Co-construction of Knowledge Objects in Computer Engineering Education

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Abstract: This study examines Computer Engineering undergraduate students' collaborative design and development of knowledge objects (e.g., webpages). Computer Engineering is a resource-rich, dynamic domain, which offers opportunities for inquiry and the construction of complex knowledge objects. However, the students must learn how to engage meaningfully in such knowledge production practices and to make use of the domain's large pool of available resources. This study provides a better understanding of how students employ programming strategies, select and mobilize knowledge resources and collaborate to co-construct knowledge objects. A rich set of data enabled a detailed examination of these aspects. The findings emphasize the necessity for students to understand the strategies and knowledge underlying the (collaborative) programming practices, besides knowing how to apply these and to develop the capacity to explore, select and assess new knowledge resources; and, for the institutions, to provide the appropriate guiding structures for this type of learning activities.

Introduction

This study examines Computer Engineering undergraduate students' participation in the collaborative design and development of knowledge objects (e.g., webpages) and aims at providing a better understanding of how students employ programming strategies, select and mobilize knowledge resources and collaborate to co-construct knowledge objects.

In recent years, higher education programs are challenged to prepare students to be competent knowledge workers. This implies ambitions for students to be more than just users of knowledge, mere "course-takers", but to develop capacities to process, assess and employ knowledge, and to become knowledge producers (Shaw, Holbrooke & Burke, 2011). Generally, there is wide agreement that such activities can be beneficial for students' later involvement in knowledge work (Spronken-Smith & Walker, 2010) and study programs are, progressively, including this type of learning activities in their curricula. Recent studies (Aditomo et al., 2013) indicate, however, that meaningful participation in learning activities that involve investigative work with knowledge and knowledge construction is not a straightforward matter, and more research is needed to understand, and be able to support, students' engagement in this type of activities within the context of knowledge domains.

Empirical studies in higher education that examine inquiry-based learning and collaborative work, which are characterized by a question-driven mindset and require sharing, understanding and building new knowledge collaboratively, appear to focus predominantly on the students' discursive participation and experiences with investigative work. These studies identified collaborative problem solving, processing of information from (scientific) sources or creating shared understanding of ideas and concepts as main features of the inquiry processes. They also indicated misunderstandings regarding the nature of these activities, which students' described as knowledge gathering (Levy & Petrulis, 2011) and difficulties they encountered when required to solve open-ended problems or to participate in unstructured tasks (Spronken-Smith & Walker, 2010). Few studies examined knowledge construction, the knowledge objects being developed and the way collaborative work is organized around these. Studies of collaborative knowledge creation in small project groups showed that such processes involve shared understanding, joint actions at the epistemic level, and a good balance between work with knowledge and the management of the process (Damşa, 2014; Muukkonen & Lakkala, 2009). This lead to the conclusion that students have difficulties to accomplish both the knowledge-productional aspect, and an active participation in the collaborative process.

This study aims at providing a better understanding of the process of collaborative work that involves the construction of knowledge objects (i.e., webpages) and the use of domain-specific knowledge resources by students in computer engineering education. The study addresses the following questions: 1) How are these knowledge objects co-constructed by the student groups through collaborative programming? 2) How do groups mobilize and use domain-specific knowledge resources? and 3) Do the developing knowledge objects and the used resources enhance the inquiry process? Ultimately, the study aims at accounting for how these activities facilitate the emergence of programming practices students are expected to learn.

Characteristics of the computer engineering domain

The characteristics of the *computer engineering* domain practices create a specific context for the knowledge practices students are expected to learn. The knowledge artifacts are a prominent feature of the domain (Mackenzie, 2005), which appears to have a high degree of structure and specialization in terms of collectively shared technologies, standards, and procedures, and a broader, outwards orientation towards evolving and dynamic epistemic practices. The knowledge content of this domain is geographically dispersed and often represented in online resources (professional databases and forums). Professionals are oriented towards these global information structures and take responsibilities for keeping up with new skills and technological advancements. Furthermore, studies of the computer engineers' epistemic practices (Nerland & Jensen, 2010) have shown a tendency to engage in solving problems and developing knowledge artifacts by using sophisticated solutions because these are considered intellectual challenges. In this context, for students, the challenges emerge to construct a deep and solid understanding of the domain-specific knowledge, develop the ability to apply key technical and professional skills fluently, and engage in authentic engineering projects (Litzinger, Hadgraft, Lattuca & Newstetter, 2011).

Knowledge object: Conceptualizations and empirical insights

Socio-cultural perspectives of learning serve the purpose of depicting the mechanisms and arrangements through which knowledge is produced and circulated (Knorr Cetina, 1999). At a micro-level of these activities, ideas regarding the mediated nature of learning, i.e., by various (intellectual) means and tools (Säljö, 2004) are of relevance. Knowledge resources are such mediational means that accumulate collective knowledge and experience and have instrumental value. Knowledge objects, inter alia, are developing entities and can be addressed in collaborative settings by negotiating, drafting, developing and materializing new ideas and solutions (Miettinen & Virkkunen, 2005).

Knowledge objects are depicted as being the same with research objects or epistemic things, which are "material entities or processes […] that constitute the objects of inquiry" (Rheinberger, 1997, p. 28). An inner contradiction in relation to the nature of the object is highlighted, namely, that it is considered to be both of a material and ideational nature; thus, it can be both a realization of a material reality, respectively, the object of thought. Rheinberger (1997) and Knorr Cetina (1999) distinguish technological objects or objects as instruments, i.e., clearly defined and finished objects with an instrumental role, from the epistemic or knowledge objects, which are question-generating, open to transformation and further exploration, and have the potential to open new lines of inquiry.

For the purpose of this study, it is exactly the dual potential of the knowledge objects that is important. The complexity of this construct lies in its dynamic position in relation to inquiry processes, which can allot the object the role of mediating tool or object of inquiry. In the case of the former, the knowledge objects are represented by an amalgam of material and conceptual (ideatic) resources, which activate a set of opportunities when they are employed. In the case of the latter, it is the open character of the knowledge objects, which makes them more processes and projections rather than definitive things. The defining features are the changing, unfolding character and their incomplete, continuously evolving nature, which makes them rather open-ended projections and generators of new conceptions and solutions.

Methods

As part of a larger research project examining knowledge practices and student learning in higher education, this study was conducted in a Computer Engineering bachelor's degree program at a university of applied sciences. This program offers bachelor's degrees in the engineering and information technology field and was selected because of its specific domain delimitation and the measures taken to introduce a research-based curriculum. Direct access to the sample group was obtained through a call to the students and teachers, with the participating students signing up voluntarily. The sixteen participating (2 female, 14 male) students were organized in four project groups. Activities in an introductory course in web design and development – *Web Project*, was observed and documented. The course contained varied learning and instructional strategies aimed at introducing students to the domain. Bi-weekly lectures were provided during a period of seven weeks to introduce the programming languages of web design and development (i.e., HTML5, CSS, PHP, Java software); ten other lectures introduced students to the field of project management. In bi-weekly lab sessions, the students worked on individual assignments on basic programming skills. A four-weeks collaborative *web development project* required student groups to design and develop a functional webpage, by using the programming languages learned during the course and web-based resources, and to write a justification report. Each group employed online platforms and tools, tailoring the use in accordance to their own needs. Github, an online repository and collaborative platform used by programmers, was used by the teacher to make available course materials, assignments, guidelines and links to resources. All groups used this platform to access these materials, and one group also as a workspace. All four groups used Facebook group pages for communication. Three groups used Dropbox to store and share their developed object versions, resources and other materials. Various online platforms (e.g., w3schoools, Stack Overflow) were used as main resources for the programming work; an online tool was used to assess the codes at different stages of the programming process.

Interaction data (video recordings of group meetings, online communication), knowledge objects (notes, mock-ups, versions of the products), and course materials were collected. The qualitative analysis focused on identifying: a) how the design and development took place through the collaborative process; b) the way knowledge resources were accessed and mobilized; and c) how the developing object mediated the collaborative work. In the analyses, relevant aspects were allowed to emerge from the data (an inductive approach). I employed a technique building on thematic analysis (Braun & Clarke, 2006) of the conversational data, the knowledge objects and resources to examine how and what the groups constructed and used in terms of knowledge. In addition, a thick description of the process was created.

Findings

The student groups organized their collaborative programming, aimed at the *development of the knowledge object,* by employing a structured set of steps. The programming work consisted of individual coding and frequent discussions of coding strategies, problems emerging, and an iterative trial-and-error strategy. The latter involved mutual progress updates, identification and improvement of errors, integration of individual contributions when correct, re-assessment when invalid; followed by a new iteration and the production of a new version of the knowledge object. The group discussions frequently raised new issues and questions, which contributed to advancing both the inquiry and the knowledge object. Generally, the discussions were object-bound, employing technical language and content, without much elaboration of knowledge but attempting to "fit" the process and product in a pragmatic way. The data excerpt below illustrates such a discussion.

Data excerpt 1. Group 3 discussion: Collaborative search for a solution; references to used resources

1. Paul: … Does it need an 'ID' there? (*points with the mouse on the screen*)
2. Lee: Yeah, does it need an 'ID'? Ethan, can you take a look?
3. Ethan: Yeah… ehm…(*looks at the screen and takes his time to think*), that would be a key to click on, right?
4. Paul: Ehm….
5. Ethan: Oh, not a key, but you use it to retrieve that (*points with his finger at the screen*). No, something like… you use JavaScript, remember? […] We figured that out with the w3schools, remember?
6. Ethan: …ehm… we must make a jQuerry to (*points at the code*)… call up, to make this key work, that part of the menu (*stands up and walks to the screen, talks while indicating specific points the code with his finger*). So here is the button you need to press (*points in the code*), and then you can use JavaScript to call jQuerry, to call this up (*points in another place in the code*), so you can call it up.
7. Paul: Ok, then I'll try to make something in CSS… we have to find out how to put these together…

We observe in this excerpt how the group deals with a problem identified in the coding work. The problem emerging in the individual programming (performed by one of the group members, but projected on a screen) is addressed by the entire group. First, the group members try to identify the exact problem (turns 3-5). This is done in conversation, by considering alternatives, identifying and pointing (though physical gestures) at the problematic point, and by drawing upon resources (turn 5, 6). Strategies learned during their own inquiry and resources mobilized are being identified as instrumental in generating a solution. The collaborative discourse, and the problem-solving actions are closely bound to the knowledge objects itself – Ethan is thinking aloud to identify the problem and, at the same time, envisioning the future use of the object. This short excerpt shows how the work on the object triggers a problem solving behavior, elicits knowledge and resources, and directs both the collaborative discourse and the programming work.

The use of online knowledge resources provided by the expert programming community was one aspect revealed by the analyses so far. Some of the sources were suggested by the teacher, such as the w3schools and the online validation tool. The students searched themselves for other resources that could support them in solving programming problems, in finding alternatives for and improving the quality of their design.

Data excerpt 2. Group 4 end interview–On the use of sources

1.	Interviewer:	… why online resources?
2.	Emma:	Because it's the most updated one. Because programming and stuff changes and the books are getting outdated.
3.	Seb:	And speed as well. Indexing. You're right there on your computer. You just need to look it up instead of 'oh, is that book, in the index, and which page and which word'. It's instant access to exactly what is necessary to continue the work...

The end interview with the four groups shows that the pursuit of online resources was not incidental or random. The students appeared very aware of the characteristics and practices of the programming domain, where the knowledge resources can be found and how they must act in order to access them. In the above excerpt, members of Group 4 explain that the online resources are the most updated ones, and that in a dynamic field such as the one of software programming working with up-to-date knowledge is essential (turn 2). Also, resources that can be accessed fast and efficiently are preferred (turn 3), because of the pressure to finalize the project in time. They mentioned also that it is the instant access to resources that is appealing, which indicates lesser focus on in-depth processing of knowledge or strategies, but inclination to use ready-made procedures and materials to support their programming work.

Discussion

Preliminary results show that creating a concrete knowledge object appeared to serve the construction of shared imaginations of this object, which guided the co-construction process at various stages. In the case analyzed in this study, the process is supported by a domain rich in easily accessible coding strategies and guidelines, procedural structures, validation standards and tools, all artifacts that enable the pursuit of productional work. Students were able to access various resources, which facilitated their programming, and opened their horizons towards the practices of the professional programmers.

The design and development work was supported by a set of procedural structures, validation standards and technologies that supported the coding process. Such knowledge artefacts (programming techniques, techniques, tools, troubleshooting procedures) offer alternative strategies and tools for programming (Mackenzie 2005). A challenge that may emerge from the existence of this rich and continuously changing pool of resources, but which is in essence 'blackboxed' within the community of expert web developers, is that it can lead to a superficial application. Rather than opening tools and representations for in-depth investigation and developing an understanding of the logics of programming, there is a danger that the resources are used merely as technical objects. While the students envisioned ways of dealing with this challenge, this study suggests, in agreement with Litzinger et al. (2011), that close guidance and support in opening up resources for scrutiny is a challenge in this domain. More concretely, I suggest that these programs support their students' entrance into this practice by providing an introduction to the conceptual knowledge underlying the web development domain. Showing personal interest and performing applied inquiries does not mean students are completely aware of the complexities that accompany such interesting tasks or that they will pursue in-depth understanding of the logics of inquiry and the knowledge construction principles of the domain. Sustained guidance and feedback during this process are also desirable to support students in exploring both the technical and the epistemic aspects of knowledge resources. Depending on how the knowledge domain is organised, different mediating tools and support structures are needed for the students to make sense of knowledge and utilise resources in productive ways.

This study yields implications for education programs that attempt to employ knowledge construction elements in the learning activities and, more generally, to support students to develop capacities to, independently, generate knowledge. From a general research perspective, this study opens up further lines for investigation and analysis that can provide deeper insights into strategies that enable students to participate meaningfully and become competent in constructing knowledge objects.

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