Learning through Collaborative Creation of Knowledge Objects in Teacher Education

Crina Damşa, Sten Ludvigsen, InterMedia, University of Oslo, Postboks 1161 Blindern 0318 Oslo, Norway
Email: crina.damsa@intermedia.uio.no, s.r.ludvigsen@intermedia.uio.no

Abstract: This contribution presents an empirical study of object-oriented collaboration. The participants are groups of teacher students, who work on knowledge objects (e.g., didactic materials, study materials and guidelines for teachers) intended to address problems identified at schools where they pursue their internships. The knowledge creation approach to learning, which places collaborative creation of knowledge objects at its core, served as a guide for the pedagogical design, which includes specifications of the collaborative activities and tools utilized. We collected different types of data. Analyses followed three lines of investigation: analysis of group interactions, of concepts and ideas uptake, and of object co-construction and development. Findings show various degrees of idea sharing and of co-elaboration of object iterations. These findings assist us in formulating recommendations for future research and pedagogical design, especially with regard to pedagogical settings, and technological support for object co-construction and co-elaboration.

Introduction

Exposing students to knowledge practices and the problems they will face as professionals is a challenging task for higher education institutions. Various studies (see Muukkonen & Lakkala, 2009) posit that collaborative settings and problems with open-ended character entice students to activate and employ knowledge acquired in different settings, and to envision solutions to these problems together with peers. This calls for theoretical and practical knowledge to be concretized in knowledge objects wherein this knowledge becomes materialized (e.g., in designs, research reports, educational material, etc.) and transparent for the participants involved. However, becoming actively involved in such complex processes and creating sophisticated knowledge objects is a challenging task for students. In order to learn more about how students can be supported in their endeavor, in-depth examination of these aspects is needed. In this paper we investigate how teacher students collaborate to create and develop knowledge objects that will be employed at the schools where they pursue their internships. In our analyses we focus on the interactions that constitute the object-oriented collaborative process, and on the mechanisms of iterative knowledge object development.

Various theoretical perspectives (Bereiter, 2003; Vygotsky, 1987) reconceptualize learning as a social activity, and knowledge as socially constructed. The idea of learning as a social activity has been explored and investigated from various angles, i.e., the situated approach or the different versions of social-cultural theory. In our work we employ the latter, and we emphasize the epistemic and regulative dimensions of learning in interaction and collaboration, aimed at creating new knowledge objects. The focus on creation and development of knowledge objects is proposed by Paavola and Hakkarainen (2005), as part of their view of learning as a collaborative, knowledge-creating activity. As posed by Van Aalst (2009), this view goes beyond objectivist stances, and emphasizes that understanding and knowing are mediated by the objects that are created and shared by a community. Rather than residing inside individual minds, ideas are regarded as cultural objects that mediate learning and understanding. In general, objects play an important role in human interactions, as they structure interaction, generate problems (Jordan & Henderson, 1995), or provide groups with motives for interaction or outcomes to reach for (Stahl, 2006). However, in spite of the theoretical account of objects in learning settings, not much is known about how they emerge from these interactions, about the way these objects develop and change over time, or about how they are mediated by collaborative technologies. When studying objects, the emphasis has been placed mostly on the role of objects (see Eckert & Boujut, 2003) rather than on the nature of the objects themselves (Ewenstein & White, 2009). Hence, in order to investigate whether objects play a key role in knowledge creation and learning, we need to understand how objects become constituted and how they are developed.

This paper attempts to examine the mechanisms of collaborative creation of knowledge objects in a teacher training program. The aim of this study is twofold. First, we aim to pin down interactions that lead to knowledge object development. Second, we seek to understand how the knowledge objects created gain shape through collaboration, and how object development can be related to interactions between participants. In the case study reported in this paper, we employ a qualitative perspective, as well as methods to gain a better understanding of the aforementioned processes and to depict their characteristics. A set of data from an extensive design study that involved teacher students working on collaborative projects is used to illustrate these mechanisms. Analyses aim to unveil the characteristics of learners' interactions that contribute to object advancement.

Productive Interactions and Object Development

The idea that interactions are productive builds on the concepts of social and constructive interaction. The former accounts for learning as a socially shared and culturally situated phenomenon wherein activities and meanings are subjectively realized (see Ludvigsen, 2009). The latter refers to learning in and through dialogue (Baker, 2009), and is related to the social construction of meaning and knowledge as proposed by the various socio-constructivist views of learning. In knowledge creation, the denotation of this concept expands from collaborative meaning-making to the materialization of knowledge objects.

A brief literature study shows that there are no clear-cut definitions of the concept of "object". Objects are referred to as a collection of artifacts that individuals work with, i.e., create, measure, and manipulate. To avoid confusion between the terms "object" and "artifact," we refer here solely to objects, given the synonymous use of both terms in the literature (see Paavola & Hakkarainen, 2005). It seems plausible to adopt a broad definition of objects, most notably because they also vary in their degree of abstraction (Ewenstein & Whyte, 2009). We adopt the distinction between historical object of activity, which is developed and represents an answer to societal needs (e.g., assessment systems), and situational object, which is a manifestation of the historical object but is procedural and discursively constructed (e.g., a report produced by a group of students in a project). The interaction of learners, in this case, is only understandable in relation to this situational object they construct together (Jahreie, 2010). Thus we employ the concept of object as conceived in the latter stance.

Knowledge objects, also referred to as epistemic objects or epistemic things (Miettinen & Virkkunen, 2005), are considered to focus on what is not yet known. These authors described epistemic objects as open-ended projections oriented towards something that does not yet exist, or to something that is not known for sure. These objects are characterized by their incompleteness and continuous evolution (Ewenstein & Whyte, 2009), and as projects under construction, moving from potential raw material to meaningful forms (i.e., iterations), resulting in a final outcome. Work itself is therefore a continuous process of transforming an object from its current state into a required end state. Examples of epistemic objects may include theories, plans, protocols, etc. Our stance becomes instrumental when attempting to understand the way objects are created and how they develop. We approach these processes with the premise that knowledge objects are evolving entities, which are shaped by the interactions around them, but which also shape those interactions. This stance allows us to understand how students' learning evolves over extensive periods of time.

Methods

This one-year study was conducted at a university of applied sciences and teacher education in the Netherlands that prepares pre- and in-service teachers for secondary vocational education. The curriculum is based on courses called Professional Situations (PS). 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. These projects required students to perform various learning tasks (literature reviews, risk assessments, designs). Twenty groups of 73 mixed-age students, enrolled in three randomly selected PSs, participated in our study.

Through the project we present here, students' learning was enhanced by facilitating participation in collaborative projects in the PSs. Groups of students were required to develop and report on knowledge objects (e.g., didactic materials, study material for teachers, guidelines for applying new teaching methods, etc.). Various scaffolds were provided, such as workshops on object-oriented collaboration, templates for work plans, and tool-training sessions. Brainstorming sessions were organized to discuss topics collected at those places where students pursued their internships. Next, topics were clustered and, based on these clusters, project topics were formulated by the students themselves. Once the project groups were formed, students' interactions focused on the chosen topic, and took place mostly within group and with the tutor. Group members had the opportunity to work online, to meet face-to-face, and to have regular coaching sessions with the tutor. Groups were required to provide theoretical grounding for their products and, at the end of the project, students were to reflect on the quality of the object and their individual and group activities.

Technological support was provided by the Knowledge Practices Environment (KPE, see www.knowledgepractices.info), a web 2.0 application that provides virtual collaboration spaces. In the KPE, each group had its own shared virtual work space. Inside these spaces, students were expected to use functionalities that supported the organization of the collaborative process (i.e., task creation and planning functionalities) and the creation and iterative development of knowledge objects (i.e., item creation, versions, commenting, linking, sources collection and display, and chatting). We collected a rich set of data, consisting of the following categories: (a) interaction data (recordings of group meetings, e-mail correspondence, field notes); (b) knowledge objects, both produced in KPE (documents, wiki, notes, comments) and during fieldwork (meeting notes, comments, course documents, project material), and (c) reflection data (reflective questionnaires, semi-structured interviews). This contribution discusses data drawn primarily upon the transcribed group discussions, object iterations (text documents), and meeting and researcher's notes. Data were chronologically ordered, and the analyzed recordings were transcribed verbatim. We used a set of analytic tools

embedded in the KPE, which provide an overview of the members' activities in the shared space and contributions to the developing objects.

For the purpose of this study, a *case* was defined as the activities and products of one group of students during the 20-week course period. The analyses followed three lines of investigation. *First*, we selected and coded action-relevant episodes from the group's interactions, in order to understand the nature of their activities. We conducted a focused examination of those episodes and selected from the five discussion sessions, equally distributed over the project period. The categories employed were based on a coding system developed by Damşa, Kirschner, Andriessen, Erkens, and Sins (2010), and refined based on the models of discourse by Van Aalst (2009). The case emerged based on a literature review and iterative analyses of other (similar) data sets. The resulting categories distinguish between epistemic actions aimed at eventually creating knowledge (i.e., creating awareness, sharing knowledge, creating shared understanding, and generative collaborative actions) and regulative actions (including planning, coordinating, monitoring, and reflecting activities). We labeled all actions and traced the newly introduced concepts and ideas. *Second*, we mapped the relevant concepts and ideas discussed during the analyzed interactions, and examined whether they were adopted and materialized into the knowledge objects (and their iterations). The relevant-concepts map was created based on the first discussion session of the group, then it was subsequently revised. Only new relevant-concepts and ideas were added to the map, based on subsequent group discussions. Next, we created a concept map based on different versions of the knowledge object the group created. We compared the concept maps created based on interaction and object versions and established the similarities, the relevant-concepts and ideas that were put forward most frequently and those that were elaborated in the final object version. *Finally*, we operationalized object progression and elaboration, and analyzed how the relevant concepts and the ideas generated were gradually materialized and elaborated into object iterations. Several readings of these iterations led to the understanding that object development can be described based on two aspects: first, the way concepts and ideas are adopted from one interaction to another and, second, how ideas and concepts are conceptually expanded from one iteration to another, i.e., elaboration. To determine the degree of elaboration, we employed an instrument containing four levels, derived from Cummings, Schlosser and Arrow's (1996) concept of the integrative complexity of ideas. The following levels were distinguished: (0) idea or concept was not further elaborated in the subsequent object iterations; (1) low integrative complexity means that the content is constructed using (literally) information selected from one or more sources; (2) moderate integrative complexity means that multiple perspectives are expressed, based on information sources and one's own insights, but without new conceptualizations; (3) high integrative complexity specifies 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.

Empirical Analyses

The analyses concern one student group, named BOKITO, consisting of four female students; however, the whole data corpus was analyzed, following an ethnographic approach, to identify variations between groups and aspects that reflect problems illustrative of students' experiences. We selected this group because their activities and knowledge object provide a good illustration of how knowledge is created. This sampling can be situated between representative and theoretical sampling. We analyzed the group's materials and activities over the course of 20 weeks (February–June 2010). This group's members were enrolled in PS11, which focuses on the analysis, design, and evaluation of assessment instruments. Students were required to conduct a literature study and, based on its conclusions, design an assessment-related product. The group conducted a study on quality criteria for authentic assessment methods in competence-based education, and developed a set of guidelines for teachers who intend to use such methods in secondary and tertiary vocational education. The product was concretized in a report containing the literature study, a description of the developed object, and explanations regarding the choices they made in the design process. Additionally, the group summarized these recommendations in artifact resembling a fan, with several plasticized sheets, containing the main guidelines.

This section begins with a discussion of an interaction sequence, followed by an illustration of the uptake of relevant concepts and ideas put forward in the respective interactions. Next, illustrations of the object progression and elaboration are presented and discussed.

Productive Interactions

In this group's work we noticed a high concern among students about understanding concepts. Concepts related to *assessment* took a central place in group discussions. A relevant portion of the interactive sessions was dedicated to deciding which concepts and ideas were relevant, what their meaning was, and how they should be explained, linked to each other, and elaborated. One strategy for elaborating such conceptual systems was by discussion; another was by searching for external information and integrating it with their own ideas.

An analysis of sources led to the development of iterations of theoretical section A, in which the group analyzed and separately presented both traditional and new quality criteria for assessment, and three assessment methods specific to competence-based education. The following step was to shape the next section of their

knowledge object, wherein they planned to establish a relationship between the three assessment methods and the quality criteria. The following discussion episode is selected from an interactive session used for brainstorming and making plans and establishing agreements for this object section.

Excerpt 1, eighth project week: Elaboration of concepts and object versions

Participant	Discussion line	Analytic categories
1. Liz:	…So, in Part A we have these theoretical sections, wherein the main criteria validity, reliability, transparency, and authenticity are defined and explained…and then …	(3) Structuring concepts
2. Ann:	Then we apply them. No, wait…	
3. Jane:	No, we don't apply them. **We establish the relationship between the criteria and each method.**	(3) Framing focus
4. Ann:	Yes, that's it. In here **it goes from broad to more specific, related to the practice situation and the specificity of the method**. […]	(3) Elaborating ideas
5. Liz :	**But how do you translate the theoretical idea to the very practical way** these assessment methods are used in our schools?	(3) Problema-tizing
6. Ann:	A good point, but we shouldn't go in that direction. I see it differently. I would suggest that **we take each method as described and discuss how we think it should be applied to meet the quality criteria.**	(4) Generating new idea
7. Jane:	But that is again very theoretical, don't you think? Why not **take the standard way designed for our schools and check that out in relation to the criteria? Then make conclusions** based on that.	(4) Negotiating ideas
8. Ann:	Can you explain? I don't get it.	
9. Jane:	Errrm, well, **in my school they have, for example, this common assessment form for proof of competence**. All the assessors must use it, and the assessment of the same pupils by **more assessors** is discussed at the end. It's something that has to do with **reliability**.	(2) Sharing information (3) Framing Focus
10. Liz:	... While reading about validity I came across things I recognized in practice. **The task, for example. How that is covered by the tests has to do with content validity**.	(2) Sharing information
11. Ann:	Also with authenticity. Tasks have to reflect the real work situation.	(3) Elaborate idea
12. Liz:	Right, see? I guess this is the way we can go.	
13. Jane:	And the **context,** too, can influence reliability.	(4) Sharing inf.
14. Ann:	Yes, **let's see how we approach this**. I guess **we can each collect the information from own school**, maybe **from the** web about other schools, too? **Then we discuss and then start writing**.	(5) Planning and coordinating process

This episode shows the way group members attempt to establish a link between the theory on quality criteria and the existing methods. The first utterance by Liz (line 1) immediately provides a good summary of the relevant quality criteria the group chose to elaborate (*validity, reliability, transparency*, and *authenticity*). At this point, the existing knowledge is structured, and it serves as a basis for brainstorming about the conceptual links possible in the respective object section. In the next lines, the students attempt to establish the focus of this section, and they do it by taking up the idea put forward in their second meeting (line 3: *We establish the relationship between the criteria and each method*). By problematizing and elaborating on the proposed idea, students come to a better understanding of what this relationship actually means and how they might approach it. This is needed because, while the general goal of this step (i.e., establishing the relationship) is clear, the way they will elaborate on this relationship still needs to be delineated. By generating a new idea (line 6), by negotiating aspects that seem not to suit some of the members' views of the conceptual system under consideration (line 7), and by elaborating on their own or others' ideas (lines 4, 11), the students reach a common understanding of the conceptual system under development. Based on this, they pin down the strategy they will use in order to materialize the ideas put forward.

Uptake - Relevant Concept Map

The concept map created based on the object iterations defined one week after the above interaction shows that the relevant concepts from this interaction sequence are adopted by the group and processed into the object. In the concept map in Figure 1, we clustered these concepts (using interrupted-line rectangular frames) in order to indicate how the concepts were treated by the group, both in the discussions and in the object iterations. In fact, this is a conceptual system created by the group members themselves during verbal interaction and, later, in the text iterations. The gradual shading indicates the importance assigned by the group to the concepts (the darker shading indicates the most important concepts), while figures attached to each box indicate the interaction analytic framework category - see excerpt above). In the center, a number of main concepts are shown (*quality criteria for authentic assessment, authentic assessment methods, relationship methods*, and *criteria*), which were adopted from the previous discussion sessions and the first object iteration. These concepts cover the main

topic of the project. In the upper-left corner are the authentic assessment methods proposed in the second meeting, which were adopted by the group as one of the focus of the knowledge object. These methods are defined and described in the first section of the knowledge object, the research report. The two clusters on the right side of the map display the quality criteria as identified by the group members, in discussions (also with their teacher) in the literature, and in the preliminary object iterations. In this map version, the group indicates that "validity" and "reliability" are traditional psychometric criteria, while the others are specifically related to authentic assessment. The group decided on the former two and on "transparency" and "authenticity" to be further elaborated in their knowledge object, and they provided arguments for their decision. The cluster of concepts in the lower section of the map indicates some concrete elements (instruments, activities) used or performed in the educational practice to ensure quality of assessment. These are used by the group in the object iterations, in order to bridge concepts and to emphasize the relationship between the two conceptual dimensions (methods and criteria) elaborated upon. The last cluster, in the lower-left corner, contains the weight points of the knowledge object and the way the relevant concepts were to be elaborated.
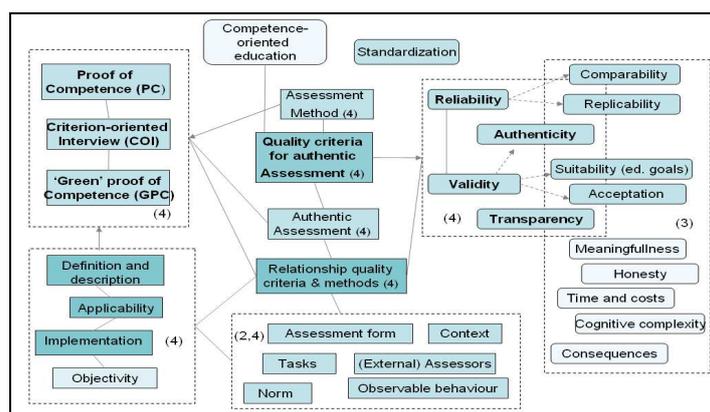

Figure 1. Relevant-concepts Map Based on Interaction in the Eighth Week and Object Iterations in Weeks 9-12.

An analysis of the progression of the knowledge objects shows that the majority of the concepts proposed in the first two group meetings were adopted and evolved into knowledge objects (materialized in the iterations) at later stages. The main concepts (*quality criteria, assessment methods*) were employed throughout the entire project period. These concepts were defined and described in general terms in the introduction of the report, but no extended analysis of these general concepts was conducted. The concepts directly addressed in the project, i.e., the three assessment methods and the four quality criteria, were adopted fully, explained and described based on information sources, and elaborated in relation to each other. Some concepts were dropped, and some interaction instances indicated that this was a deliberate decision of the group, since these concepts were not (directly) linked to the focus of the study.

Object Progression and Elaboration

The general overview based on the analytic tools provides an insight into the individual contributions to the shared knowledge object, in terms of types of items created using functionalities at their disposal in the shared virtual work space. As the figures in Table 1 show, the number of contributions is rather comparable, without obvious outliers. Jane is the only member who seems to have uploaded or modified most files, but the meeting notes and observations indicated that she was the one who was assigned to upload all product iterations when finished. The higher number of links created by Liz indicates that she organized the materials and created the relationship between various sections and iterations of the object.

Table 1: Illustrative overview of contribution to the object.

Group member	Files (iterations)	Links between items	Comments (on files)	Web links
Jane	38	12	7	5
Ann	26	11	5	0
Liz	21	21	6	0
Julie	23	11	8	0
Teacher 1	0	0	8	2

In qualitative terms, the activities emerged according to the general research activities phases. In the beginning, brainstorming took place and ideas were proposed as topics for investigation. Once the focus was decided upon, following discussions with the stakeholders and a preliminary source search, a joint plan was created. The plan consisted of the research topic, focus, and the types of activities to be performed. Once this

plan was accepted, the group proceeded with individual source searching and information processing. Information was first summarized, then discussed with the group, then processed individually in text (in object iterations), and later discussed in the group again. Also, group members gave written feedback on the written draftsAll the object iterations were placed in the group's shared space, where there were possibilities for conceptual structuring and commenting. Once the theoretical section on methods and criteria was partially elaborated, work on linking the theory with the practical solutions commenced. The same strategy was applied as in the previous phase. Once various sections were commented upon and finalized, they were organized and integrated into the final object.

Object elaboration at level zero (0) was applicable to 10 concepts identified in the group's interactions, which were then omitted. Other types of data indicate that these concepts were not elaborated, based on deliberate decisions, because they were considered too marginal to the main topic. While the purpose of these analyses was not quantification and normative assessment, we can state that, on average, overall elaboration is situated as the second level of our framework. At this level, information from sources and group's own ideas were used, sometimes combined, in order to explain and expand the concepts in discussion. However, the levels of conceptualization differed between the sections of the report. In section A, the literature study of the assessment methods and criteria, the average level was two (2). This indicates that the literature was not interpreted and processed in depth. In Table 2, we present an example of a comparison between the source text and the text written by the students, which was assigned level 1 of elaboration, a rather low elaboration level. Furthermore, a relatively low number of sources were used when defining and describing the quality criteria. Nevertheless, the group succeeded in structuring the text and employing the source information in a meaningful manner, which contributed to achieving their goal, namely presenting the given concepts in a concise manner.

Table 2: Example of a level 1 elaboration object sequence.

Text from sources	Group's text
2 Comparability Consists of that a Competence Assessment Program (a) must be performed consistently. The (b) assignments done by students, the de-evaluation procedure, and the evaluation criteria must be comparable in sufficient degree for all students. In competence-based education this is (c) not always easy to oversee and it also doesn't means that the entire assessment should be standardized. But a study program can (d) pose particular requirements to the practical training in a company and to (e) the tasks a student must perform as part of this practical training.	Comparability Consists of that the assessment (a) must be performed consistently. The (b) assignments done by students, the de-evaluation procedure, and the evaluation criteria must be comparable for all students. In competence-based education this is (c) not always easy to oversee. It also doesn't mean that for each assessment there is a standard that can be employed, but there are, for example, (d) particular requirements that can be posed to the practical training and to (e) the tasks students must perform during the practical training.

In section B of the product, elaboration of concepts was at the highest level. Information sources were used to explain various theoretical aspects but, in general, the information from the sources was well integrated with students' own ideas. In this section, it was students' interpretations that were the leading element in the elaboration, and not the structures provided by the literature. The former became visible in the way particular ideas were elaborated across the versions, and by the conceptual elaboration techniques that were employed. Such techniques involved: creating arguments based on conflicting input from the literature versus education practice, providing examples, or providing elements of reference for comparison. To illustrate the aspect of gradual elaboration of one's own ideas and materialization into the text, we present an example of how a text section evolved across the three iterations we analyzed. Because the original text was too extended to be presented here, we summarized and synthesized the content (see Table 3). The text deals with the relationship between the method (*Proof of Competence*) and the criterion (*Authenticity*). In each of the three columns, the type of material and the strategy used to work with that material are described, while in the boxes attached to the table we indicate the type of action taken by the group upon the respective iteration. In the first iteration (column 1), the idea of the relationship between the two concepts is in an initial phase of elaboration. Knowledge presented in the previous section is repeated, and information from sources is used to provide arguments for this relationship. Here the students establish an unelaborated link with educational practice. Iteration 2 is further elaborated towards a more integrative use of one's own ideas, information from sources, and information from practice. There are not yet any conceptualizations based on these different perspectives and there is, still, information presented in list form, without explanations. The third iteration, which follows a systematic round of feedback by all group members, shows a higher degree of elaboration and the creation of a new conceptualization that employs different perspectives. Examples are used to support the given explanations.

In general it appears that students adapted their strategy to the purpose of each section. In the first section the goal was to provide definitions and descriptions of the concepts agreed upon in the interaction sessions, not to provide extended elaborations. In the second section, the goal was to establish a link between the quality criteria and the three assessment methods, which required interpretations, conceptual expansion, and

application of theory. To conclude, we can state that the level of conceptual elaboration varied rather strongly between sections, which means that the object development was not optimal.

Table 3: Example of elaboration across object versions.

Iteration 1	Iteration 2	Iteration 3
1. Method and criterion – definition and explanation	1. Method and criterion – definition and explanation	1. Method and criterion – definition and explanation
2. One paragraph containing a summary of source information on why this criterion is important	2. One paragraph containing a summary of source information on why this criterion is important	2. One paragraph containing summarizing source information on why this criterion is important
3. Three sentences on possible assessment situations to be taken into consideration as assessing institution.	3. Elaborated paragraph explaining several assessment situations to be taken into account by the assessing institution	3. Elaborated paragraph explaining several assessment situations to be taken into account by the assessing institution
	4. Summary of literature on a framework used to formalize the possibilities and the options the assessing institutions has to meet the criterion	4. Presentation of the framework using the source information, but processed reformulated) and using quoting
	5. List of tools associated with the above framework	5. List of tools associated with the above framework with explanations for each tool
		6. Paragraph on how the tools can be employed and applied in to the given situations presented by point 3; with examples.

Group discussion on the applicability of the criterion	Written feedback on preliminary text by group	Structure of final version

Discussion and Concluding Remarks

This paper focused on understanding the mechanisms of collaborative creation of knowledge objects, by analyzing the interactions of students engaged in authentic projects, and by tracing the development process of the group`s knowledge objects. The analyses and preliminary findings presented in this paper provide an insight into how knowledge objects are created through a collective effort in this type of pedagogical setting. We were able to interpret the interactions as being productive through mapping of concepts and ideas put forward in interaction sequences and by "following" these concepts as they were pursued and as they "grew" through object iterations. The analyzed *interaction*s had a heterogeneous character. The productive interactions that explicitly led to shared agreement and understanding, and to generation of new ideas, enhanced the conceptual development of the shared knowledge objects. The analyses yielded *sets of relevant concepts*. The relevant concepts identified through concept-mapping showed that the majority of concepts and ideas put forward in these productive interactions were adopted, expanded, and elaborated. *Elaborations* led to the materialization of the group's shared views and stance, since the concepts chosen for elaboration were decided upon in the interaction. However, much of the work of expanding these concepts and ideas took place individually and led, at times, to lower levels of elaboration. Finally, individual contributions were closely combined with joint activities. Individual elaboration led to numerous feedback moments by the other group members. The analyses indicated that the object sections that were discussed more than once showed a higher degree of elaboration.

These findings provide ideas for improvements of the pedagogical setting. First, productive interactions should focus on the epistemic aspects of work on the shared object (see also Damşa et al., 2010). This group of students approached their interaction not only from a procedural level, but also interacted around concepts, ideas, and the knowledge object itself. They became involved in desirable practices that should be further stimulated and applied in other settings. Next, we partly illustrated successful instances showing the materialization of the group's views and ideas into concrete objects. Different studies (Van Aalst, 2009) indicate that this is not the default way of working on shared knowledge objects. In most cases, complete division of labor occurs. In this group we also observed deliberate attempts to discuss knowledge domain-related ideas, collaborative editing, and consistent feedback on individually written texts. This indicates an orientation towards a collective way of acting upon the shared object, to be considered when organizing and coaching group work. It is 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 pedagogical setting and, also, to how these types of designs can provide more specific scaffolds for students when entering knowledge co-construction processes. At *theoretical* level, our study contributes to the field by, first, problematizing and extending the discussion on the concept of "knowledge object". A second contribution consists of the attempt to link this concept, and the way it is materialized, to the productive interaction concept. This theoretical discussion is taken up at *empirical* level, where we investigate this link by creating and integrated analytic framework that addresses both the interaction process and the developing knowledge objects. Hence, at *empirical-analytic* level, our contribution rests in the

attempt to employ different analytic angles and to tackle these processes from an organic perspective. However, while very functional in categorizing interactions, our analytic categories prove to be insufficient in unveiling the way students follow up on the topics based on the interactions. In the same way, the elaboration framework developed based on Cummings et al. (1996) provides us with an ideal model. This model is useful when unpacking the conceptual structure and elaboration of the object but it leaves out important aspects of the collective contributions to and the (gradual) progression of the object. As such, this study contributes to the field by demonstrating the necessity of an integrated analytic approach, and a joint interpretation of the processes involved. Nevertheless, there are several aspects that require careful consideration when attempting to formalize the analysis framework employed. We have used an explorative in-depth case-study approach that attempts to unveil mechanisms of a complex process. In order to refine the method used here and to increase the potential for future generalizations, an extended analysis on a larger sample is recommended. Regarding the design and use of *technology*, this study showed how face-to-face collaboration can be organically combined with online support. Although the analyses in this paper did not focus specifically on the use of technology, the processes and products analyzed emerged in the context of technology-supported collaboration. Reflections on these activities indicated that KPE provided good support for work on developing the knowledge objects (individually or jointly) and organizing the group work, but lesser support for communication.

To conclude, our assumption that productive interactions lead to the emergence and development of knowledge objects worked upon by the participating groups is partially confirmed by the illustrative material analyzed and discussed. Furthermore, the emphasis was on envisioning ways to analyze and display the (interactional) processes taking place and whether there is a follow-up to these interactions in the object iterations and the final knowledge objects. Our attempts to understand and depict the process of collaborative creation of knowledge objects and the way these object develop provided important insight, but more work is needed to specify and ground these phenomena.

References

Baker, M.J. (2009). Argumentative interactions and the social construction of knowledge, in N.M. Mirza & A.-N. Perret-Clermont (Eds.), *Argumentation and Education: Theoretical Foundations and Practices*, Berlin: Springer Verlag, pp. 127-144.

Cummings, A., Schlosser, A., & Arrow, H. (1996). Developing complex group products: Idea combination in computer-mediated and face-to-face groups. *Computer Supported Cooperative Work, 4*, 229-251.

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. *The Journal of the Learning Sciences*, *19(2*), 143-186.

Eckert, C., & Boujut, J.F. (2003). The role of objects in design co-operation: Communication through physical or virtual objects. *Computer Supported Cooperative Work, 12,* 145-151.

Ewenstein, B., & Whyte, J. (2009). Knowledge practices in design: The role of visual representations as 'epistemic objects'. *Organization Studies, 30*(1), 7-30.

Jahreie, C.F., & Ottesen, E. (2010). *Construction of boundaries in teacher education: Analyzing student teachers' accounts*. Mind, culture and activity ISSN: 1074-9039

Jordan, B., & Henderson, A. (1995). Interaction analysis: Foundations and practice. *Journal of the Learning Sciences, 4*(1), 39-103.

Miettinen, R., & Virkkunen, J. (2005). Epistemic objects, artefacts, and organizational change. *Organization, 12*(3), 437-456.

Muukkonen, H., Lakkala, M. (2009). Exploring metaskills of knowledge-creating inquiry in higher education. *Computer-Supported Collaborative Learning, 4,* 187-211.

Paavola, S., & Hakkarainen, K. (2005). The knowledge creation metaphor – An emergent epistemological approach to learning. *Science & Education, 14,* 535-557.

Stahl, G. (2006). *Group cognition: Computer support for building collaborative knowledge*. Cambridge, MA.

van Aalst, J. (2009). Distinguishing knowledge-sharing, knowledge-construction, and knowledge-creation discourses. *Computer-Supported Collaborative Learning, 4*, 259-287.

Vygotsky, L. (1978). *Mind in society: the development of higher social processes*. Cambridge, MA: Harvard University Press.

Acknowledgments