Learning computer systems in a distributed course: Problematizing content and context

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Abstract

In this paper, a research study of learning computer systems in a complex, internationally distributed course environment is described. The relation between a learner and the object of his/her studies being in focus in phenomenographic research is enhanced to encompass also the relation between the learner and factors that together form the environment of which the learning of the subject area is a part and in which it takes place. The research question, from which the need for this approach arises, concerns how master level students in computer science, who are taking an internationally distributed project-based course in computer systems, learn some aspects of computer science, and in what ways their learning situation influences their learning, all with an ultimate aim of improving students' learning of computer systems in project-based courses. The learning situation is modelled as an activity system (Engeström, 1987), in which the socially based nature of complex activities, as learning in a distributed project course, are analysed and described. In this paper an approach, where the learning activity is analysed and described as it is experienced by the students, is described and discussed.

1. Introduction

How computer science students, who participate in an international distributed master level course, learn computer networks is in focus in this research project. The course participants, who are third or fourth year students in computer science, work jointly in groups of six students, three from Uppsala University, Sweden and three from Grand Valley State University, MI, USA, on an advanced software development project.

Berglund and Booth (2002) describes the assignment that the students should solve:

> The task given to the students was to produce a working software that gives an end-user a possibility to "play" over the internet with a modified version of Brio labyrinth [...], a Swedish toy in which a tilting platter with a maze of paths and holes is manipulated by rotators, the aim being to get a ball through the maze without falling into a hole (Berglund, 2002). To complete the task, an extensive collaboration over Internet was needed within the groups.

The learning of the computer network protocols[1] and their applications that takes place is thus related to the complex learning environment, a course without any classic lecturers, but with a group project on a technically advanced task in groups distributed over two continents.

To study the learning that takes place, I have adapted a phenomenographic research approach[2], since this will allow me to study the variation in the relation between the learners and the object of their learning. The intended result of my work is to increase our understanding of how students learn concepts within computer science when they take an international distributed course, with the overall aim to improve teaching and learning in computer science at a university level. With this goal for my work, the subject area (here computer science) as well as the learning and the context for the learning, as experienced by the students, is of necessity important to consider.

As I study learning in a complex environment, I have to extend the object of my studies from primarily being the relation between the learner and the object of his/her learning to encompass also the learning environment, or the context of the learning. Phenomenography, with its focus on the learners and the phenomena that is learnt about, does not alone offer the intellectual tools that are needed for extending the study object to include to the relation between the learner and his/her whole learning environment, a relation in which the learning of the subject matter is a part, possibly in many cases, the most important part. In order to extend my use of phenomenography, I have chosen to explore the possibilities of activity theory (Engeström,

1. *Computer network protocols* or *network protocols* are the sets of rules that governs communication between computers. These rules defines the communication, and how it shall take place. The term is used both for a protocol as an abstract entity, with formally defined rules, as well as for a program package that are used to implement a protocol in a real programming project.

2. Since this paper is presented at the EARLI (SIG 10) conference *Current Issues in Phenomenography*, I will not further discuss phenomenography as a research approach. Marton and Booth (1997) discuss in detail different aspects of phenomenography. As examples of phenomenographic research within the field of computer science and information science the studies of Booth (1992) concerning first year university students' learning to program, Cope (2000) concerning learning information system, as well as my earlier work concerning students understanding of computer network protocols in the current project (Berglund, 2002).

1987). With an activity theoretical approach, the relation between a subject (a learner, or worker or even a collective) and the object (as learning computer networks, or building a house) is mediated through tools (as a computer with a compiler, or a hammer). Furthermore, the subject-tool-object triad is integrated in a collective, or community, (of other learners, or of other workers) and other mediating factors, into a whole: a constantly changing and evolving activity.

Activity theory offers tools to study the environment of the learning as an activity. In the current project I aim to analyse and describe this learning activity, as it is experienced by the learners. In other words I will analyse the learner's relation to the object of his/her studies as a part of his/her relation to the learning activity using a phenomenographic research approach. With this approach I will thus describe and analyse the variation on the experience of the learning of computer networks as it takes place in a complex environment.

In this paper I will first give a brief overview of the Runestone initiative, of which my project is a part. I will then, in section 3, with the project as a background, describe activity theory, and particularly stress features that are interesting for my research. In the following section I will present and discuss my research approach and present related research. Finally in section 5, I will discuss some implications of the work and develop some thoughts about the future work on the project.

2. An advanced internationally distributed project course in computer systems - the Runestone project

As was briefly mentioned in the introduction above, the students work in internationally distributed teams, consisting of three members from Sweden and three from USA. In this section I will describe the programming project the students make, and relate the students project, and my research to the Runestone initiative.

There were 16 groups during the giving of the course the year 2000. Each of these groups developed software that should control a Brio-labyrinth, a Swedish wooden toy that has been modified for the purpose. Figure 1 shows the original toy and the modified version with step engines to tilt the board and a camera to get feedback about the ball's position.

Figure 1. A Brio labyrinth, and a modified version with a camera and motors added (from Berglund, 2002). The aim of the game is to move a steel ball on the board from a starting point to a final point. The knobs are used to tilt the board and in this way move the ball

This is a complicated task that demands that the whole team work together, using different internet-based tools for their collaboration, in most cases e-mail and IRC-chat[3]. There were not any classical lectures during the course, but weekly group meetings, using IRC, with a teacher.

The learning objectives are presented in the following way in Berglund (2002):

> The computer science learning objectives for the students who take the course are to learn about computer systems by developing a software system and by building virtual working teams, [...]. However, the complete aims of the course that the students are taking should be seen in a wider context, where the students' experience of an international collaboration is another essential goal (Daniels et al., 1998). They point out that by working in internationally distributed teams, where some of the group members live in a different country and have a different educational background, an international experience is offered that reaches students who do not participate in student exchanges.

My research project is related to the Runestone initiative (Daniels et al., 1998, Daniels, 1999), a joint computer science education research and development project, based on the project course in computer systems initiated and run by Uppsala University (UU), Uppsala, Sweden and Grand Valley State University (GVSU), Allendale, MI, USA. Within this initiative other aspects of the students collaboration is researched. Last (2002) studies the team creation process, and the role of conflicts, while Hause and Woodroffe (2002) focuses on software development performance.

3. Activity theory as a framework for research on learning

While the last section focused on the project the students worked on and the educational framework of which the course is a part, in this section I will describe activity theory as a framework for describing, analysing and explaining human activities, as learning, in a complex setting. The theoretical aspects are based of the interpretations of activity theory by Engeström (1987, 1993) as well as other researchers in this tradition (Kuutti, 1996, Bannon, 1997, Kaptelinin et al., 1995). My interpretations, as they are presented here, are also grounded in the needs of my research.

Activity theory, as it is known today, is a research tradition, or research approach, that is developed from the work performed in the Soviet Union by Vygotsky (1978, 1981) and Leontev (1981). Kaptelinin et al. (1995) points out that activity theory, in spite of its "name", is not a theory in the strict interpretation of the term:

> First, while it is usually associated with Leontev's approach, there are also several other interpretations of Activity Theory. Second, and more important, it is not what people usually mean by a theory, but rather consists of a set of basic principles which constitute a general conceptual system which can be used as a foundation for more specific theories. (p.189).

3. *Internet Rely Chat*, *IRC,* is a system for human communication over Internet that offers the possibility to use the program as a text telephone

Activity theory is not in itself fixed and stable and does not have a given interpretation. The activity theory and its community can in itself be modelled as an activity system, that develops over time in the multi-voiced international network of researchers (Engeström, 1993). Human-computer interaction (Nardi, 1996a, Kaptelinin, 1996, Kuutti, 1996), educational technology (Bellamy, 1996), health care (Engeström, 1993), projects in programming (Holland and Reeves, 1996), children learning graphs (Åberg-Bengtsson, 1998), learning astronomy in a technology rich setting (Barab et al., in press), and distributed collaborative learning (Fjuk, 1998) can be mentioned as examples of areas to which activity theory has been applied during recent years. These diverse research projects use activity theory as a way to analyse complex systems where several individuals interact in and within a system rich in technology, rules of conduct etc. Certainly, other interpretations of activity theory are possible.

Before going into a deeper discussion on activity theory, a short clarification on the terminology I have chosen, might be useful: I let the term *activity* denote a "real", "concrete" activity in the "real" world, built up by its *constituents*. The model or description of an activity is an *activity system*, consisting of different *components*. Finally, the graphical representation of an activity system a *triangle*, consisting of *nodes*. These terms all reflect the same activity, but emphasise or express different aspects of it, as different sides of the same coin[4]. In most situations in the text, the terms could be interchangeable for each other with only small changes in the interpretations.

In this section, I will first describe an activity as a system and briefly describe its components. Then I will discuss some principles of activity systems in the light of the project described here.

3.1. An activity understood as a system

With an activity theoretical approach, learning, as well as other human activities, can be understood as being an integrated in a larger system: an activity. An activity is a theoretical entity, discerned, described and used by the researcher, that considers the socially based nature of human activity. The interacting constituents of an activity continuously develop into new forms that together create an activity. Used in this way, activity theory serves as a "clarifying and descriptive tool rather than a strongly predictive theory" (Nardi, 1996a), and does not prescribe any particular way of understanding learning or any fixed ontology.

An activity system basically describes the interaction between a *subject*, that can be individual or collective, and an *object*. The activity, as a whole, is directed towards the *object.* Through this interaction the object is transformed into an *outcome*. The relation is not direct, that is, the subject does not interact directly with the object, but indirect through the *tools*, both physical and intellectual. The interaction is *mediated* by the tools. The activity is, however, larger than the tool-mediated relation between a subject and an object. It is integrated in a collective activity. The *community* that shares the same object, for example of learners or practitioners, is a fundamental component. The relation between the subject and the community is mediated by *rules*. The term *rules* must be understood in a broad sense, integrating the legal systems, cultural rules for interacting between humans, as well as the rules that have developed within the current activity. The relationship between the community that together share an object and the object itself is mediated through a *division of labour* (Nardi, 1996b, Bellamy, 1996), that also is

4. Although these are three aspects and a coin has two sides, the analogy is appropriate

developing and changing over time. An activity can be modelled as an activity system, consisting of these components, as illustrated in Fig 2..

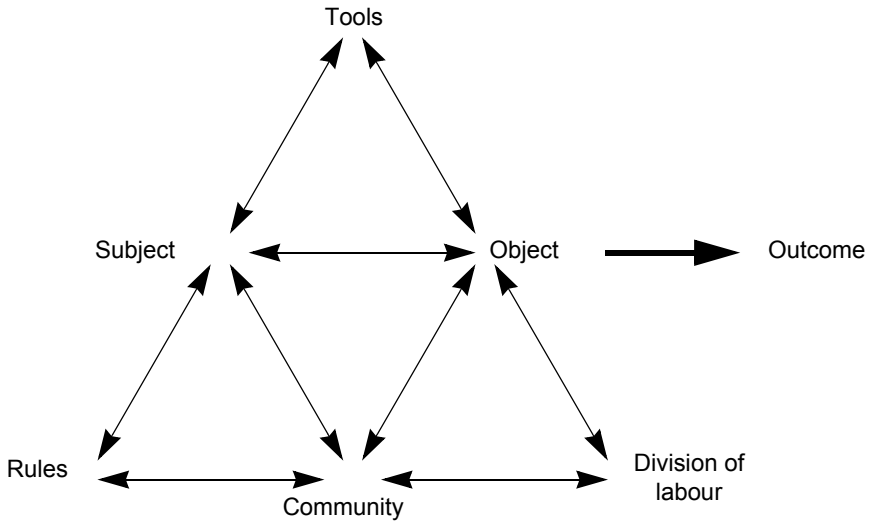


Figure 2. The relation between components in an activity

An activity is continuously constructed and reconstructed by the individuals within the system. The activity system as such is more than the sum of individual discrete actions (Engeström, 1987). The behaviour, or actions, of the individuals is constantly influencing the activity and are a parts of what constitutes the activity itself. As the activity is evolving it thereby affords new actions by individuals, actions that in their turn are parts of the activity. Hence the individual and the activity are inseparably intertwined.

Before going further into the activity theory, it might be fruitful to consider some examples. In example 1 activity theory is used in research about learning to describe the context in which the young children learn graphs and charts in a school situation.

Example 1. Activity theory applied to the study of young children's learning

Åberg-Bengtsson (1998) analyses in her thesis how young children learn graphs and charts. She uses a phenomenographic approach to study the students' understanding of the *object* of their study, namely graphs and charts. To analyse and describe the context in which the learning takes place, she uses activity theory. Two young children together with the researcher, who serves as a collaborator or guide constitute the *subject*. During the construction of some of the early graphs, plastic toy cubes, served as mediating *tools*. The school setting as such offered *rules* for the interaction and how tasks should be solved. Also, graphs and charts have a conventional use that can be seen as *rules*. As is expected there was a *division of labour* within the group consisting of one adult and two students.

In example 2 Kuutti (1996) presents a software development team that works on a project for a client and points to the different components in the activity system.

Example 2. The components in a software development activity.

Kuutti (1996) describes a software team (a *subject*) who produces code for a client. The not-ready-code (the *object*) is transformed to ready code (the outcome), using computers, guidelines, programs as *tools*. A certain number of *rules* cover what it means to be a member of the team. Also, a *division of labour* is needed to fulfil the projects for the team.

3.2. Basic principles of activity

As Kaptelinin et al. point out in the quote on page 4, activity theory can be described through a set of principles, or key concepts, that together describe what constitutes an activity. The principles I will discuss below, based on the work of Engeström, and Kuutti (1996), as well as Bannon's (1997) interpretation of activity theory, reflect my personal stand, and my use of the activity theory as a tool for analysing learning in a complex situation.

The principles I will discuss are:
a. The dynamic structure and historicity of an activity
b. The object as a reason for existence of an activity
c. An activity as a context
d. The role of mediation
e. The role of inner contradictions
f. Individual actions as parts of an activity

In the remaining part of this subsection I will further explore these principles.

a. The dynamic structure and historicity of an activity

An activity is a dynamic entity that is always under development. Its current state is thus related to its history, and thus a historical perspective is needed. Kaptelinin et al. (1995) argue that also tools must be seen in this way, since they are carriers of other people's experience:

> [...] tools usually reflect the experiences of other people who have tried to solve similar problems at an earlier time and invented/ modified the tool to make it more efficient. This experience is accumulated in the structural properties of tools (shape, material, etc.) as well as in the knowledge of how the tool should be used. Tools are created and transformed during the development of the activity itself and carry with them a particular culture — the historical remnants from that development. So, the use of tools is a means for the accumulation and transmission of social knowledge. (p.192)

The same reasoning holds, according to Kuutti (1996) for the activity as a whole. Since it is under continuous change, it has a history of its own. Parts of that history, he argues, stay embedded within the system as it develops. Thus, the activity contains its own history and a historical analysis is often needed to understand its current state and development.

b. The object as a reason for existence of an activity

Engeström claims that an activity is defined by its object. The object is then the motive for the existence of the activity. What an individual does, might seem meaningless without considering the object of the activity. The role of a goalkeeper in a football team, cannot be understood without relating it to the object of a football game, to win by making more goals then the opposite team. Engeström (1987) makes a still stronger claim:

> Furthermore, what distinguishes one activity from another is its object. According to Leontev, the object of an activity is its true motive. Thus, the concept of activity is necessarily connected with the concept of motive. Under the conditions of division of labour, the individual participates in activities mostly without being fully conscious of their objects and motives. The total activity seems to control the individual, instead of the individual controlling the activity. (p.66)

According to Engeström the *object-focused*[5] character is thus a key principal of an activity. As an example of an object in an activity a medical institution (Engeström, 1993) can be mentioned. Everything that takes place in the medical institution aims at curing patients.

Engeström and Escalante (1996) discuss what an object "really" is, and why it has such "slippery and transitional nature":

> The object should not be confused with a conscious goal or aim. In activity theory, conscious goals are related to discrete, finite, and individual actions; objects are related to continuous, collective activity systems and their motives. [...] [T]his animate and transitional nature of objects is their necessary characteristic as objects of activity, that is, integral components of a system of human practice. [...] But objects do not exist for themselves, directly and without mediation. We relate to objects *by means* of other objects. [...] This means that objects have two fundamentally different roles: as objects [...] and as mediating artifacts or tools. (p 360 - 361, italics in original)

As an illustration of the multiple roles can be mentioned a compiler in a programming development project. Normally it functions as a tool, that transforms code from one form to another. Occasionally, however, when problems with the compiler are encountered, possibly because a bug within the compiler is suspected, the compiler becomes the object of the program developing activity. Then, when the problems are solved, the compiler regains its role as a tool. When working practically, it is clear that there are no sharp limits between these two understandings of what the compiler "is". Before starting to debug the compiler, in order to identify possible bugs, there has been a period, long or short, with evolving tensions between the components in the system when problems have been suspected, and when the role of the compiler as a tool has been unclear.

More complex is the issue of object presented by Holland and Reeves (1996). They have studied groups of computer science students at university level, who work with software development projects. They discuss the collectively defined perspective on the assignment that evolves in each group, and the correspondingly different objects of the activity. The object is thus for

5. Engström uses the term *object-oriented.* However, *object-oriented* has a different meaning within the field of computer science (see for example Budd, 1999). To avoid confusion, I will write *object-focused* as a synonym to *object-oriented*, as the word is normally used with the community of activity theory.

Holland and Reeves a collectively constructed and shared stand about the meaning or purpose with a particular activity.

c. An activity as a context

As mentioned above, an activity is a theoretical construct that serves to describe and analyse a complex system as a unified whole. The activity is what gives "meaning to seemingly random individual events" (Engeström, 1993, p.65), that is, an activity is a context[6], in which the participating individuals and the different events are integrated. With this approach, it is impossible to study a part of the activity as a separate unit without seeing it as belonging to and being interacting with the whole system. The activity is the context and is analysed as a unified whole.

That is, an activity is a unit of analysis. This does not imply that the activity is a homogenous and harmonious entity. On the contrary, it has a multi-voiced character and a history embedding and containing different, often contradictory, expressions and events.

This argument has been put forward on many different occasions. As an example relevant for the current study, Fjuk and Ludvigsen (2001) can be mentioned. They argue, based on a number of empirically based studies, that collaborative ICT-based learning situations only can be understood when the whole system is considered, that is, when the "*unit of analysis* [is extended] from technology and pedagogy themselves to real-life experiences".

d. The role of mediation

The role of tools, abstract or physical, is fundamental in human activity. The tools, or signs, have mediating functions between the subject and the object and are "at the same time both enabling and limiting" to use the words of Kuutti (1996, p 27). That is, a human never interacts directly with an object; instead, "a simple stimuli-response process is replaced by a complex, mediated act" (Vygostky, 1978, from Engström, 1987, p 58). In this way, "the use of signs leads humans to a specific structure of behaviour that breaks away from biological development and creates new forms of a culturally-based psychological process" (Vygostky, 1978, from Engström, 1987, p 59).

Kaptelinin (1997) describes the roles of tools in the following way:

> Human activity is mediated by a number of tools [...]. These tools specify the modes of operation, that is, those developed over the history of the society. The use of these culture-specific tools shapes the way people act and, through the process of internalization, greatly influences the nature of mental development. Tool mediation is no less an important source of socialization than formal education is. (p. 109)

Computer science and programming are clearly areas where the use of tools is visible. Not only is a computer needed to run a program - without the computer as a tool the program has lost its principle reason to exist. Also, compilers and other programs that are used for the program development are tools, through which the development of the program is mediated. They

6. The different meanings of the term *context* within phenomenography and activity theory will be further developed in section 4.4a.

contain their historical development within themselves and reflect in this way earlier experience of other people concerning the programming languages that are used.

e. The role of inner contradictions

The multi-voiced, continuously changing character of an activity makes inner tensions or contradictions between and within its constituents inevitable. Furthermore, an activity is not an isolated system (see section 3.2f) but rather a part of a network of interacting activities. Tensions between different activities, each with its particular object, are also sources of contradictions. The contradictions, or with the words of Engeström "double bind situations" indicate "misfits" within the system. Kuutti (1996) describes the contradictions in the following way:

> Contradictions manifest themselves as problems, ruptures, breakdowns and clashes. Activity theory sees contradictions as sources of development; activities are virtually always in the process of working though contradictions (p.34)

The contradictions serve as driving forces, Engeström argues:

> Contradictions are not just inevitable features of activity. They are 'principal of its self-movement and (...) the form in which the development is cast' (Ilyenkov, 1977, 330). This means that new qualitative stages and forms of an activity emerge as solutions to the contradictions of the preceding stage [or] form (1987, p.91).

In a medical institution contradictions could, for example, be found between bureaucratic or economical constraints (or rules) and the patients searching for medical support because of complex and ill-defined problems. (Engeström, 1993). Within the group work in computer science, analysed by Holland and Reeves (1996), contradictions can be discerned within the process of defining common objectives for a group. Fjuk (1998) has in her work concerning computer supported distributed collaborative learning, identified a contradiction, or a double bind situation, between the physical separation of students collaborating in a distance course, and the need for a joint construction of problems.

f. Individual actions as parts of an activity

The long and complex activity consists of smaller entities and can be described in three levels that express the "hierarchical nature of human activity" (Engeström 1990, p. 172). Engeström (1990) articulates the three levels, distinguished by Leontev (1978, 1991), in the following words:

> *Activity* is the molar unit, collective in nature and driven by a complex motive of which the individual actors are seldom aware. Activity manifests itself in the form of goal-oriented individual *actions* in which the subject is consciously aware of what he or she is trying to accomplish. Actions, in turn rely on automatic *operations*, dependent on the conditions at hand (p. 172 - 173, italics in original)

As stressed above, an activity should be understood as a collective, changing context, that consists of, and gives meaning to, individual actions. Engeström stresses that "we may very well speak of the activity *of the individual*, but never of *individual activity*; only actions are individual" (1987, p 66, italics in original).

As an activity is defined by its object, see section 3.2b, an action has its immediate, defined *goal,* of which the actors are consciously aware. The relatively short-lived actions have different reasons to be performed in different activities and can thus not be understood without its activity, or context. Someone can, for example, read a book in order to learn the programming language Java to use in a programming project. A book can also be read for pure joy, as a moment of escape from a tiring daily routine.

Actions are carried out by chains of operations, which are routinely made and determined by their *conditions*. Normally they are performed without conscious decisions. Turning the page, when reading the book about Java, serves as an example.

The relationship between an activity, an action and an operation and their respective object, goal and conditions are illustrated in Figure 3, adapted from Kuutti (1996).

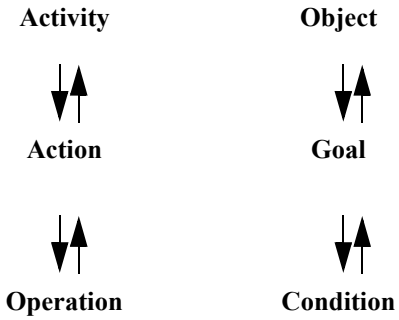


Figure 3.The levels of an activity (Adapted from Kuutti, 1996)

Activities do not exist alone, in a vacuum. Rather activities are connected to each others and interact in networks (Engeström, 1987). For example, the tools that form a part of the activity, are produced by another activity or other activities.

4. Research approach in this project: Studying activity as experienced by the participants

As was pointed out in the first section, I have selected a phenomenographic approach in my research on computer science students' learning of computer networks in an advanced, internationally distributed course. Furthermore, activity theory, presented in the previous sections, is used to guide my understanding of the learning situation, of which the network protocols, and the students' relation to them is a part. In this section, I will describe on what basis, and how, I aim to use and combine the two approaches in my research. I will start by a brief description of my approach of studying an activity as it is experienced by its participants, and will then express my phenomenographic stand and relate it to activity theory.

4.1. The selected research approach

The research approach I present to use in this project can be summarised in the following way:

Phenomenography is extended from focusing mainly on the variations in the relation between the students and the object of his/her studies to include also the variations in the relations between the students and phenomena contextual to the study object. This approach offers me the possibility to analyse and describe *the learning of computer networks in a complex course setting as experienced by the students*.

4.2. A phenomenographic approach to studying an activity

Marton and Booth (1997) define the research object in phenomenographic research:

> [...] unit of phenomenographic research - a way of experiencing something - which [...] is an internal relationship between the experiencer and the experienced. (p. 113)

They continue by stressing that, in phenomenographic research, the description and the describer are related:

> We cannot describe a world that is independent of our descriptions or of us as describers. We cannot separate out the describer from the description. Our world is a real world, but it is a described world, a world experienced by humans. (p. 113)

Also, they address the issue of what "a way of experiencing something" is:

> "A way of experiencing something" is experiencing something *as* something [...]. "A way of experiencing something" is a way of discerning something from, and relating it to, a context. The meaning of something for someone at a particular point in time corresponds to the pattern of parts or aspects that are discerned and are simultaneously objects of focal awareness. (p. 112)

Taking this as a point of departure that expresses the theoretical foundation of my phenomenographic research approach, the issue of relating this to the framework of an activity becomes crucial.

An activity is, as it was described in section 3, a theoretical entity, discerned and described by the researcher as an activity system. A subject of the activity (in this study: a student) cannot experience the activity as a complete whole at a particular point of time, since, as Marton and Booth (1997) point out, different parts or aspects of the world are in focus of the attention at different times. A student can for example at a particular moment have his or her focus on an aspect of a network protocol, while another issue, such as concerns about the grade, is in the background. Later, focus can shift to be on the grading, with the network protocols residing in the background. The students' relations to these phenomena are thus dynamically changing.

Both the learning of the course content, here network protocols, and the experience of other phenomena related to the course, as for example grading, become important for understanding the students' experience of their studies. The experience of these phenomena, whether directly related to the learning objectives or not, is analysed in the phenomenographic tradition. The outcome of a phenomenographic analysis is sets of categories of description, where each set describes the experience of a particular phenomenon. In the approach proposed in this paper,

these categories and their relations are then further analysed based on activity theory. The outcome of the phenomenographic research is thus not the entire final outcome of my research, it is not only an end itself, but also serves as a material for analysing the activity of learning in this course, as it is experienced by its participants.

In order to advance the analysis further when the categories are discerned, now with the aim of studying the variations in the learning situation as experienced by the students who take the course, the categories are related to different constituents of the activity. The categories at each constituent then come to indicate how this particular constituent is experienced. The activity described in this way, based on the phenomenographic analysis, is capturing the variation of the experience by its participants, *from inside* the activity.

This is illustrated in example 3 (see page 14), where a preliminary study in this project (Berglund and Booth, 2002) is presented. Students' experience of grading is tentatively associated to the components of an activity. As is illustrated in the example, the different ways of experiencing a particular phenomenon (as grading) can be related to different components of the activity (as object, community or rules). Clearly, there is not a one-to-one mapping between a particular phenomenon and one specific component.

Further analyses can be performed in several ways. First, contradictions within and between components offer possibilities for the researcher to learn about the activity. The different ways a particular components is experienced is a possible source of contradictions, if the ways in which the component is experienced do not easily coexist. Also, contradictions between nodes can be discerned and analysed. Since the study here is based on the descriptions by the participants, the contradictions discerned in the analysis relates to and reveals contradictions as they are experienced by the students.

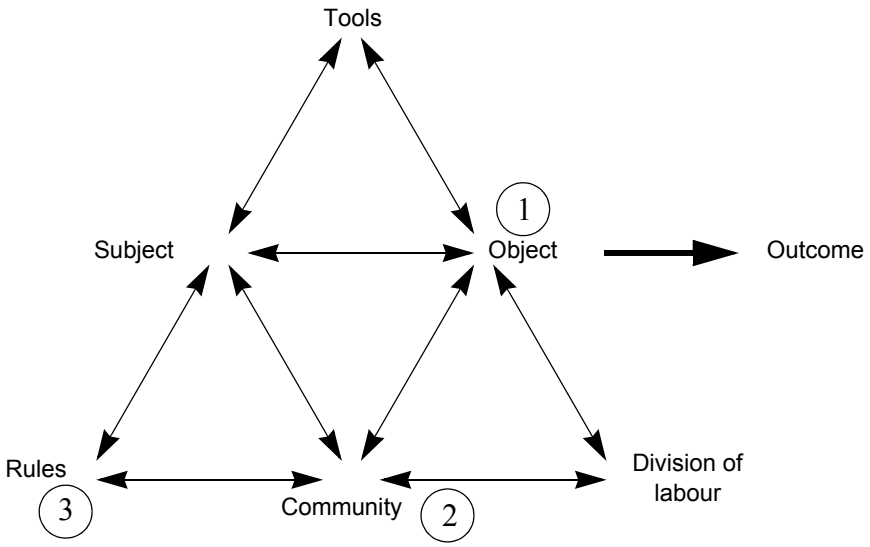
Secondly, a further phenomenographic analysis at a particular component can be performed, by returning to the interview excerpts that now, through the categories, are related to this component. These interview excerpts can again be analysed with the component and the earlier analyses as a background. The new analyses would reveal aspects related to the component in question, and to those phenomena that originally, through different aspects, fed into the description of the component. New dimensions of variation would open, related to the components (as rules, tools etc.) of the system rather than to particular phenomena in the learning situation. By performing this kind of analysis, the researcher can gain insights into the learners' experience of a particular constituent of the activity.

In the discussion above, I have distinguished between, on the one hand, those phenomena that are parts of the learning object within the subject area, and on the other hand, those phenomena, that although not being presented as learning objectives, are parts of what constitutes the learning environment for the students. As examples of the first, that I will refer to as *phenomena within the subject area*, can be mentioned the different network protocols, both in practice and in theory, as well as the use of compilers and methodologies for programming design. The latter, that I will refer to as *phenomena that are contextual to learning*, can be exemplified by the collaboration with other group members or the grading, issues that often are regarded as important by the students, and that sometimes play the role as goals in themselves. The distinction is important, since my aim is to study students' learning *of computer science*, that is their learning within the subject area and, from the conclusions drawn about their learning,

Example 3. Students' experience of grades, in a phenomenographic study, association to components of an activity

The table below illustrates the ways of experiencing grading that have been discerned in an earlier preliminary study in this project by Berglund and Booth (2002). The categories identified have been associated to components in an activity system. The category "getting a good grade is a goal in itself" (category 1) is, by us, associated to the object component of the activity, as is illustrated in the figure. In category 2 the experience of finding the grading as an unimportant feature is described. Here the importance of doing a good work together with other group members or to show good results in front of other participants are experienced as stronger than the interest in a good grade. Consequently, we have judged this category as related to the community. Grading can also be experienced as an obstacle that hinders learning and work (category 3). Experienced in this way it has the role of a rule that governs the work

	Category
1.	Getting good grades is a goal in itself
2.	Grading is not an important feature of the work
3.	Grading is an obstacle



suggest how the education and learning environments can be changed to improve learning in computer science.

A starting point for analysing the learning situation as it is experienced could be to use the categories of description for the phenomena that are contextual to learning. However, these categories are not alone, by themselves, sufficient to form an activity. An activity is an indivisible whole, and must be studied as an entity. Some specific phenomena, how well selected they might be, do not alone constitute an activity, although they constitute one of the

grounds for research on the activity. The phenomena within the subject area can not be isolated, but must be studied as a part of the whole together with other phenomena.

A cornerstone in phenomenography is *variation,* as phenomenographic research aims at discerning the *variation* in the ways in which something can be experienced. Individuals experience something in differing ways, although the phenomenographic research can discern a limited number of qualitatively different ways in which a phenomenon is experienced. The description of these categories, each corresponding to a particular way of experiencing the phenomena, discerned by the researcher, forms the basis for the outcome.

With the aim of activity theory, to study an activity as an entity in its own right, the situation becomes different. A research project within this tradition normally focuses on the development of *one* activity, or *one* network of activities, and is analysed in an externalist perspective (compare section 4.3), that is, from a view-point from the outside. With this approach, where the study object is *one course of events*, the issue of variation becomes subordinate or disappears completely.

Thus, the question of by whom, or from which perspective, a phenomenon or activity is experienced or analysed has become a key issue. Since I study an activity, as it is experienced by its participants, I need to analyse and describe the *variation in the ways* in which the activity can be experienced.

4.3. An activity or the experience of an activity as the study object

In Adawi et al. (2002), we discuss the distinction between *experientialist* and *externalist* approaches to research introduced by Ekeblad and Bond:

> A similar distinction between the ways in which two different research forms treat the notion of context. On the one hand, in "an *experientialist* perspective … the research question is designed to seek an understanding of what it is that is experienced" whereas, on the other hand "an explanatory or *externalist* approach to research assumes that we are looking at the impact of context *on* an individual" ([Ekeblad and Bond,] p. 148; our italics). The first, experientialist, perspective is in line with what we take as our starting point [...]. The "externalist" perspective leads researchers to observe events and to analyse them from within their theoretical and methodological frameworks, rather than seeking to see them through the experiences of the actors in the events.

Making this distinction, a phenomenographer clearly takes an experientialist's perspective, while a research project in the activity theoretical tradition rather can be expressed as having the or externalist's perspective.

However, looking deeper into this aspect of activity theory a more complex picture evolves. As stated in section 3, a participant in an activity, a subject, as for example a student in a university course, is part of the activity. The activity is a context in and within which he or she acts and interacts. In this way the student, through his or her actions, is integrated with the activity. It is thus meaningless, with this approach, to discuss the "impact of context *on* an individual" (compare the quote above). Still, I argue, the activity theoretical research approach is an externalist approach, since its research object is the *activity as such.* An activity is a theoretical construct, that is formed by the researcher to analyse a complex situation. When describing an

activity as an evolving system, stressing the collective structure and the historical components, the perspectives from outside are needed.

My perspective is different, as I do not focus on the system as such, but on the experience of the individuals who are parts of the activity. With my approach, I get "close" to the participants as I describe their experience, while I, as a consequence, have a lesser possibility to study the activity system as an entity in its own right.

Another aspect that makes firm statements on activity theory as a "pure" externalist approach questionable is related to the choice of empirical data. Data based on experience can, and according to Engeström (1987) should, be used by the researcher for gaining insights about the activity.

4.4. The use of some concepts in the proposed approach

A research approach within pedagogy does not only carry with it the basic assumptions about learning, and how learning can be studied. It is also, in itself, a system with its own history and its own language to express ideas. When combining research perspectives, some clarifications about basic concepts as well as the terminology might be needed. I will, in this section, discuss *context*, *collective* and *experience* in relation to my approach.

a. Context

There has been lively discussions on the issue of *context* and its implications for learning and for research about learning. Adawi et al. (2002) discuss context in phenomenographic research, while van Oers (1998) indicates important aspects of context in relation to practice in activity theory and related socio-cultural research approaches. In this section I will discuss the differences between the phenomenographic use, based on the phenomenological distinction between theme and thematic field, and activity theory use describing the whole activity as a context.

Engeström (1993) summaries the notion of context within activity theory in the following way:

> For activity theory, contexts are neither containers nor situationally created experiential spaces. Contexts are activity systems. An activity system integrates the subject, object and the instrument [...] into a unified whole. (p. 67)

With this meaning of context, earlier discussed in section 3.2c, a learner is a part of and is acting with and within the context. The course that this project is based on can, as an example, be regarded as an activity and thereby a context.

In phenomenographic research the word has a different meaning, related to the awareness of the experiencer, as presented in Marton and Booth (1997):

> Gurwitsch (1964) made a distinction between the object of the focal awareness, the *theme*, and those aspects of the experienced world that are related to the world and in which is embedded, the *thematic field*. (p. 98, italics in original)

This distinction is developed and applied to phenomenographic research by Marton and Booth, keeping the relation to experience. Replace the word "situation" with "context" in the quote below.

> We cannot separate our understanding of the *situation* and our understanding of the *phenomena* that lend sense to the situation. Not only is the situation understood in terms of the phenomena involved, but we are aware of the phenomena from the point of view of the particular situation. And, further, not only is our experience of the situation moulded by the phenomena as we experience them, but our experience of the phenomena is modified, transformed and developed through the situations we experience them in (p. 83, italics in original).

Although the context and the phenomenon are intertwined, as researchers we can separate analytically separate a phenomenon from its context, taking a second-order perspective. As we point out in Adawi et al. (2002) this analytical separation is one of the keystones in the analysis performed during a phenomenographic research project.

Clearly the two usages of the word are different. The phenomenographic use of the word is at the same time more narrow (since it is delimited to experience) and broader (since it is not limited by the activity, as it is discerned by the researcher). It would thus be incorrect to compare activity theory and phenomenography through the use of the term. Instead, the different meanings can be related to the different needs within the two traditions: Activity theory focusing on a system as a whole, and phenomenography taking the experience of individual learner as its point of departure.

With the approach presented in this paper, the two notions of context are both important. It is impossible to discuss the research process in a phenomenographic research project, as this, without considering context in a phenomenographic sense, and without using the concepts of phenomenography, as de- and re- contextualisations. Thus, at the level of the researcher (see page 18) the phenomenographic concept of context has to be considered. On the other hand, the students' experience of their learning and the learning environment are analysed and described as activity systems. Naturally, when discussing the experience of a student or groups of students, with the activity analysed and described from the inside, the activity theoretical notion of context, being equivalent to activity, comes into focus.

b. Collective

Another word that has different interpretations within activity theory and phenomenography is *collective*, expressing a unit or an entity on its own within activity theory, while the word within phenomenography describes an analytic abstract construct, comprising the collection of people from whom data has been collected, and extending to similar people to whom one wants to apply the result.

Within the tradition of activity theory, a collective can denote a group that acts as a unit, that is, the collective is comprising and superseding the individuals that it is formed by. A collective is, with this view, a unit in itself, as an organism, with its specific identity. Nardi (1996a) phrases this as "a subject [in an activity system] is a person or a group engaged in an activity".

Marton and Booth (1997) distinguish between individual and collective levels of description, pointing out that the categories of description represent a collective level. In Adawi et al. (2002),

we continue this discussion by addressing the issue of the "ownership" of the context in phenomenographic research, as data in a phenomenographic research project stems from the experiencer, but the researcher is present in the analysis. Thus both the original experiencer and the researcher has a relation to the phenomena discussed and their contexts. Also another level exists, apart from the individual or the researcher: Data from one interviewee can, during the analysis, be read with data from other interviews as a background. Then these interviews together form a background, or a context, at a collective level, that renders meaning to statements of individuals.

The contexts at the level of the researcher and at the individual level are experienced by someone: a researcher or an interviewee. The collective level on the other hand is a theoretical entity, created during the analysis in a phenomenographic research project. In Adawi et al. (2002) we justify the introduction of a collective level in the following way:

> When analysing the interviews, the researcher finds that light is shed on some utterance made by one interviewee by reading it against the background of the context deduced or assumed by the researcher from reading an interview extract by another interviewee. Switching between these two perspectives allows the researcher to let an aspect of a phenomenon as experienced by one participant interplay with an expression of an experienced context that originates from another participant. This leads us to introduce the notion of *the experienced context of the collective*. [..] [I]t facilitates the researcher in (1) making better sense of individual utterances, and (2) bringing to light otherwise neglected aspects of the cultural assumptions present in the study.

Thus the collective context is an analytical tool, or a theoretical entity, that offers to the researcher the possibility to read statements from one interviewee against statements of others. If interviews were studied one by one, some relationships would not have come to light, as is illustrated in the examples in Adawi at al., where statements about the physical concept of "heat", uttered by one interviewee, only can be understood by reading it against another interviewee's statement about heat as something that can be converted to useful work

While the *collective* in activity theory is an entity, or a unit, in its own right, in phenomenography the collective level is an analytically constructed idea used by the researcher.

In the project forming the basis for this paper learning is interpreted as a change in the relation between an *individual* and a phenomenon. Thus, since I do not study learning of a collective, as a unit, the activity theoretical interpretation of the term is of little importance in my work. In this paper, I use the word collective in the phenomenographic sense, unless otherwise stated.

c. Experience

The idea of *experience* and of experiencing something is a keystone in phenomenographic research and has thus a well-defined meaning related both to the individual that experiences something and to what he or she experiences. In activity theory, on the other hand, the word is used in vague way and has no well-defined meaning.

Marton and Booth (1997) define *experience* in the phenomenographic perspective:

> An experience is an internal relationship between the person experiencing and the phenomenon experienced: It reflects the latter as much as the former. (p.108)

Clearly, this particular meaning of the word is not relevant in research in the activity theoretical approach, since it relates to an idea that is not present within that research approach. Instead, the word is used in different way: sometimes in a commonplace meaning, sometimes more specifically to contrast data collected through interviews or in similar ways as *experiential* in the quote by Engeström in section 4.4a from data collected in other ways. With this research being carried out with a phenomenographic approach, I use the word experience as is commonplace within the tradition.

4.5. Related research

An extensive literature review has revealed that only a few research projects have been carried out where the use of phenomenography is extended to encompass aspects from activity theory. Also, the related approach has been searched for: to extend a research project in activity theory by considering aspects that are normally referred to as phenomenographic is also rare. The studies that have been found are different in their characters and their ways of encompassing the two approaches:

Åberg-Bengtsson (1998) studies young children who learn to draw and interpret graphs and charts in a basically phenomenographic project, which has been mentioned earlier in example 1. The relation between the learners, who collaborate with a researcher/mentor, and the object of their studies are studied in a phenomenographic tradition. She thus presents the learning that takes place as a outcome space consisting of sets of categories of description. The learning that she describes is however not only the children's relation to what they study. Rather, since the children work in teams together with the researcher, the working group is a collective entity. In order to address this complex situation, as well as other contextual issues, Åberg-Bengtsson studies the whole learning situation in the light of an activity theoretical model.

In their work concerning the introduction of a new ICT-based tool into teaching and learning of mathematics at first year university level, Coupland and Crawford (in preparation) aim at describing the different ways in which the students engage with the software, and how they appropriate it. The authors link phenomenography with activity theory at two "levels": On the surface level, phenomenography serves as a guide to the kind of data to be sought and a way to deal with the data collected. At a deeper level, they argue that the second-order perspective and non-dualistic views of the two approaches offer links.

Gordon (1998) has in her thesis investigated university students' orientations to learning statistics. She uses phenomenography combined with statistical analyses, to explore relationships and events for particular individuals in a setting that was bounded in space and in time. Activity theory served as a framework to transcend the particular context.

In their study of distance learning for engineers Hultén and Booth (2002) have extended their phenomenographic approach through activity theory. They describe an extended relationship between an experiencer and the experienced, where this relationship is mediated through the tools as well as other components in the activity. Thus it is clear, that their approach in important ways resembles the approach presented in this paper.

Kärkkäinen's research (1999) is predominantly within the activity theoretical approach, when she studies Finnish and American teachers who collaboratively produce a curriculum for

elementary school. However, when analysing interview data concerning network building outside classrooms she is approaching a phenomenographic analysis.

5. Discussion and future work

In this paper I have presented a research approach, aimed to inform my studies of students' learning of computer networks in an internationally distributed course. The research I perform within this setting, aims at revealing

- how the students understand and learn some computer network concepts
- how the collaborative learning experience is experienced and tackled
- how ICT is experienced as support for peer learning and peer teaching
- in what ways the situation is seen as a contribution to a future professional life

Through this project, the universities involved learn about their students' experience of their learning, all with an aim to redesign this particular course and to design courses that promotes students' learning of computer networks. Insights will also be gained on how students' collaborate and how different elements in the course setting relates to the learning of the subject matter in focus.

In the approach proposed in this paper, learning is studied as a part of the situation as experienced by the students who take the course. The experience of collaborating within the project groups and within larger communities, including classmates and teachers, as well as the experience of learning environment, containing both physical and abstract entities, must be considered. In doing so, the researcher should not lose sight of the subject area that is learnt about, here computer networks. Both the course content and the context of the learning play important roles for the students' experience of learning computer networks, and neither can be omitted in a study of the learning that takes place.

In my future research within this project, I will continue the analysis of the data collected from one of the years the course has been given. My research on students' understanding of network protocols (Berglund, 2002) will be supplemented by a study on the experienced context of the studies, with the aim of linking the two together to describe the students' learning of computer networks in this particular context. The results will then be used to inform the teaching and educational design in relevant subject areas.

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