A phenomenographic view on the socio-cultural activity theory in research concerning university students' learning of computer science in an internationally distributed environment

Anders Berglund
Department of Computer Systems
Information Technology
Uppsala University
Anders.Berglund@docs.uu.se

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Abstract

This PhD student paper discusses a possible approach for studying students' learning about computer networks in a course that is jointly taught by two universities as an internationally distributed course. Since the students are working in virtual teams, consisting of six students, three in Sweden and three in the US, with a technically advanced assignment, the environment in which the learning takes place has a significant influence on the learning. An approach to studying the students' experience of their learning as well as their experience of the context of the learning, combining phenomenography with activity system, is proposed. While the experience of the learning is studied with a phenomenographic approach, an activity system seen "from within" through the eyes of a learner is used to analyse the experienced context.

My Phd project - its background and purpose

Phenomenography has proved to be a fruitful approach for studying students' experience of learning in higher education. It has, however, been criticised for not paying sufficient attention to the context of the learning.

In my research, studying students' learning in an internationally distributed course, that is students' learning in a particular environment, the context becomes important. Since this context is an integrated part of the students' experience of their learning, as well as a factor that is expected to influence the outcome of the learning to a large degree, I need to analyse the context as it is experienced by the students. My choice is to use a phenomenographic perspective on the context seen which is seen as an activity system, a choice that I argue will give me the possibility to analyse the students' experience of their learning in the experienced context.

Motivations for my research

Information and communication technology (ICT) is a priori an essential ingredient in computer science education at university level. It is both the study object per se and an important tool for learning.

Some key issues facing the future computer science professionals involve globalisation of the knowledge base, and increased specialisation and distribution of expertise with resulting need to collaborate in a culturally and linguistically complex environment. This is coupled with rapid changes in techniques, which demands life-long learning within the profession. Future professionals must be capable of collaborating internationally in order to maintain their roles within the professional community.

Knowledge construction in remote collaboration and the creation of virtual environments in which the cooperation becomes fruitful and productive are thus important when considering the education

of future computer science professionals. These processes must be understood in order to be able design suitable instructional environments.

The question I am addressing in my research is in what ways students, who take part in international collaboration as part of courses in computer science, experience their learning and collaboration. The question can be analysed into a number of aspects which relate to:

- how the collaborative learning situation is experienced and tackled
- how ICT is experienced as support for peer learning and peer teaching
- how the situation is seen as a contribution to future professional life

Further, these can be examined in the light of the outcomes of learning in the specific course context in the field of computer science.

The setting

The study is performed within the Runestone project (Daniels et al 1998, Daniels, Berglund, Petre 1999, and Last et al 2000.) The main objective as seen by the two universities is, of course, the students learning within the field of computer science. Other important aims for the project are to give students experiences in working in teams and to offer international experience. The students attending this course, third and fourth year computer science students at Uppsala university, Uppsala, Sweden and Grand Valley State University, Allendale, MI, USA are jointly, in groups of 5 - 6 students, 2 -3 at each university, solving a technically advanced computer science project. The goal of the project is to produce or improve a software that can control a Brio labyrinth. This task demands skills in computer networks, distributed systems, network programming, C/C++ and Java, as well as software engineering. The students use various forms of communication, mainly e-mail and chat. There are other research projects carried out on data from the Runestone project, at University of Texas at Austin, Austin, TX, USA, and at Open University, Milton Keynes, UK. These projects emphasise other aspects of the course as group dynamics.

The software development project

During the project the students should develop a software that gives an end-user the possibility to "play" with a Brio labyrinth. During the course, as it was given 2001, the students started with code from earlier years giving of the course. On the Web-page related to the course (http://www.csis.gvsu.edu/class/brio/BrioProject/BrioProjectOverview.html), the project is described in the following way:

> This project involves designing and implementing a distributed, real-time system to navigate a steel ball through a board by tilting the surface of the board via positioning motors. The board and ball are a modified version of the well-known Brio Labyrinth game. A monochrome digital video camera focused on the board is available to aid in navigation. The user interface is presented through a web browser. Users who play the game specify a path for the ball to follow, then get feedback on the result of their run.
>
> This project has elements of real-time control (the Brio game), low-level distributed systems (multiple CPUs to gather data, drive motors), and high-level distributed systems (web interface, network programming), in addition to some demanding requirements on the language used to implement portions of the project (dynamic code loading, security).

Fig 1. A brio labyrinth.

The descriptions above indicate that the software consists of several more or less independent modules, that might (or might not) be distributed over several different computers. These software modules must communicate to create a whole that can be used by an end-user.

Informal findings from 2000 indicate that students choose different technical solutions to data communication issues: TCP, UDP or RMI. The preliminary finding also show that the majority of the students did not have any experience of using any of these solutions in larger projects.

In the project they need, among other issues, to analyse which technical data communication solutions that could be used for the project, choose one or many solutions, learn the specific details of this solution and implement it. This is made by the group, and needs negotiations between the group members at all stages.

The focus of my research is though:

- What do the students learn about these data communication issues and how do they go about learning in this environment?

and

- What is the significance of the experienced context for learning?

Data collection

Data is collected in various ways in the Runestone project in order to serve the needs of different researchers doing various research on the Runestone project: interviews, logged e-mail messages, logged IRC chat sessions, saved web-pages, questionnaires etc. The interviews are the most important source for my research.

I have interviewed eight students at each site in Uppsala and Allendale on two occasions during 2000, once at the beginning of the course, and at the end of the course. The interviewees where chosen to represent a broad spectrum of backgrounds, study results, ages etc., with the aim of getting a large variation in the descriptions of experience obtained. Interviews mainly emphasised on their experience of learning in this course, being taught in a non-traditional environment. These interviews are currently being transcribed and analysed.

During spring 2001, I will perform the interviews again, this time focusing on variations in their experiences of learning the technical issues of data communication that are a main component in the project.

Theoretical framework chosen

The aim of the research is to investigate the variation in the ways that the students experience essential aspects of their learning of some computer science concepts in this international

collaborative environment. The research is performed using a phenomenographic approach (see for example Marton & Booth (1997)), combined with the socio-cultural activity theory (see for example Engeström (1987)).

By combining these two perspectives, I get a framework for studying the variations in the ways in which the students experience their learning of computer science in the context as they experience it, in the internationally distributed project-oriented course that they are taking.

Motives for choosing the two perspectives phenomenography and activity theory

An important objective for using a phenomenographic approach is my interest to have a strong emphasis on the actual content of the learning, in this case computer science, or, more specifically, computer networks. Phenomenography also gives me a possibility to see the variations in the experiences of learning at a collective level. At this collective level, the individual learner "disappears" from the results of the investigation, but his or her various expressions of learning remain as data.

The learning that I study takes place in a certain environment, a course given in an internationally distributed environment. This means that the study partners of each individual student live both in the neighbourhood (and frequently also physically present) and at a long distance, in another country. A collaboration in this environment highlights many factors that normally are not present in locally taught university courses: time differences, different mother tongues, cultural differences, different student populations, lack of personal contact etc.

The students' experiences of the environment for the learning are thus important factors for their experience of the learning (Adawi, Berglund, Ingerman, Booth (2001, in preparation)), and for the outcome of the learning, and needs to be studied.

I have chosen to describe the context of the learning, that is the course and its surrounding factors as an activity system using the framework of socio-cultural activity theory (see for example Engeström 1987). An activity system is an integrated whole, consisting of subjects aiming to the transformation of an object into an outcome using tools and taking other factors: rules, the community and division of labour into account.

An activity system is, according to Engeström (1993), the context. Here, the activity system is the learning environment centred around the course with the subjects (students) aim at learning.

Activity Theory

Activity theory aims at giving a framework for describing, analysing and understanding complex systems or activities. So far it has mainly been applied in analysing work settings, human computer interaction (HCI) etc. , that is, complex systems where several individuals interact in a system rich in technology, rules of conduct etc. (see for example Engeström, Miettinen, Punamäki (1999), Nardi (1993)).

An activity system is mainly defined and motivated by a shared idea about its object, which can be seen as the "raw material", that is the material that will be transformed to an outcome or a result, that can be "glimpsed on the horizon". The object could in the hypothetic case of a hospital be patients, seen as ill persons, that get better or possibly become well, or in the terms of activity theory: are transformed to the an outcome of cured patients. The activity system is object-focused [2] (or, to use Engeström word: object-oriented) since the system, and all its parts are oriented toward and focused on this continuous transformation of the object.

The collective of participants in the activity system are the subjects, who are related with and interact with the object. This relationship is not symmetric: the subjects are active and thus takes the initiatives (Engeström, 1987), while the object mainly are passive but functions as an overall meaning for the subjects to be active. In the example of a hospital the subjects could be doctors, nurses, and

the personal taking care of the hospitals equipment. The patients, seen as persons who struggle to become cured can also be seen as a part of the subject.

The interaction between the subjects and the object is not direct, but is mediated by tools. The tools can be abstract or concrete and are "at the same time both enabling and limiting" to use the words of Kuutti (Kuutti, 1993). The tools contain the historically collected experience of the activity and afford the use of this experience in a new situation in an evolving activity system. In the case of a hospital tools could be different instruments used during a surgery, the language used, both everyday English and the specialised language of medicine, but also skills and experiences of different professionals in the hospital, as well as the patient's understanding of his own problems.

A minimal activity system can be drawn in the following way (Kuutti, 1993):

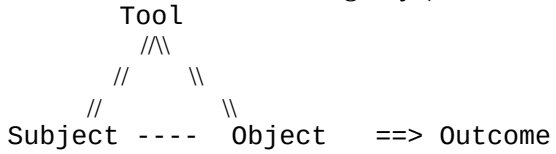

Fig 2. A minimal activity system

The minimal activity system, the relation between the subject and the object, mediated by the tool, is simple, even too simple to be useful. This structure has to be embedded (Kuutti, 1993): The participants, the subjects are part of a community sharing the same object. The relationship between the subject and the community is mediated by rules, both implicit or explicit. The community has a division of labour related to the transformation process. In the hospital example the staff follows legal rules for their activities (keeping a "journal"), as well as conventions (carrying certain clothes) and social rules. Thus the rules mediate the relationship between the subject and the community. There is a division of labour in a hospital among participants sharing the same goal (curing the patients). Doctors, nurses, laboratory personnel, secretaries all have their given duties.

The complete activity system, that according to Engeström is "object-oriented, collective and culturally mediated" (Engeström, Miettinen, 1999), can be drawn like this:

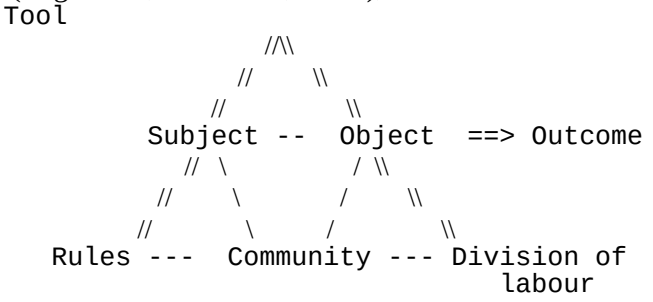

Fig 3. A complete activity system, as described by Engeström

Another example from Kuutti (Kuutti, 1993) will tie the pieces together: The staff (subject) of a software development team (a community) transforms a half-ready program (object) using computers, pens and their experience (tools) into an application (outcome). They follow laws, habits and rules set up (rules) and have all different tasks (division of labour).

The dynamics of an activity system

An activity system is continuously constructed and reconstructed by the individuals within the system. However, the activity system as such is more than the sum of individual discrete actions. The individual actions are influencing the activity system and are a part of the system itself. As the activity system is evolving it thereby affords new actions by individuals, actions that are a part of the system. Hence the individual and the activity system are inseparably intertwined. In the hospital example, the efforts of the subjects, mediated by the tools, continuously changes the object: New patients come, other patients leave, and the problems of the patients within the system do not remain

the same. Also , new tools (as new equipment, new medicine) are used. The community of staff changes, there are neither the same individuals nor the same professions in the same proportions at two different occasions. Social rules and funding change over time, so does division of labour. Thus, a hospital is a system in continuous change and development. The process of transformation of the system and the object into outcome is a long-term process, that might be without a clear beginning and a clear end (Engeström, 1987).

The long and complex activity consists of smaller entities, actions, that have consciously planned, immediate and well-defined goals. The actions get their meaning from the activity, and could not be understood without the context of the activity. A typical action in the hospital could be giving a patient a specific injection to cure a certain decease. This action gets its meaning in the activity, the hospital, explaining why pricking someone is a useful and good thing to do, although it hurts, and would, without the context seem meaningless. In a different activity, a nursing school, the same action could have another interpretation: In this school school students prick each other to learn their profession.

Even at the hospital there are different activities that could explain the action of pricking: In an era of cut-backs, the hospital might need to take patients who want and are willing to pay for vaccinations before going on a holiday trip. In the light of this activity, the vaccination could be performed to bring an income to the hospital.

Actions consist of chains of operations. Operations are routinely made and are in a normal situation made without conscious decisions, like the nursing fetching the syringe in order to give the injection.

A large activity system could be seen as constituted by smaller, intertwined and interdependent systems, each with clear objects. The level of analyses has to be a conscious decision taken by the researcher. To continue the hospital example, one could note that the hospital consists of many different departments, all with different objects. At aftercare the patients will be more or less healthy when they leave, while patients leaving the surgery often might need intensive care. Obviously the outcome, as well as the object, of these two departments are different. Still other departments have completely different functions (and thereby objects), as taking care of the economy or serving food the the patients. The hospital as a whole can be analysed and described as one entity or as many coexisting and interacting systems that influence each others continuously as the system evolve.

Some studies have been carried out where phenomenography and activity theory are used together. Of particular interest is the work performed by Åberg-Bengtsson (Åberg-Bengtsson, 1998) in her theses. She has studied how pupils in the age 7 - 10 learn, interpret and construct graphical representations of numerical data during group work in school. A phenomenographic approach has been used for the unravelling of which aspects of graphs that are crucial the students' understanding, while the context of the learning, the school, is been described as an activity system. She argues that the object of this system, the school, is learning. Thus, it is the object node of the activity system that her study is focused on, and that is studied with the phenomenographic approach.

Engeström and Escalante (Engeström, Escalante (1993)) argue that the object has a multifaceted character and that its character constantly is changing. Their reasoning, applied to the hospital example, could be illustrated by a new method for treating a certain disease: While it is new, it takes the place as an object, being of a specific interest and having an activity focused on it. Once it becomes a part of a normal treatment, it rather moves to the role of a tool. This tool could again become in focus, and thus be the object, if the method becomes questioned or the object of further research at a later stage. Engeström and Escalante further argue that the object manifests itself, not only differently on different occasions, but also in different ways for different participants in the activity. Objects are never understood "alone". We understand them by means of other objects, containing and expressing social norms, historical development etc. A tool can turn into an object - being the end in itself or a object can turn into a tool, when stable and established

Åberg-Bengtsson reason in a similar way, when she says that the pupils' understanding of the field of study tends to become something that is used to solve more advanced problems within the field as the learning goes on. The learning, once being "set", moves towards the role of a tool.

Large complex systems, such as an activity system with its many facets, by necessity contain inner conflicts, or with the terminology of Engeström "double bind situations", both within a certain node of the system and between different nodes (Engeström (1987). A double bind situation within the object node in the hospital could be the interest to do research on and develop new methods of treatment to help future patients, which can stand in double bind situation with the interest to do maximum to cure patients already in the hospital. An "obvious" examples of double bind situations between nodes is the need for new, sometimes expensive, equipment (tools), and budget constraints (rules). Double bind situations offer the driving force for changes, but are also in the same time the threat of the system.

A quote of Engeström can serve as a summary of this section:

First, collective activity system can be taken as the unit of analysis, giving context and meaning to seemingly random individual events. Second, the activity system and its components can be understood historically. Third, inner contradictions of the activity system can be analysed ...

Activity system as a tool in my research

The distributed international course that I study can be analysed and described in several different ways and at different levels. As an example I will regard one group of six students as an activity system. Since data is currently collected and thus not yet analysed, the description below must be seen as a guess about one aspects of this research project. I will call the system described a "toy system", to stress that this system at the best can serve as a hypotheses about the outcome.

As the unit of analysis, that is, as the toy activity system itself, I have chosen a hypothetical project group consisting of six students, three in each country.

The object for the activity, that unifies the group and defines the activity system, is to transform the incomplete software with which they started into an outcome of a working program that lets a user play with the Brio labyrinth. One could also assume, at this stage, that the students are interested in learning about computers through this activity, that is, in some way become transformed to more skilful students and future professionals. The experience of working in international teams, or getting odd grades, might also be objects for the students.

Any students in the group, or rather a theoretical student (or any constellation of theoretical students), without individual characteristics, serve as the subject in this toy system. As subjects they play the active role. Their wish to transform the object into outcome can be seen as a motor that makes the system change.

The students do not interact directly with the object. Instead the interaction is mediated by tools of different kinds. In this particular setting, it is obvious that computers serve as important tools. They have at least a twofold function: they serve as the bearer of the software the students develop, as well as a communication tool within the team of six and with their teachers. Other tools that could be mentioned are languages, and earlier experiences of programming.

A student is a part of a community. At different occasions different communities become important: The group of three (that is, the part of the group that is in the same country), the group of six, the full class, the course team, understood as students, teachers and support staff, as well as the communities of Internet users or Linux users are other possible communities to which a student relate during this activity.

There are a certain set of rules regulating the interaction within the activity. There are different codes of conduct developed within the groups. These rules could be inspired by a behaviour affected by the

e-community and a collaboration over ICT. The fact that this is a university course imposes other rules, as grading requirements.

Finally, to accomplish a task of this complexity, the work-load has to be spread among the participants, giving different subtasks to different smaller groups or individuals. One of the student carries out the task of being a group leader. Other roles within the activity system are held by teachers and the technical support.

The toy activity system could thus be illustrated like this:

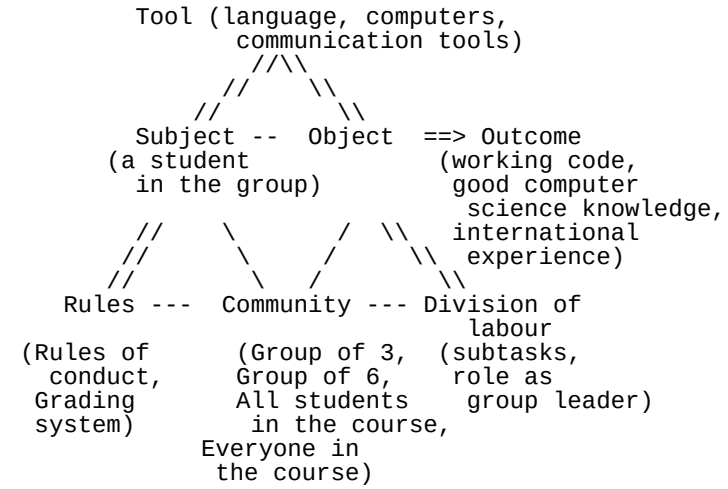

Fig 3. A toy activity system, describing a group in an internationally distributed course in computer science

It is almost "tempting" to assume that a toy activity system like this is rich on conflicts or double bind situations. One could guess that there might be a double bind situation in the object node between getting the international experience, a task that requires that a large amount of time is spent talking to group members in the other country, and the actual learning of computer science, also a time-consuming task. Another possible double bind situation might arise as a result of the rules: the grading systems are different in the two different countries.

Between the nodes there are several possible double bind situations: The course rules, with clear Milestone and weekly reports, could be regarded as an obstacle (as well as a resource) for the students when aiming at finishing their project. The communication tools are maybe not powerful enough to facilitate the communication within the group (the community), in that case possible creating two subgroups.

Combining the two approaches in my project

Combining the two approaches in the context of university students learning computer science in a internationally distributed course seems challenging as well as promising to me. The approaches are different in character. Activity theory is object focused, which means that object and the outcome of the activity are essential aspects. Phenomenography, on the other hand, takes the perspective of the learner, looking through his or her eyes. The purpose of this perspective is to get a subjective view of the learning, in order to reveal variations in the experiences of the learning that takes place. In short, one could say that while activity theory, as it normally is used, gives a view of the learning as seen from the outside, phenomenography looks at learning from the inside.

By combining them, I intend to study the experience of "learning in a context". In other words, the view in my research is the view of a learner, "from the inside": **The experience of learning in the experienced context.**

Would this approach give me the tools to study learning in context "from the inside"? As I understand Åberg-Bengtsson, she has not done this. She has used the activity system to get an "outside view" of the environment in which the learning takes place, and the phenomenographic research on learning to get an "inside view". However, this does not exclude that her approach could be further investigated, putting more emphasise on creating a whole of the two approaches and on a development the a inside view on the context .

Another possible approach is to regard the field of study, that is the subject content of the studies, mainly as a tool, but to a certain degree playing the double roles of tool and object. When studying students at a university level, this seems like a reasonable approach: Their knowledge of the field of study could already be assumed to be important. This understanding presents experiences, methods, tools etc. that mediates the learning of something new within the field.

I argue for a development of the above positions: I plan to get an "insiders' view" of learning in an experienced context. The activity system that describes the context should be based on the learners' experience of the learning, as well as his or her experience of the tools, the rules, the community and the division of labour. With such an approach, the activity system will be a tool for describing and analysing the context as it is experienced by the learner.

Questions concerning this approach :

If this is a reasonable approach, several "new" questions arises:

1. To what extent can I use the approach inspired phenomenography to describe and analyse, at a collective level, the nodes within the activity system that are not directly related to the learning, that is, other nodes than "object" and "tool"? Would this be useful to do? What can I learn about the learning in this way?
2. A large activity system, like the course I study, can be seen as constituted of several interacting systems as Engeström points out. What more, if anything, could I learn about the students' learning by analysing in this way?
3. One of the objectives with this analyses is to find possible double bind situations, both within different nodes and between nodes. Such double bind situations are both sources from which development springs, and sources for problems and obstacles of different kinds. Can these double bind situations be productively described on a collective level

Notes

[1] The three concepts TCP, UDP and RMI are three technically different computer network tools, that are used in this project.

[2] I will use the term "object-focused" instead of the more frequently used term "object-oriented" in this paper, since the term "object-oriented" to a computer scientist denotes an "object-oriented computer-related activity", as for example object-oriented programming or object-oriented design. The basic unit of analysis for a computer scientist is the "object" in "object-oriented" programming or other computer-related activities (see for example Budd, 2000). Since I will discuss issues of related to computer science in this paper I prefer to avoid using the term for two conceptually different ideas.

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