scaffolding social interaction practices and should explain: what social interaction means in this specific context, how it takes place, what joint efforts and outcomes mean, what is the meaning of "sharedness" versus "division of labor," and the needs and meaning of sustained and prolonged collaborative work. *Epistemic modeling* is aimed at explicating notions such as knowledge co-construction, open-ended problems and shared knowledge objects, and what those entail in the specific context of the respective course, what object-oriented inquiry means, and what joint and iterative elaboration of knowledge objects means and requires. In addition, a demonstration and hands-on training of technology, if the case, can alleviate possible constraints and facilitate students' equal participation in work.

It is also important to consider how to evaluate knowledge co-construction from a curriculum perspective and how to measure the impact of these pedagogical interventions. While both aspects were beyond the scope of this dissertation, the experiences during this work lead to some suggestions in this regard. For the former, one main concern is how to evaluate not only the final outcomes of the learning activity, but also the process and the progress registered by groups during their iterative co-construction work. For instance, such measurement would benefit from creating a set of specific goals that related to the institutional norm. The complexity of the knowledge problems can be specified, in order to make clear the knowledge and strategies needed to address it, and the efforts needed to arrive at a solution. The nature and complexity of the knowledge objects expected to represent an alternative solution could also be spelled out. Further, the type of collective products and processes can be outlined with equal formality as individual outcomes and processes of learning. For the latter, a clear depiction of the nature of the pedagogical interventions, and the possible challenges, could be spelled out. Such learning scenarios

often involve unfamiliar work for teachers and place them in situations where they have to assess and respond promptly, but also thoughtfully, to students' needs. As one of the teachers involved in the fieldwork of this dissertation stated, "You cannot really teach this." It takes insight, spontaneity, and courage to dive into the process together with the students.

6.5 Future directions

The theoretical and empirical research conducted in this dissertation has argued for a deeper understanding of the process of knowledge co-construction and indicated a potential pedagogical reorientation that proposes this type of learning activity for educational practices. However, a more profound understanding of the constructs and models that depict object-oriented interaction and how this type of collaboration can be embedded in the curriculum is needed. This requires both an epistemological shift towards a dynamic view of learning that makes it possible for students to engage in collective inquiries, solve complex and ill-structured problems, and substantiation provided by empirical studies of pedagogical design of such learning practices. Based on the findings, and in line with recommendations by Muukkonen and Lakkala (2009), I suggest a further investigation of how collaborative learning can be organized around the joint development of knowledge objects. Specifically, such studies should focus on describing how the object-oriented interaction and the co-elaboration process can be designed and enhanced by providing tailored pedagogical and technological support.

Closely building on the findings of this dissertation and the methodological reflections presented above, a clear need for a more advanced understanding of the multi-layeredness of learning in interaction is crystallizing. My studies focused on how the constitutive aspects of the process (i.e., social interaction and knowledge objects) emerged, unfolded, and were interconnected at a microgenetic level. However, the findings also indicated that it is important to attempt to grasp the aspects playing out at other levels. This represents an interesting area that is still underexplored. Recent discussions in the learning sciences field (Stahl, 2012; 2013) also indicate that there is a strong need to take a closer look at the pedagogical framework and actions that are built around and guide this learning process, and to analyze the resources that feed into the infrastructure and the processes that support learning in interaction (Stahl, 2013). From a methodological perspective, it is important to devise analytic approaches that depict the way the interconnected aspects

discussed above play out in relation to each other and the instruments that capture the qualitative developments of the knowledge involved in a formative manner.

Traditionally, higher education graduates take the knowledge and skills acquired during their academic studies into the practice, but in recent years the practices of professional knowledge communities have penetrated academic educational environments. A more dynamic relationship is being established. Aspects of importance for both environments are processes of knowledge production spanning over time and sites, and how to operate in a knowledge-rich environment that relies on knowledge objects and epistemic activities (Goodyear & Zenios, 2007; Knorr-Cetina, 2007). Considering these developments, two main directions for future research become important. The first one is based on the insights provided by this research into the notion of knowledge objects, and especially how knowledge objects are employed and developed in learning in interaction contexts. While the analyses employed here were useful for understanding how knowledge is generated and, ideally, built into the object at the micro-level, it is important to extend this investigation. A way to elaborate is by investigating the way knowledge objects become employed and serve further knowledge development and knowledge construction. This involves following the knowledge and the knowledge objects across the boundaries of educational institutions and understanding how they "travel," change, and gain new uses within new contexts (e.g., the internship institutions).

A second direction for future investigation is represented by research on the networked aspects of learning. Learning for the future becomes rather complicated considering that current challenges concerning knowledge development can no longer be met by existing institutional and disciplinary boundaries (Goodyear & Zenios, 2007). In this dissertation, I explored the alternatives of distributed project work (see also Bucciarelli, 2003; Muukkonen et al., 2010; Stankovic, 2009), with the main emphasis on students' learning being situated within institutionalized settings of higher education. These studies, too, emphasized that extending the focus of research towards epistemic practice across sites and domains is an important objective. Following this line of investigation would provide a valuable understanding of the processes that serve knowledge production across domains and how higher education can prepare students to enter these processes. This would involve examining how the knowledge and epistemic practices (Knorr-Cettina, 2001) characteristic of the professional domains influence learning both in formal and informal settings. More specifically, conceptual and empirical studies of learning situations could focus on the design and support for opportunistic collaboration or networked learning, in which students

engage in knowledge-driven activities together with peers, external experts, and access knowledge resources across sites and domains.

6.6 Closing remark

Hacking's (1999) influential work, "The Social Construction of What?", points at the fact that understanding how knowledge emerges as a result of social construction requires a sophisticated approach. From the perspective of learning, this poses us with the interesting challenge of studying both *what* learners construct, the knowledge content, and *how* they engage in social interaction that makes this construction possible. This dissertation provided an in-depth insight into the process of knowledge co-construction, which involved social interaction and joint elaboration of knowledge objects, by elaborating on sociocultural ideas and by empirically investigating learning activities in higher education settings. The findings showed that the processes of collaborative knowledge construction are of increased complexity and that their investigation and understanding are, consequently, far from being straightforward processes. Therefore, it is essential to further pursue lines of inquiry that have the potential to unravel the way intellectual interdependence (Valsiner, 1996; Valsiner & Van der Veer, 2000) occurs and can be enhanced. This research attempted to untangle this complexity at an analytical level and, by this means, offered a deeper understanding of aspects that characterize learning as a social process aimed at constructing knowledge. Based on the insights gained by means of this investigation, I maintain that stimulating and supporting collaboration that entails epistemic interaction, open-ended problems, and complex knowledge objects developed through joint work is a challenging but diligent strategy to entice students into engaging with knowledge.

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Part II

The Empirical Studies

Study 1.

Damşa, C. I., Kirschner, P. A., Andriessen, J. E. B., Erkens, G., Sins, P. H. M. (2010). Shared epistemic agency - An empirical study of an emergent construct. *Journal of the Learning Sciences*, 19(2), 143 – 186.

Study 2.

Damşa, C. I. (in press). The multi-layered nature of small-group learning: Productive interactions in object-oriented collaboration. *International Journal of Computer-Supported Collaborative Learning*.

Study 3.

Damşa, C., Ludvigsen, S., & Andriessen, J. (2013). Knowledge co-construction – epistemic consensus or relational assent? In M. Baker , J. Andriessen & S. Jaarvela, *Affective Learning Together. Social and emotional dimensions of collaborative learning,* EARLI series: New Perspectives on Learning and Instruction, Routlegde Academic Publishers & Taylor and Francis Group, London, UK.

Study 4.

Damşa, C. I., & Ludvigsen, S. R. (under review). *The collaborative construction of what? Learning through interaction and co-construction of knowledge objects in teacher education.* (Learning, Culture and Social Interaction)