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Unwinding Processes in Computer Science Student Projects

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March 2008

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Dissertation for the degree of Licentiate of Philosophy in Computer Science Education Research
at Uppsala University 2008

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ISSN 1404-5117
Printed by the Department of Information Technology, Uppsala University, Sweden

Abstract

This thesis investigates computer science student projects and some of the processes involved in the running of such projects. The reason for this investigation is that there are some interesting claims concerning the use of projects as learning approach. For example, they are supposed to give an extra challenge to the students and prepare them for working life, by adding known development methods from industry the sense of reality is emphasized, and involving industry partners as mock clients also increases the feeling of reality, but still unclear if these features contribute to the students' learning and what can be done to increase the potential for learning. There are thus interesting pedagogical challenges with computer science student projects. There is a need to better understand the effects on learning outcomes as a function of how a student project is designed. The focus in this thesis is on the effects of role taking in the project groups, work allocation, and goal setting in student projects.

In this thesis, three studies investigating different aspects of processes in computer science student projects are presented. A number of conclusions are drawn, which serve as a starting point for further research.

The first study investigates how power is distributed within a group of students in a full semester computer science project course. Perceived competence of fellow students contributes to personal influence in the student project groups, and three qualitatively different ways of experiencing competence among other students have been identified.

The second study investigates experiences of the process of decision-making in a full semester computer science project course. Six categories describing the experience of decision-making have been identified spanning from the experience of decision-making in individual decisions too small and unimportant to handle by anyone else than the individual to the experience of decision-making as a democratic process involving both the full group and the context in which the group acts.

The third study investigates Swedish engineering students' conceptions of engineering, where dealing with problems and their solutions and creativity are identified as core concepts. Subject concepts, as math, and physics do not appear in any top position. "Math", for example, accounts for only five percent of the total mentioned engineering terms. "Physics", the second highest ranked subject term, only accounts for circa 1 percent.

By combining the results from the three studies, four central areas of general interest for designing and running student projects have been identified. These four features are: 1) the mechanism for work allocation; 2) students connection to external stakeholders; 3) focus on result or process; and 4) level of freedom in the project task. These four features are related to the results from the three studies in this thesis. The thesis is concluded by proposing an analytical framework based on those four features. The intention with the framework is to provide a useful tool for the analysis and development of future computer science student projects.

Acknowledgments

First, I would like to thank my supervisor Mats Daniels. Your extensive knowledge in the field has contributed a lot to the quality of this thesis, your creativity has led me in new and exiting directions, and your faith in me has been very valuable and appreciated. Thank you.

I would also like to thank my co-supervisor Lecia J. Barker. Your theoretical advice has lit up the thesis, your ability to find weak points has strengthened the thesis, and your attitude has helped me believe in the thesis. Thank you.

Anders Berglund, Ivan Christoff, Per Gunningberg, Håkan Lanshammar, Britt Magnusson, Filip Rosenbaum, and Aruna Seneviratne – the support and help you have provided me has been very valuable. Thank you.

Colleagues in Uppsala Computing Research Group – Jonas Boustedt, Anna Danielsson, Liselott Dominicus van den Bussche, Anna Eckerdal, Arnold Pears, and Michael Thuné. Thank you for creating a fun and challenging research atmosphere.

I let those who have shared in the ups and downs be represented by Richard Bengtsson, Madeleine Dahl, Joakim Lindqvist, Mats Nordenborg, Petra Ornstein, Pelle Rödin, Jim Wilenius, and Magnus Ågren. It is very valuable to be your friend.

I am most grateful to all women and men, in past and present times, devoted to working for an equal, top-class, free of charge, educational system. My working towards a Ph.D. is just a small evidence of your success.

My parents Kerstin Nyström-Wiggberg and Anders Wiggberg together with their co-pilots Anne-Cathrine Hedin and Jan Hedin have provided me with the self-confidence and attitude needed to hang in there. I am most grateful for all the efforts and love you spent on me. Thank you.

Anna Ardin for all above, and more. Love.

Did I forget someone? If so, that can be remedied in my forthcoming Ph.D. thesis – let us enter that final journey.

February 2008
Mattias Wiggberg

The work in this thesis is partly funded by Science and Technology Studies Centre, Uppsala University for which I am most grateful.

List of Publications

This thesis is based on the following publications:

Paper A M. Wiggberg. (2007). *"I Think It's Better if Those Who Know the Area Decide About It" – A Pilot Study Concerning Power in CS Student Project Groups.* In A. Berglund & M. Wiggberg (Eds.) Proceedings of the 6th Baltic Sea Conference on Computing Education Research, Koli Calling. Uppsala University, Uppsala, Sweden. Also available at `http://cs.joensuu.fi/kolistelut/`

Paper B M. Wiggberg. (2008).*Experiences of Decision Making in Computer Science Student Project Groups.* Australian Computer Society, Inc. This paper appeared at the Seventh Baltic Sea Conference on Computing Education Research (Koli Calling 2007), Koli National Park, Finland, November 15-18, 2007. Conferences in Research and Practice in Information Technology, Vol. 88. Raymond Lister and Simon, Eds.

Paper C M. Wiggberg & P. Dalenius. (2008). *Bridges and Problem Solving – Swedish Engineering Students Conceptions of Engineering in 2007.* Submitted.

Comment on Paper C First author. I have contributed with data collection, analysis and writing of roughly half of the different sections.

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Chapter 1

Introduction

> **Benjamin**[1]: If it is a real project, then it feels really stupid to put someone in a position, just because he wants to learn about that.

What is a good computer science student project? How could such learning environments be an effective learning experience? This thesis is a part of a Ph.D. research project that aims to provide an insight into the complex processes in computer science student projects. Special attention will be given to the relationship between personal influence, decision-making and learning of concepts. The subject of the study is groups[2] of computer science students studying at an advanced university level.

Today, universities in the Western world largely organize computer science education in such a way that group work is an integral part of the students' education. As an example, this is manifested in the important role of teamwork in the Association for Computing Machinery (ACM) Curriculum (The Joint Task Force for Computing Curricula, 2005), as well as in many study programs. The Master's program in Information Technology at Uppsala University is one example where projects are emphasized as a model for learning approaches. Still, little research has been made that highlights the learning outcome of group work and relates that to the group's processes in computer science (with the exception of recent work by Berglund (2005); Kinnunen and Malmi (2004); Barker and Garvin-Doxas (2004)). By investi-

[1]An excerpt from an interviewed student in paper B. Names have been changed to preserve the anonymity of those involved. More on this process can be found in section 4.2.3.

[2]Mirriam-Webster `http://www.merriam-webster.com/dictionary` defines a *group* as "a number of individuals assembled together or having some unifying relationship", while a *team* is defined as "a number of persons associated together in work or activity". Throughout this thesis, *group* will be used as a reference to the students participating in a project course, striving to fulfil a common task. When referring to other work, *team* might be used if that is the choice of the original works.

gating different aspects and processes in computer science student projects, combining the different results and proposing a framework for analysis and design of the projects, this thesis contributes in the area.

1.1 General Research Questions

Given the importance of group work in the computer science curriculum, the following general research questions are posed as a setting for the Ph.D. work of which this thesis is a part of:

A How do participants in groups of advanced students experience personal influence, the decision-making, the responsibility, and the goal setting processes while working on industry-like projects?

B How is the distribution of these processes in the groups related to the students' competence in computer science?

C How is the distribution of processes in the groups connected to the learning outcome?

D What are the pedagogical implications of the above stated questions?

This thesis will address questions A, B and D. The origin of these questions and a discussion of them will be presented in chapter 2.

1.2 Studies to Explore the Research Questions

The general research questions constitute the full Ph.D. research project, and this thesis gives a status report in which three of the four questions have been addressed and thus provides a basis for the remaining research project. At this time, three different studies have been performed.

Wiggberg (2007) is the first study, referred to as Paper A in this thesis, and is a study of students participating in a full semester computer science project course for information technology students. The focus is on how personal influence is distributed within a group of students. A phenomenographic research approach was used to reveal some of the aspects of personal influence within computer science projects.

The second study, Wiggberg (2008), referred to as Paper B in this thesis, aims to understand the ways in which students experience the process of decision-making in computer science student projects. It also investigates the ways in which student groups work to make decisions. The empirical setting for the study is a semester long project with 22 final year computer science students. It is a qualitative study where data are gathered through interviews which are analyzed using phenomenography.

The third study, Wiggberg and Dalenius (2008), referred to as Paper C in this thesis, is based on a large nationwide investigation of Swedish engineering students, teachers, and alumni (Adams et al., 2007). Surveys and interviews were used in order to extract conceptions about engineering. The overall investigation included questions regarding why, or why not, students enter engineering programs, and the aim with this particular study is to find and describe what conceptions of engineering education Swedish engineering students have in 2007. Empirical data comes from the nationwide Stepping Stones project, organized by CeTUSS [3]. This study aims to describe the general conception of engineering within a larger student population, of which computer science students are a part. Their conception of engineering might help to clarify the motivation and goals of their participation in the projects.

These three empirical studies prove to be a useful stepping stone in answering the general research questions. Hence, these studies provide a basis for learning more about the processes in computer science student projects. Based on the three empirical studies, four important features for the learning outcome can in this thesis be identified as important to consider when designing computer science student projects: mechanisms for work allocation; connection to external stakeholders; focus on result or process; and level of freedom in task.

1.3 Organization of Thesis

In this first chapter, an introduction to the Ph.D. research project is presented, together with the general research questions. In the second chapter, a rationale for the research interest is provided as a motivation for this research. This is followed by a chapter on related work, describing the educational landscape in which this research fits. The main research approach and phenomenography are then presented including a discussion about the reliability of the material. A presentation of key findings and what these imply follows and finally conclusions and future work are presented. The three papers this thesis is built upon are also given as appendixes.

[3] Nationellt ämnesdidaktiskt Centrum för Teknikutbildning i Studenternas Sammanhang (CeTUSS) www.cetuss.se

Chapter 2

Rationale

This thesis aims to increase our knowledge of student project work as computer scientists. The rationale for researching important features for the learning outcome influencing computer science student projects and the ways in which students develop solutions to technical tasks can be found in my varied educational background and my interest in applications of information technology.

The rationale for studying computer science student projects is expounded in the following chapter. An illustration of a computer science student project follows, together with my general research interest and the more specific research questions. Finally, a summary of the rationale describes the direction for the reminder of the Ph.D. research.

2.1 My Background

Growing up in the 1980s meant being an active or passive part of a massive increase in electronic information. While the area of information technology existed, digital equipment was not in broad usage prior to 1980. Pre-school was computer clean, middle school involved tiny gleams of early applications such as pocket calculators and digital watches, and it was not until highschool that I was introduced to my first personal computer. My early fascination with computing's possible gains in efficiency and its numerous applications led me to a computer science university program at Uppsala University, Sweden. After graduation, I became interested in the underlying dynamics of the information technology era and hence I started my way toward a Ph.D.

My curiosity in information technology as a tool to facilitate communication led me to study computer science. Other interests such as work processes and organization became another major focus of my university studies, which in turn led to thoughts of combining the tool (information technology) and the task (communication). My interest in education and learning processes made me reflect on questions about group work, group performance, and the particular field of important features for the learning outcome in computer science student projects. Being a part of the Department of Information Technology at Uppsala University meant teaching undergraduate students, and provided the melting point where my different interests, learning, work processes, and information technology was found.

2.2 Computer Science Student Projects

Computer science student projects constitute both the subject of the research and the empirical setting where the students are supposed to learn. This section will introduce computer science student projects by an illustration of one such project. Aim, formal goals, and physical environment will be described together with a specific project group and its tasks. The chosen illustration does not describe all different projects, but is representative of a typical project.

The project setting chosen to illustrate computer science student projects comes from the main study in this work – the decision-making study in Paper B. Different projects have different settings, but this project has certain characteristics that make it suitable as an illustration of the concept of computer science student projects.

2.2.1 Overview of the Project Course

The computer science project course that is used as a representative example is given in the final year of the computer science Master's program at the Department of Information Technology, Uppsala University. The course duration was 20 weeks and the particular instance was held between August 2006 and January 2007. The course was taught in English (Wiggberg, 2008).

The general setting for the course is that participating students work with one project for the full duration of the course. The requirements of the product are set by the team of teachers together with an industry partner and are new for each course instance. This is an example of that computer science student projects sometimes have connections to external stakeholders representing the software industry. The projects might be connected to the external stakeholders by allowing an industry partner to contribute with tasks, knowledge on planning models and sometimes funding. More than one external stakeholder can be involved in the project at one time. However, in course instance described only one external stakeholder was involved in each project, helping out with the requirements of the task. The exact specifications of the product are not set. Instead, the students are required to set their requirement specification themselves from an initial idea formulated by the team of teachers in cooperation with the participating industry partner (Wiggberg, 2008).

The number of projects varies with the number of students, since the aim is to have between 10 and 15 students in each project. Furthermore, the projects will be different from each other if there is more than one project. In the specific course instance, 22 students participated and were divided in two projects, (1) designing software for a game for mobile phones (Nilsson et al., 2007) and (2) mobile phone positioning (Back et al., 2007). The industrial partners also contributed to the projects as mock customers (Wiggberg, 2008).

2.2.2 Course Goals

The course goals are stated in the formal course description. These are then, for each course instance, interpreted by the current teacher or team of teachers. The formal course goals are set up by the Faculty of Science and Technology. The following excerpt serves as a typical example of such goals [author's translation]:

> The participants should gain insight, as members in a project group, into how a large-scale project is run from planning to realization within the field of distributed systems, i.e. a system where the computer resources are distributed but require synchronizing to work. During the project, the participants should get the opportunity to experience modern design principles, modern programming methodology, and practice in narrowing a task and choose suitable components. Each participant should also get the possibility to enter deeply into at least one aspect of how a complex distributed system should work (Faculty of Science and Technology, Uppsala University, 2007a).

Based on those formal objectives, the team of teachers have formulated and communicated the following interpretation for the current course to the students:

> The goal of the course is to give students knowledge and insights into how a big project is run (from planing to realization), [to] give deep knowledge in modern construction principles and programming methodology, and knowledge about how to construct a complex distributed system (Pettersson, Gällmo, Hessel, & Mokrushin, 2006).

The teachers' interpretation is hence a shortened, but straightforward, interpretation of the formal course description.

2.2.3 The Physical Environment

During the project, the students worked in two project rooms. Each group sat in a separate room but the rooms were located close to each other. Collaboration between the project groups was encouraged. The work environment was an open-plan office where people located themselves close to the members of the smaller groups they ended up working in. Each student was given a workspace and a computer. The room was equipped with a whiteboard, printer and other for the project relevant hardware. The groups were also asked to use software for keeping track of bugs, a version handler, a content management system and personal diary software. The students were expected to work eight hours a day during the second half of the semester, and presence was compulsory from 9 am to 4 pm (Pettersson et al., 2006). According to Jaques (1995, p. 120) the physical environment plays an important role in a project.

Prior to the course, the students were asked to sign a contract regarding the intellectual property of the coming project. In short, the contract stated that both the University and the industry partner, in addition to the students, were granted unlimited use of the intellectual properties at no charge (Pettersson, 2006).

2.2.4 Project Groups and Their Tasks

22 students participated in the course. Five of them were exchange students from Tongji University, Shanghai, China, whereof four were male. The exchange students had completed two years of computer science in China and one year at Uppsala University prior to the project course. The other 17 students were Swedish, whereof 15 were male, and all were enrolled in the computer science Master's program and were about to start their fourth year – although most had studied more than three years. The course is an elective course for both the exchange students and the Swedish students [1].

Two different projects, with different tasks, were formed in the beginning of the project course. Although the projects were different, there were high levels of collaboration between the two projects. Members of the different groups discussed common technical challenges and project issues on an informal basis.

As a preparation for the project course, some introducing lectures in project methodology were given to the participants of both project groups. A model for work allocation was borrowed from the software industry during the project methodology lectures (Pettersson, 2006). It is not likely that the students had any deeper experience of project methodology from other large-scale projects, and it is thus interesting to observe how they tackle the

[1] Anders Berglund, Director of international undergraduate collaboration, Department of Information Technology, Uppsala University, private communication.

use of the project model and to address the following questions. Does the illustrated project model from industry support what is needed in order to create a good learning experience for the students? What does the project model emphasize as the aim with the experience? Is that aim coherent with the desired learning outcomes? That is, it is valuable to understand how introduction of project models from industry affects the students' goal with the project. How the chosen project methodology interacts with the decision-making processes in the projects is another area of interest in this work.

The project group "Point of Interest" (POI) was assigned the overall task of designing and implementing a mobile positioning system based on information provided by the GSM [2] network and GPS [3]/WLAN [4] when available. The specific part of the task was to create a map where a set with points of interest could be displayed (Back et al., 2007). The task is described as follows in the project plan:

> The more specific goal with Point of Interest was broken down into two parts. The first subtask is to create a system that can interact with mobile phones with respect to their geographical position, without using GPS. This method should use re-engineering of the GSM network, but also be able to use GPS if available. WLAN shall also be supported if available on the phone.
>
> The other goal is to create a[n] interactive service based on client positions disregarding localization method. Depending on the users position a set of Point of Interests shall be displayed on a map. The user shall be able to read info on each of these POIs, comment [on] them, add their own POIs and filter by interest. In addition, support for uploading images with POI shall be implemented. The service shall be community based where users can create their own groups. An easy web interface acting as a community shall be made. This should be demonstrated in a field test. (Nibon, 2006, p. 5)

The project members in Point of Interest organized themselves in accordance with the general system design as shown in figure 2.1. Following the appointment of project manager, the group assigned formal roles and responsibilities among the participants. An analysis of required roles and

[2] Global System for Mobile communications (GSM) is today the most popular standard for mobile phone systems

[3] Global Positioning System, GPS, is a satellite based positioning system allowing you to locate yourselves at the earth with an accuracy of some meters

[4] Wireless Local Area Network, WLAN, is a standard for linking two or more computers using a wireless network device.

responsibilities were done by the whole group resulting in a list of possible roles. The list contained more roles than the number of participants. All roles were put on a whiteboard and the students wrote their name on the roles they were interested in. One of three scenarios then followed: just one person had written their name on a specific role; more than one person had written their name on the role; or no one had written their name on the role. In the first case, the person interested got its role. In the second case, an open discussion about the appropriateness of different candidates followed and in some cases, people withdrew from their earlier preference. A random choice was made if more than one candidate was left after the discussion. In the third case, where no one had stated their interest for a role, the group assigned the role to someone they found suitable. Some people took care of the server side including everything but the client application that ran on the mobile phone. The server side group consisted of six people while the client side involved five people. Each of these subgroups had their own sub-manager, product manager, and test manager. In addition, roles like project administrator, configuration manager, system administrator, user interface manager, bug administrator, documentation manager, quality manager, and final report manager were distributed among the participants. Four students from both the server side and client side formed a virtual group for dealing with the communication issues.

Students chose or were assigned roles in the project for which they had little, if any, professional experience. How did they come to decide which role to aimd for? Was this an arbitrary decision? With so much work ahead of them, the task of assigning roles must happen quickly and with little experience of what the role would mean. Therefore, it is interesting to investigate how personal influence, decision-making, and responsibility among the participants in the projects affect these choices.

Project group "Teazle Goes Mobile" (TGM), was assigned the task of implementing a distributed multi-player game for mobile devices. The game was originally developed in 1997 under the name "Teazle" (Nilsson, 2006). In the project plan, this is described as follows:

> A part of the project is to produce a client game application for mobile phones. The client shall be able to connect to a server and play against other players, the server will host the internet-based multiplayer game. The application should also be able to act as a multiplayer application where 2-6 persons shall be able to play on the same phone without internet communication, in a turnbased fashion (hotseat). A user-friendly interface that allows the player to control the game shall be delivered onto the mobile phone screen by the application. (Nilsson, 2006, p. 6)

Although the technical goals were given by the industry partner and the team of teachers, the specific shape of the technical goals as well as design and implementation issues was open. Therefore, the project groups had to take the initiative to form the specific details of the goal. The projects were rather unspecific regarding their final design. The project groups thus had to interpret their task and develop a system design, a requirement specification, and an implementation plan. An interesting question here is how the industry partner's presence affects the choice of roles and goals? Is the project group tweaking the outcome of the project towards the industry partners expected result or do they see the process of the project experience as the main goal?

The members in Teazle Goes Mobile originally organized themselves around the three major development areas, and the selection of project roles among the participants was analogous to the selection of Point of Interest. The Teazle Goes Mobile organization illustrates this in the system overview in figure 2.2. The server side took care of the login server, the game server, the game database, and the web database. This subpart of the project consisted of four people. The second sub-group was the client side, which took care of the mobile application. This sub-group consisted of five people. Finally, the web portal sub-group had two people working on the game's web interface. There were also additional responsibilities, such as lead programmer, testing manager, system administrator, configuration manager, bug manager, final report manager, user interface manager, and requirement specification managers for all three sub-groups (Nilsson, 2006).

During the Teazle Goes Mobile project, the client side kept its time plan while the server side fell behind. The project group then decided to let one of the client side people work with both client side and server side. This slight reorganization improved the situation.

For both projects, the students were asked to apply to be a project manager to the team of teachers who then appointed the role to one of the applicants.

2.3 Sequences of Project Courses

Computer science study programs often include smaller or larger projects that have been run prior to a final, capstone like project, like the previously illustrated computer science student project course. The Department of Information Technology has within the IT engineering program and the Master in Computer Science program during the past ten years been running several projects in which students collaborate with each other. Sometimes students from other countries and education programs or exchange students have participated. Project courses have been run both early and late in both education programs. The first exposure to project courses for the IT engineering students is in the first course, Information Technology, where they conduct a small collaboration with students at Auckland University of Tech-

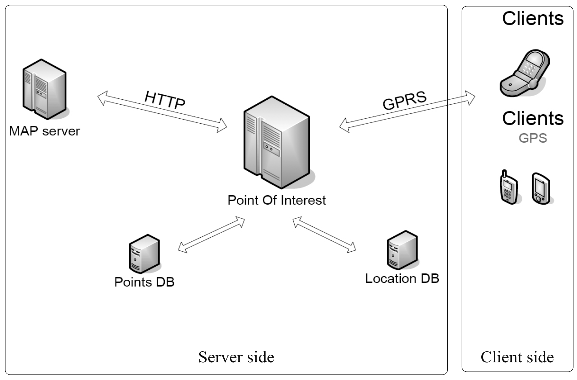

Figure 2.1 – A system overview of the Point of Interest project (Back et al., 2007).

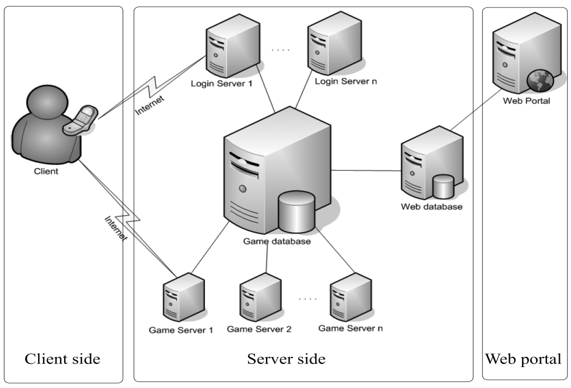

Figure 2.2 – A system overview of the Teazle Goes Mobile project (Nilsson et al., 2007).

nology. A later instance is in the Runestone part of the Computer Systems II course during the second semester in year three, where students collaborate with American students in a medium scale project, 500-600 person-hours. Runestone is well described in, for example, Hause (2003), Last (2003), and Berglund (2005). A third project has been run in the first semester of year four during the last five years. This collaboration is with American students in the IT in Society course, and is a large-scale project with authentic real-life customers, e.g. the Academic Hospital in Uppsala (Newman, Daniels, & Faulkner, 2003). The final year of both programs contains a full semester project course (for the Computer Science Program it is a 75 percent load) that is aimed at giving an experience of a large-scale project (Faculty of Science and Technology, Uppsala University, 2007a).

This final course has, essentially, been run for over twenty years. The tasks have varied greatly. Examples from the last five years include soccer playing robots, map-making systems, real-time middle-ware for robots, distributed mobile game and GPS-systems (Pettersson, 2006). Daniels and Asplund (2000) and Wiggberg (2007) have described earlier instances of this course.

2.4 Research Interests

My interest to learn more about the prerequisites for good learning experiences in student projects grew as I became more familiar with them. As presented in work by Waite, Jackson, Diwan, and Leonardi (2004), Barker (2005), Beranek, Zuser, and Grechenig (2005), and Berglund (2005) a plentiful set of dynamic factors exist which contribute to the effectiveness of the project model as pedagogic method in computer science. My experience as being part of teaching groups in project courses, was that there was more to learn about computer science student projects.

The use of learning approaches based on projects is in many ways interesting. In accordance with computer science department's folk pedagogies[5] it gives an extra challenge to the students and prepares them for working life. Adding known development methods from industry emphasizes the reality component and increases the students' preparation for working life (Coppit & Haddox-Schatz, 2005). Involvement of industry partners as mock clients also adds to the feeling of reality in the student projects.

There are pedagogical challenges with computer science student projects. An example is a mismatch between intended and real outcomes that can be found in one of the studied projects. The learning purpose with using a project model was communicated at the beginning of the course. Arguments for using the project model were stated or at least identified internally in the team of teachers. The team of teachers in the beginning of the course

[5]the term 'folk pedagogies' is coined by Bruner (1996).

described the goal with the course on an abstract level, where process and technical knowledge is emphasized (Pettersson et al., 2006). As a contrast the goal with the same course is described by the students in their final reports in terms of physical outcomes, that is, the product that the group is supposed to deliver at the end of the project and not by any learning purposes (Back et al., 2007; Nilsson et al., 2007). This example illustrates a potential disparity between teachers' intentions and students' experiences that I believe warrants further investigation.

The effects on learning outcome when using student projects are usually not well explored when designing the student projects; the traces of such in the literature are few. Effects of role taking in the project groups, work allocation, goal setting etcetera are seldom a part of the planning process. Instead, the argument is that the students will learn at least something from the student project, but that should not be a problem. In Säljö (2000), Lave (1993) discusses this [author's translation]:

> The choice is not between if people learn something or not, it is about *what* they learn from situations they are a part of. (Säljö, 2000, p. 28)

In a more general study, Entwistle (1977) discusses the need for reflection on group methods and points at the importance of group methods in higher education:

> What may, however, be necessary is to think more clearly about the functions of large-group and small-group methods in relation to the particular intellectual skills, or cognitive style, they are expected to foster and whether the assignments and examination questions given to students provide sufficient encouragement for deep-level processing. Entwistle (1977, p. 235)

The challenge for a teacher is to design a student project in a manner where participants reach as many of the learning goals as possible. Säljö (2000) emphasizes the important issue of how people gain interest in learning [author's translation]:

> The interesting question to scrutinize is why people engage and become motivated by some learning processes, while it often is difficult to create engagements in other contexts. But people cannot avoid learning. (Säljö, 2000, p. 28)

The starting point in my Ph.D. research project is connected to the reasoning above, namely how different processes in computer science student projects together contribute to the learning outcome of the projects. More precisely, the following research questions, first stated in section 1.1 will be addressed:

A How do participants in groups of advanced students experience personal influence, the decision-making, the responsibility, and the goal setting processes while working on industry-like projects?

B How is the distribution of these processes in the groups related to the students' competence in computer science?

C How is the distribution of processes in the groups connected to the learning outcome?

D What are the pedagogical implications of the above stated questions?

2.5 The Way Forward

Because of my background, interest and the proposed research questions, I started to explore and learn about computer science student projects. In the greater Ph.D. research project of which this thesis is a part, I will investigate different themes, such as how students perceive other students' competence, decision-making in project groups, and their conceptions of the subject area. Results from the three studies will be combined to form a cohesive knowledge contribution to the area of project approaches in computer science education. This will be done with the understanding that the unit of analysis is the collaborating project group.

The above research questions are part of a complex and to some extent unexplored field. To reveal important features for the learning outcome in computer science student projects I will approach the subject by a set of different research methods. This approach is not novel in the field of computer science education research, some earlier examples of a mixed method approach can be found in Kolikant (2005) and Berglund (2005).

One of my general research questions is *what processes contribute to learning in computer science student projects?* A fundamental issue in this research project is whether there are certain features that constitute a computer science student project. If so, could a pilot framework based on identification of these features be derived and used as a base for analysis of the studies included in this thesis?

Previous research in the field of student projects has contributed with various knowledge on group processes. The work in this thesis is aimed at increasing the research-based body of knowledge concerning group processes and especially in the field of computer science student projects in order to unwind the above mentioned processes, i.e. personal influence, decision-making, responsibility and goal setting.

Chapter 3

Related Studies

The field of project work as an educational setting in computer science projects is still in its infancy, but some studies in the area have been conducted. In order to present the research surrounding the work in this thesis, studies close to the core issues of the thesis are presented in this chapter, and summarized in the end of the chapter.

3.1 Groups and Efficiency

Kinnunen and Malmi (2004) explores the efficiency of Problem-based Learning in an introductory programming course. Different tutor-less groups were observed for their efficiency in working together. Based on those observations, the authors were able to distinguish between groups that worked efficiently and inefficiently. An efficient group was defined as a group that reached their weekly learning goals, where the atmosphere was pro-study and group members gained good studying results. In addition to this, three tutored groups were asked to state the tutor's role in the group. A result from the study is a description of characteristics of an efficient and an inefficient group. In the efficient group, members participated in the group meetings and made them responsible for their studying. In the groups' conversations, all members participated actively. The atmosphere in the efficient groups was relaxed and open. It was also found that members of efficient groups felt that their interaction and the way they worked together developed during the course. Inefficient groups had for example problems with students' free riding on others work, low participation, and a lack of common understanding on how to plan and carry out work. Even though this study concerns a project course at a first year university level, its conclusions regarding the value of communication and group interaction skills are still relevant for this piece of research. It its clear that the way the students choose to work together matters in regards to outcome of their group effort.

Waite et al. (2004) conducted a study of computer science students in undergraduate project courses, where there are indications that the students perform poorly in group skills. Through ethnographic observation and in-depth interviews of students during projects, they attempted to discover why using the project model did not give the students group skills. Waite et al. (2004) state:

> In order to improve the students' collaborative skills, we need to change some of the characteristics of their occupational community. This cannot be done by teaching a course in group work or telling them to work in groups to solve a problem. It has to be done by understanding the enculturation process, and establishing conditions that favour development of a collaborative culture. (Waite et al., 2004, p. 3)

The same study concludes that group decision-making is often experienced as an ineffective time consuming processes. Two characteristics of the decision-making process contribute to this: the predilection for their own opinions and their low trust in the rationality of using decision-making methods. By experimentation, the authors developed a viable group decision-making exercise that helps students to retreat from favouring the individual choice in decision-making situations (Waite et al., 2004). Waite et al. emphasize the importance of not just adopting the project model, but instead carefully designing the project course in order to achieve the desired learning outcome. Which factors that should be specifically considered in computer science student projects is however an open question. The described mechanism to meet different levels of challenges is interesting in the context of the current research project.

Leeper (1989) proposes progressive projects that help student achieve their maximum potential when working with major software projects. The project task is divided in three different levels, A-C, and students progressively follow the different levels. The first level contains a mandatory core of the project that all students need to pass. The second level extends the project in some meaningful way and is voluntary, this was the same with the third level. By using such progressive projects, Leeper argues that students feel more self confident by being able to complete at least one level. The outstanding students will also be challenged in a meaningful way.

The role of communication in student teams developing software has been investigated by Hause, Almstrum, Last, and Woodroffe (2001), utilising the Runestone course. Runestone is an initiative where 93 participants from two countries had the task to construct a piece of software. The students formed teams with 5-6 members where each team had students from both countries. Each team had a team leader that was actively participating in the work. Two teams were selected based on their production during the course, one high performing and one low performing, and their email communication was monitored. In an earlier study of the same data, 12 different categories were identified using discourse analysis. The current study coded the phrases into those 12 different categories. The frequency of each category where plotted along the time line of the project period. The main result from the study was that the successful team had a major part of their planning messages in the start phase of the project. The low performing team, on the other hand, had their phase of planning at the end of the project. The authors conclude that early planning is important (Hause et al., 2001).

Vartiainen (2006) looks at moral conflicts in student project courses. The aim of the study was to learn more about what students taking information system project courses perceive as moral conflicts. Vartiainen (2006) used participant observations in a project group performing an information systems project. The project group consisted of students aged 20-25 in their third year, put together in groups of five with the task of implementing a project task defined by an external, industrial partner, or client. During the project course, Vartiainen arranged ethics courses. The aim of the courses was to develop the students' moral sensitivity and judgment. The students were asked to produce diaries during the course. The diaries and interviews, drawings and questionnaires were used to reveal moral questions that the students came across. In order to capture conceptualizations that are close to the personal experience of the student, the analysis of diaries, questionnaires and drawings was done by a method inspired by phenomenography. Moral conflicts identified in the data were coded and categorized. Among the findings is a categorization of six categories of the different kind of moral conflicts found in the empirical data. Besides the general result that moral conflicts are an active process in the student project course, one finding worth mentioning was that the most severe moral conflicts occurred when a student played the role of the project manager. An excerpt form the study illustrates this moral conflict:

> Student S2, in the project manager's role, confronted a moral conflict related to assigning a work task to a fellow-student whose ability to complete it was in doubt. On the one hand, he thought that, for the sake of honesty, he should probably tell the student of his concern, although the truth might hurt him. On the other hand, if he assigned the work task to him without taking any precautions, he might endanger the project. (Vartiainen, 2006, p. 82)

Vartiainen (2006) points at an interesting part of students´ life in student project courses. The moral conflicts described concern issues that sometimes lead to decisions affecting fellow students. This decision-making and its implications on the work process and learning outcome is of great value and demands further research.

3.2 Group Skills

Seat and Lord (1998) emphasize the importance of practising interpersonal skills such as communication and teaming. They refer to a program for teaching interaction skills to engineering students with the aim of increasing the efficiency of their technical skills. The approach for teaching these soft skills was to let the students adopt a simple set of general principles and apply them to their own context. From there, the students could experiment and interact in supervised groups with the possibility of getting feedback.

In an empirical study, Barker (2005) investigates how perceived pressure to finish a project for clients, together with poor understanding of how to work well in groups, has a negative impact on the learning environment and learning outcome from the project model.

> When students are allowed to select their roles based on expediency or comfort, it works against the benefits of collaborative learning, particularly in the case of IT education. While this approach may seem eminently practical and efficient, it does not provide any of the students with a new learning experience, but instead practice of existing skills. (Barker, 2005, p. 4)

Hence, when students select their own roles within the group, they tend to choose tasks where they already have well-developed skills, and through that choice eventually lose the major impact of the peer learning exchange expected in collaborative work. Barker also argues that only when group processes are made explicit can activities lead to enhanced learning. Even though performed in another cultural and social context than the current project, Barker presents findings worth considering. The findings put to fore the question of what role taking and process or result focus makes with the learning outcome of the project.

Brown and Dobbie (1999) reports from a computer science course where the authors had designed a different learning experience by supporting the teamworking students with team support and coaching in teamwork skills. Their previous investigation, reported in Brown and Dobbie (1998), leading the study was that Brown and Dobbie noted that few efforts were usually made to support the teams in their work. Neither were the students or teams monitored or evaluated during or after their team experience. Based on these previous experiences by the authors, they introduced the support system. The impact of the support system was probed by a survey and an essay. The survey was used in the middle of the course and at the end of the course, while the essay was written by the students at the end of the course. The results from the assessments show that different parts of the support system were judged as valuable by the students. Based on student's assessments, a set of guidelines were developed that should help to support teams: use a method to form the teams which takes into account student preferences, skills, and work habits; use projects that interest students; use regular deadlines and clear expectations; assign a leader; have support staff that helps with programming, tools etcetera; provide communication tools such as mailing lists, web pages; make role descriptions of the project roles. These findings may be supporting thoughts when looking into how computer science student projects could be developed.

Team structure and other factors, e.g. personality and skills of individual team members, are thought to be of high importance in order to form successful software teams. Beranek et al. (2005) has investigated these in a study were they focused upon three key elements: power; knowledge distribution; and role distribution. Role distribution consists of both formal and informal rolls. Beranek et al. (2005) focuses on role distribution and performs an empirical examination of 78 students divided in teams of six. Each team was appointed a team coordinator, technical coordinator and test coordinator and a written survey covering preferences for different task, self-assessments, typical work styles, and behaviour in groups were filled out by the students, once in the beginning of the project and once after completion. A statistical analysis was performed on the surveys and the found functional group roles matched the functional group roles defined by Benne and Sheats (1948). A predominance of task-oriented roles was found. Students reported high technical skills and a preference for technical, programming, tasks. The article advises that educational programs should encourage the awareness that successful software development in software development teams relies on task-oriented roles as well as on group-oriented roles within each team. Soft skills should also be improved since they are necessary for fulfilling group building and maintenance roles.

3.3 Motives in Computer Science Student Teams

Holland and Reeves (1996) describe an ethnographic study aimed at investigating the cognitive work of three programming teams. The study was performed on a course aimed at develop a complex piece of software in a collaborative manner. The course duration was three months and the task demanded close collaboration within the team. The students chose which project they preferred to work with and were accordingly divided into three different teams accordingly. The instructors specified the organization of teams. The teams were then closely monitored by the instructors. The anthropologist then observed the teams' work as well as the students participating in the introduction software classes. The main finding was that different teams assigned their priorities to a set of tasks in a very different way. One team strived to develop an elegant piece of software, one just wanted to fulfil the minimum formal course requirements and the last team focused on the challenges created by group dynamics. The different perspectives of the group affected the ways in which they defined their cognitive tasks.

Berglund (2005) explores students' learning in a project course, Runestone, where teams of three students from Sweden worked together with three students from USA. The team's task was to produce a piece of distributed controlling software. Data communication was a highly active element in the task. By interviewing the students Berglund was able to collect data about their learning and their learning environment. A phenomenographic framework was used to analyze the students' experiences of learning. In latter parts of the study Berglund uses a mixed method approach incorporating activity theory from the phenomenographic base. In the analysis, an analytical separation has been done based on what, why, how, and where the students learn. Students were shown to understand what they should learn, that is the network protocols, in four different ways: as communication between two computers; as a connection over a network; as a set of rules; as a standard. Berglund identifies three different motives for taking the course in focus: academic achievement; project and teamworking capacity; and social competence. How students go about learning computer science was also investigated. In addition, seven different was to act when they learn computer science were identified in the study (this result is also reported in Berglund and Wiggberg (2006)). Finally, the environment in which students learn computer science has been investigated, analyzed and described (Berglund, 2005). Berglund's study is performed in a similar setting to the ones in this thesis.

Another example of studies with mixed methods is Kolikant (2005). In an analysis of students perception of correctness Kolikant uses qualitative data about students' perceptions, norms and practices regarding testing and verification to make a quantitative study of their definition of correctness. The main result in the study is that students' definition of correctness differs from those of professionals. Kolikant's methodological approach combining qualitative and quantitative methods is another interesting example of a mixed method approach.

3.4 Summary of Related Studies

Waite et al. (2004) reports on ineffective computer science group performance due to poor group skills. Barker (2005) continues by adding perceived pressure to finish projects for clients as a problematic area for groups. Clearly, there is a need for research on computer science student groups, which is why different researchers address those issues. Entwistle (1977) emphasizes this by denoting the need for research on large- and small-group methods in teaching. Beranek et al. (2005) shows the importance of certain factors and their distribution within the projects. Earlier, research also show that computer science student projects can handle their effectiveness in different ways. Hause et al. (2001), for example, compares the effectiveness of teams depending on their communication pattern in the planning phase. Holland and Reeves (1996) extensive study on programming teams performing the same task showed that different teams ended up with a broad variation in their priorities. Berglund (2005) performance study along the same line as Holland and Reeves (1996), concluding that motives for taking a computer science project course differs a lot. Vartiainen (2006) and Berglund (2005) both use a phenomenographic research approach in their studies on computer science student projects, showing that phenomenography is a usable and reasonable research approach when revealing information about student experiences in computer science student projects.

As shown by the literature review, studies on computer science student projects have been carried out with a variety of different perspectives. There are nevertheless more to learn on those projects. The studies included in this thesis can therefore, among other things, contribution to the body of research surrounding learning process within computer science student projects. By revealing this information, we can learn more about the factors in project structures.

Chapter 4

Phenomenography

The Ph.D. research project of which this thesis is a part, aims to find relevant factors that influence the outcomes of student projects. So far, three different studies has been performed where the research questions have targeted how students experience each other as competent or skilled in computer science, how students experience decision-making in computer science student projects, and what conceptions of engineering students have. The first two studies, Paper A and Paper B, used a phenomenographic research approach. The research approach in Paper C is mainly a descriptive account of results from a survey, while Paper A and Paper B rely on phenomenography as a research framework. Marton and Booth (1997) provide a general discussion about phenomenography and Berglund (2005) about its applications within computer science education. In this chapter, the phenomenographic research approach, the methods used, and ethical considerations will be presented. Finally, a word on discipline based research and reliability is given.

4.1 Phenomenography as Research Framework

I have used a phenomenographic approach to reveal different ways of experiencing how processes in computer science student projects work. The data analyzed was collected by using semi-structured interviews (Kvale, 1997). Phenomenography allows researchers to explore the qualitatively different ways in which people experience a phenomenon (Marton & Booth, 1997). The word itself gives clues as to its meaning being composed of the terms *phenomenon* and *graph* meaning *representing an object of study as qualitatively distinct phenomena* Kroksmark (1987) in Marton and Booth (1997).

4.1.1 The Idea Behind Phenomenography

Phenomenography was developed as a research specialisation in Gothenburg, Sweden in the 1970's (Marton & Fai, 1999). Its pioneers, Marton, Dahlgren, Svensson and Säljö studied students reading a text. The main conclusion from the study was that students read the text in qualitatively different ways and their understanding of it varied. Those findings lead to the development of the phenomenographic research approach (Marton & Booth, 1997).

A phenomenon, for example decision-making or the experience of someone else as competent, can be understood in many different ways by different individuals. Marton and Booth describe the idea behind phenomenography:

> The unit of phenomenographic research is *a way of experiencing something*, [...], and the object of the research is the *variation* in ways of experiencing phenomena. At the root of phenomenography lies an interest in describing the phenomena in the world as others see them, and in revealing and describing the variation therein, especially in an educational context [...]. (Marton & Booth, 1997, p. 111)

The phenomenographic research framework is a second order research perspective, which means that it tells the researcher something about other peoples' experiences of the world. A first order research perspective, on the other hand, makes statements about the world (Marton & Booth, 1997). Phenomenography thusly begin's with someone else's experience of a phenomenon, in this case the students in a project group. The variation of experiences found is classified into different categories. An important feature of these categories is that they can form a hierarchy based on their quality, or level of advancement. Marton and Booth (1997) explains how:

> This implies an interest in the variation and change in capabilities for experiencing the world, or rather in capabilities for experiencing particular phenomena in the world in certain ways. These capabilities can, as a rule, be hierarchically ordered. Some capabilities can, from a point of view adopted in each case, be seen as more advanced, more complex, or more powerful than other capabilities. Differences between them are educationally critical differences, and changes between them I consider to be the most important kind of learning. (Marton & Booth, 1997, p. 111)

Hence, the starting point for analyzing data in phenomenography is an assumption that the different categorized experiences contain qualitatively different understandings of a phenomenon where more complex and powerful understandings exist.

An important characteristic of a valid phenomenographic outcome space is the relationships between the categories. Cope (2002) describes this:

> One of the consistent findings of phenomenographic studies is that a group of individuals will experience the same phenomenon in a limited number of distinctly different ways. Importantly the different experiences have been found to be related hierarchically based on logical inclusiveness and increased level of understanding. (Cope, 2002, p. 68)

It is also possible to describe the categories and emphasize the different values of the categories derived by the phenomenographic research approach by relating them to each other. Since the categories illustrate different aspects of the same phenomenon, they are logically related to each other. Were they not, they would describe aspects of different phenomena, and that is an important distinction. Often, some categories offer a wider or richer perspective and come to encompass others in an inclusive structure Berglund and Wiggberg (2006).

Thus, in order to learn about how students experience computer science student projects, I identified phenomenography as an appropriate research framework. It also aims at gaining knowledge on variations in experiences on the collective level and not individual experiences.

4.1.2 An Analytic Tool for Experiences

The complex process of learning is multi-faceted. In order to offer a framework for analyzing learning, phenomenography introduces a main distinction between two aspects of learning, *how* and *what*. Figure 4.1 shows the *how* and *what* of learning, and a more nuanced division of the two main distinctions. The explanation of these concepts may begin with Berglund and Wiggberg (2006) who describes those aspects:

> (1) the *what* aspect of the learning, describing the content of the learning (for example a network protocol) and (2) the *how* aspect, describing how the students go about learning, or how they tackle their learning. While the first normally is referred to as the *object of learning*, the latter is labelled the *act of learning*. This distinction is, as Marton and Booth [(1997)] point out, purely analytical: the aspects can only be "thought apart" for research purposes and do not represent different concepts. (Berglund & Wiggberg, 2006, p. 266)

Hence, even though the experience of learning something from the students' perspective is a whole process, phenomenography helps us to separate the process analytically into different parts, the *what* and *how*. The former deals with the content of learning, often referred to as the *direct object*, and the latter as the *act of learning*.

The analysis can be taken a step further by dividing the *how*-branch in two different parts, the *act of learning* and the *indirect object of learning*. The *act of learning* refers to how the students' experience the learning. Berglund (2005) interprets this *act of learning* as:

> The term "act" should here be interpreted in a broad sense, beyond the physical acts that a student performs in order to learn, such as reading a book, solving a problem and asking a friend. The term "act of learning" also includes abstract aspects, such as how students go about achieving their aims. (Berglund, 2005, p. 42)

The *indirect object of learning* is about the quality of the act of learning, or what the act of learning aims at. This can also be seen as the motive for learning (Berglund, 2005).

While the above descriptions form the main analytical separation in the experience of learning, the *act of learning*, *indirect object of learning*, and *direct object* can all be divided into *structural* and *referential* aspects. The former denotes the structure by which the learner identifies or recognizes the phenomenon, and the latter refers to the meaning of the experienced phenomenon. Again, this is just an analytical separation. The structure identified helps clarify the meaning, and the meaning helps us to find the structure. A final analytical separation of the *structural* aspect helps to distinguish between the phenomenon itself, or *internal horizon*, and its surrounding, its *external horizon*. The internal horizon signifies the parts and their relationships in conjunction with the contours of the phenomenon. Looking at the phenomenon from the other side, its surrounding and, again, its contours constitutes its external horizon Marton and Booth (1997).

In for example the study on decision-making, Paper B, the phenomenon studied is on *how* students experience the process of decision-making. As explained in Paper B, the effects of decision-making in the group impacts upon the possibility to learn and can thus be seen as the *how* in Marton and Booth's analytical separation of experiences of learning. How students decide things in the project is therefore a strategy, and hence this strategy can be seen as one of the 'capabilities the learner is trying to master' (Marton & Booth, 1997, 84) and thus the indirect object of learning.

4.2 Method

4.2.1 Interviews

In Paper A and Paper B, a phenomenographic research approach was used. The data for the phenomenographic analysis were collected through interviews, which is described in detail in Wiggberg (2007, 2008). Even though

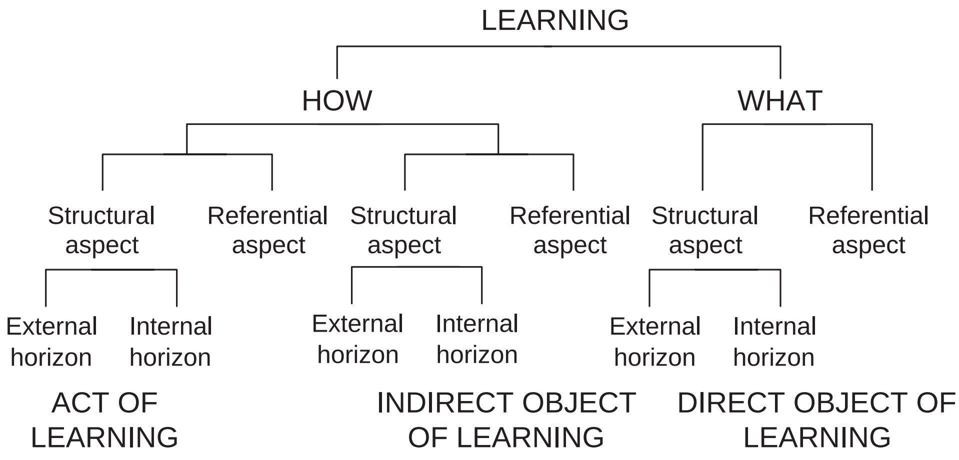

Figure 4.1 – An analytical view on the experience of learning something Marton and Booth (1997, p. 91). Note that the divisions in external and internal horizons are not used in the analysis in this thesis.

performed in slightly different ways, the interview approach has a substantial number of similarities. To create a dynamic interview session, semi-structured interviews (Kvale, 1997) were used. Some pre-defined questions were prepared and asked, followed by follow-up questions. This approach is in line with Kvale's description of semi-structured interviews as interviews where central themes and openings on relevant questions are prepared beforehand, but where it is also possible to adjust the order and formulation of the questions during the interview.

4.2.2 Data Analysis

In 4.2 a sketch of the process of categorization of understandings is presented. The sketch shows how a student cohort can have different experiences of a phenomenon (the different figures). The different experiences were brought to the surface by the researcher through the interviews. To analyze the interview data, an iterative process of identifying and categorizing the interviews experiences followed the data collection. In this process, statements from students were assigned different preliminary categories (represented by the different shaped figures) by the researcher. Those categories are at first tentative. As the sorting process continues, the categories form a particular context giving a meaning to the different statements. During this iterative process, resorting of the statements occurs since each newly added statement changes the meaning of the full set of categories. Finally, a set of categories was formed that could be described by the researcher's own words (the different shapes of the figures).

The final categories were then shared and discussed with a second re-

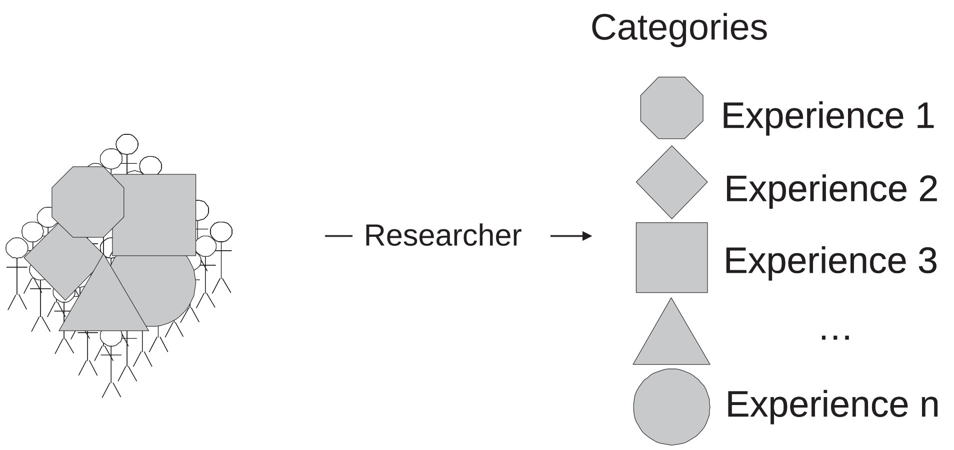

Figure 4.2 – Categorization of different experiences of a phenomenon, where the object shapes represents the different experiences.

searcher in order to establish the soundness of the categorization. The categories and their meaning were also compared to full interview transcripts in order to check their consistency.

4.2.3 Ethical Considerations

Kvale (1997) discusses the ethical considerations associated with interviewing, and especially the confidentiality of the interviewee (Kvale, 1997). In order to preserve the confidentiality, the interviewees' names and other personal references are removed from the transcripts presented in the studies. In order to keep the integrity of the interviewed students, all names has been changed in the presented excerpts. The new names have been randomly chosen without preserving gender or nationality. The full transcripts were only discussed in a small group of three people. Prior to beginning the interviews, the interviewees were informed in writing about the measures that will be taken to preserve their confidentiality, and how eventual excerpts will be published and which people will have full access to the interviews. This information was repeated at the end of the interview process.

In addition to Kvale (1997), the research ethics were closely guided by the recommended rules of ethics from the Swedish Research Council (Vetenskapsrådet, 1990).

4.3 Reliability

The quality of results presented in this thesis relies heavily on the quality of the methodology and approach to produce them. In a separate study, presented in appendix A, a walk-through evaluation of one of the papers in this thesis has been performed. The aim was to present an argumentation for the quality and soundness of the methodology and approach in the research presented in this thesis. The tool for the evaluation was Klein and Myers (1999) seven principles for interpretative field research. A summarized version of the evaluation and its results will be presented here. For details on the evaluation, see appendix A.

Klein and Myers (1999) has been widely used as framework for investigation of theoretical approaches in computer science and related disciplines. Gregor (2006) explores the structural nature of theory in the discipline of information systems; the use of interpretative research methods versus positivistic ones is explored in Trauth and Jessup (2000); a case study of engineering team developing software is investigated in Segal (2005); and Clear (2001) discusses the need for a conscious and appropriate choice of research methods and paradigms, where evaluations such as the one described in Klein and Myers (1999) are mentioned as one way to assure quality.

The paper most central to this thesis, Paper B, is chosen as the subject for the evaluation since it well represents the nature of my research. In that paper the research framework phenomenography is a central component, the empirical setting and data collection is the most extensive, the computer science student project is close to the corpus of my overall research, and its data and empirical setting will form the base for my next paper. In short, the study is representative.

The rationale behind the evaluation is two-fold. As stated by Klein and Myers, the approach of case studies conducted using natural science models of social science, are identified as fair within information science. When using a non-positivistic approach in an interpretative case study, the assumption of acceptance no longer holds. Klein and Myers state:

> However, while the criteria are useful in evaluating case study research conducted according to the natural science model of social science, the positivist criteria suggested are inappropriate for interpretive research. (Klein & Myers, 1999, p. 69)

In my own research, I am working with interpretative studies in an area where positivistic research approaches are the norm. One of the application areas is among computer scientists belonging to that positivistic norm. Therefore, it is useful to strengthen the outcome of it by conducting a thorough quality analysis.

Another reason for evaluating the research is to support my results from the study by carefully trying out the seven principles. A successful evaluation will strengthen my results and their reliability while a not so successful evaluation will serve to improve future studies.

The primary intention with this study is not to judge the reported research as good or bad, but to elaborate on its quality and soundness in order to improve future research.

Based on the walk-through of the seven principles, the evaluation shows that the applicable principles have been taken care of to a reasonable extent. Hence the research presented in the evaluated paper is of reasonable quality. Some remarks on parts that could have been taken care of better can be found in the evaluation. A number of points can be noted:

- describe the interviewees' cultural background more carefully,
- a use of other research methods could help better generalize the results, perhaps a second stage where other similar project courses are investigated based on the result from the current study could be performed,
- give details on external stakeholders and teachers involved in the course,
- it would have been worth exploring my, the reasearcher's, relation to the participants and dealing with this in an effective manner.

4.4 A Word on Discipline Based Research

One may wonder if questions regarding project work, group performances, collaboration etcetera can be effectively investigated from a researcher within the field of computer science. The one major argument here is that a computer science researcher, as every discipline based researcher, is a part of the computer science discipline. The inside perspective is both a strength and a weaknesses. The study plan for graduate study programme reasons about this issue and states:

> Teaching and learning in different areas within computer science are the targets for computer science education research. To have good subject skills within computer science combined with deep knowledge about, and skills in applying, research methods used to study learning from the social science area are essential to successfully conduct such endeavours. (Faculty of Science and Technology, Uppsala University, 2007b, p. 1)

An insider will most likely discover issues and factors connected to the discipline since they are aware of it at a considerably high level. Understanding of the subject, culture matters and discourse is most likely easier to acquire for an insider perspective. The possibility to put pertinent questions to students when collecting data is also of importance in order to get as much as possible from the students. When discussing disciplines it is effective to share the same discipline context. Interviewed students will recognize the researcher as being part of same context and hence find it possible to elaborate on computer science together with the researcher. Finally, when analyzing the data my knowledge of the discipline makes interpretations easier since technical concepts and other discipline bound material are known. I can also compare the interviewed students' perspectives with my own experiences of the field.

Being a computer scientist doing research on project groups will also mean that I will not be able to see, or reveal, the same things as colleagues within the social sciences. Even though using methods and theories from the social sciences, I will still lack the deep and extensive understanding that only a person with solid experience in the field has.

The research questions in this thesis might have a broader applicability than merely within computer science. Computer science education research can then contribute with an elucidation on how those more general mechanisms function within computer science.

Chapter 5

Findings in the Studies

Three different studies are included in this thesis. In the first study, issues of perceived competence and its relation to personal influence has been addressed. The second study dealt with decision-making among students in project groups. These two studies are important as a base for investigating the general research questions in the Ph.D. project. A third study on conceptions of engineering has been performed to get an understanding of what students recognize as important issues connected to their education. This study contributes with information on expectations on the engineering subject, and hence clarifies the prerequisites for pedagogical design.

Together, those studies establish a firm ground to explore the research questions stated in 1.1. In this chapter, I will summarize the key findings from the three studies. For more details on the results and studies, the three papers are attached.

5.1 Key Findings

5.1.1 Paper A

In the Paper A, a full semester computer science project course is investigated where focus is on how power is distributed within a group of students. Computer science skills are shown to be a contributing factor when it comes to power. Using a phenomenographic research approach, some aspects on power within computer science projects groups are demonstrated. A couple of results are especially important. Firstly, perceived competence of fellow students contributes to personal influence in the student project groups. Secondly, three qualitatively different ways of experiencing competence among other students have been identified.

The first result is consistent with other research on computer science projects. It indicates that what has been said in the literature about importance of competence can be shown to hold for a computer science project group. Grant, Baumgardner, and Shane (1997) reason in an article regarding the importance of technical competence to project managers:

> A majority of respondents in the sample, regardless of personal or situational factors indicated technical competence is extremely important or absolutely essential. (Grant et al., 1997, p. 17)

In the computer science field, Barker and Garvin-Doxas (2004) has shown that status is something you earn in the classroom by talking as if you know, but no real evidence is given. Different actions that communicate competence are thought to be important when it comes to status:

> ...status is informally accorded to those who display their ability to write 'elegant programs', display ability to reason well [...] or provide other needed information. (Barker & Garvin-Doxas, 2004, p. 16)

Hence competence is seen as an important factor when it comes to personal influence, and in the study, this is shown to also be the case for a computer science project.

The second result about the different ways of experiencing competence gives more information on what is seen as competence. The three ways to be identified as competent are by being identified through presumed skills, earlier demonstrated skills and/or demonstrated skills, see figure 5.1 for details about the categories. The different categories of experiencing competence have varying levels of detail, especially with respect to the skills relevant to the current project.

5.1.2 Paper B

The second study, Paper B, investigates how computer science students experience the process of decision-making in computer science projects (Wiggberg, 2008). It also investigates the ways in which the student teamworks make decisions. The empirical setting for the study is a semester long project with 22 final year computer science students. It is a qualitative study where data is gathered using interviews and analyzed using phenomenography. Six categories describing the experience of decision-making have been identified, see figure 5.2 for details about the categories. The level of sophistication differs between the categories where the first describes an experience of decision-making as individual decisions too small and unimportant to handle by anyone else than the individual. At the other end is the experience of decision-making as a democratic process involving both the full group and the context in which the group acts.

There is an interesting divide between the first two categories and the last four. Some decision-making is done individually (category 1-2) and

Category	**Meaning**	**Characteristics**
One	Presumed skills	Expressions that support a presumption of competence.
Two	Earlier demonstrated skills	Expressions of abilities to solve problems not within, but close to, the current project. Presumptions about someone as competent are based on evidence, but not from the same area as the project deals with.
Three	Demonstrated skills	Someone's actions during the current project work constitute the basis for fellow student's perception of his/her competence. Gradually shown skills within the particular field of application are interpreted as evidence of competence. The category implies that the student is presumed to be competent, but now with evidence.

Table 5.1 – Categories of description of what makes computer science students experience fellow students as being competent within the subject area (Wiggberg, 2007, p. 135).

some is recognized as subject for group discussions (category 3-6). There is a thin line between those different strategies, and which way to go seems to be a decision for the individual project member.

Decision-making is shown to be an active part of the computer science student project. Decision-making is an important part of running a project and thus it seems likely that *how* and *what* decisions are made will have substantial implications on the learning environment. An example of how decision-making might affect the learning is if group decisions are made instead of decisions made by an individual student. In the latter case, the level of collaborative learning might be lower than in the former case. Hence, how and what decisions are made is an important factor to consider.

Revealing decision-making experiences in computer science student project groups shows that decision-making is, as expected, an active process in the project groups. The different experiences of decision-making that happens also shows that the level of interaction between the students depends on how the students interpret the decision. If the decision is interpreted as too small to regard anyone else than the individual, then the individual makes them without interacting with the rest of the project group. On the other hand, when they interpret a decision as being of importance to other people in the project they tend to involve a reasonable amount of colleagues in the decision. Decisions when a small or large group is involved can be done in a more or less formalized manner.

5.1.3 Paper C

The third paper, Paper C, investigates Swedish engineering students' conceptions of engineering. The study leading to Paper C is a large nation-wide study of ten Swedish higher education institutions involving students typical as participants of computer science student projects. Based on data from surveys and interviews, categories and toplists it presents a picture of students conceptions of engineering.

When using the project model as pedagogical models it can be seen as an application of Communities of Practice (described by Wenger (1998) and exemplified within computer science by Fincher and Tenenberg (2006))It is important to have an understanding of the motives within the certain community studied, and hence is knowledge on conception of engineering valuable.

Students' conceptions of engineering are somewhat divergent, but dealing with problems and their solutions and creativity are identified as core concepts. The survey data is in general more varied and deals with somewhat different kinds of terms. When explicitly asking for five engineering terms, as in the survey, a broader picture arises including terms, or concepts, denoting how students think of engineering and work in a more personal way. For example, words like hard work, stressful, challenging, interesting, and

	Label	**Decision-making is understood as... (referential aspect)**	**The focus is on... (structural aspect)**
1	Decisions by individuals.	... too small or regard too few to be handled by anything else than the individual first encountering the decision. The individual perceives the unimportance of the decision and therefore it becomes a private issue.	...one person and those particular individuals decisions.
2	Decisions by individuals with preferential right of interpretation.	...an informal right to interpret and make decisions even though the decision might involve other people.	...the knowledge that the decision may be of importance to other people in the project, but still it is recognized and treated as an individual decision.
3	Decisions by small group discussions.	...a mutual agreement in a smaller group. The decision discussed is also something that matters for not just one individual and therefore automatically also involves opinions from more people.	...on the smaller group and its discussion.
4	Decisions by group discussions supported by a facilitator.	...group discussions supported by a facilitator.	...the facilitator and the small group.
5	Decisions by democracy in full team.	...a democratic process in a formalized full team setting.	...focus here is on the teams as a formal body where strategies for structured decision-making are present.
6	Decisions by mutual agreement between team and external stakeholder.	...democratic involving the full team, but in the same time the 'reality' is involved in some way.	...the full team and its context, namely the surrounding stakeholders and their interaction with the team.

Table 5.2 – Categories describing the outcome space of how decision-making is understood by participants in the computer science students project (Wiggberg, 2008, p. 7).

fun are used. On the other hand, it seems like the interviewed students tried to give more general answers that were not always connected to their personal experiences.

Another interesting observation is that academic subjects, like mathematics and physics, do not appear in any of the top positions. Even though mathematics is third in the list of terms from the survey, it represents only five percent of the terms, and the second highest ranked subject, physics, represents only one percent. In the interviews, the category including academic courses is the seventh most frequent category of a total of ten. We believe that this tells us something about the contrast between the subjects that constitute an engineering education and the application of these to engineering problems. According to our results, students value the latter aspect higher.

Chapter 6

Generalizations from the Studies and Future Work

The various studies presented in this thesis reveal information about experiences of influence and decision-making in student group projects and beliefs on conceptions of engineering in general. The interesting question is what we can learn from these studies. What conclusions can then be drawn from them?

The following chapter will detail the key features of computer science student projects that were identified. These are summarized in a proposed framework for design of computer science student projects, and some pedagogical implications. The proposed framework is intended as a supporting framework to address the general research questions identified for this Ph.D. work by providing help to clarify the processes involved in the projects. The proposed framework can also be used for analysis and design of the projects. At the end of the chapter, a short section on further work is presented.

6.1 Key Features in Computer Science Student Projects

The studies carried out, all contribute to the understanding of computer science student projects. Because the focus differs from study to study a more complete picture of the different processes within the projects can be built up. The results paint a complex image of underlying structures and mechanisms of a computer science student project. The settings and tools provided in the student projects influence the way in which students work.

The described computer science student projects have a certain set of features that can be said to be of a more general nature. In order to learn more about the processes involved in these projects, it is important to identify those features, their interdependence and their impact on the learning outcome.

By combining parts of the results, it is possible to develop a theory manifested in a framework, where some central areas within the projects that appear to share certain common elements are included. Hence, the theoretical model proposed is grounded in the empirical evidences from the three different studies. The proposed theoretical framework consists of four features that are presented and explained: the mechanism for work allocation; connection to external stakeholders; focus on result or process; and level of freedom in task. Results from the studies carried out are related to those features. The purpose of establishing these features is to provide an analytical framework for analyzing a computer science student project.

6.1.1 Mechanism for Work Allocation

In the computer science student projects studied, it has been obvious that some kind of mechanism to allocate work among its members must exist – 'work' here refers to the tasks necessary to fulfil the main project task. Waite et al. (2004) reports that understanding the enculturation process in computer science student projects is important in order to develop collaborative cultures in the projects. Teaching group process or project models does not solve this issue by default, though it is considered important (Waite et al., 2004). Barker (2005) argues further that by letting the students chose their own roles based on expediency or comfort may work against the benefits of collaborative learning in computer science student projects (Barker, 2005). An example of this from the study described in Paper B is when Viktor talks about how he suggested a fellow student to work with things he already know:

> **Viktor**: Eh, well, I've been in the same class as him the last three years, I've known him a while. Thus I knew he knew a lot. But my main reason for choosing him was that I knew he was a good at writing.
> **Interviewer**: Writing, you mean authoring?
> **Viktor**: Yes, I knew.. he sort of knows how, how a good document should look like.
> **Interviewer**: Hmm.
> **Viktor**: Not just the content, but also the other stuff.
> **Interviewer**: Yeah, right, layout...
> **Viktor**: I thought he was the obvious choice as responsible for the documents.

This excerpt shows that what Barker (2005) notes on role allocation is valid in the studied computer science student project. It also shows how students influence each other's choice. Paper A shows that competence, demonstrated in a number of ways, influences critical decisions in the computer science student project by giving students recognized as competent greater influence.

The chosen mechanism for work allocation is important for the learning outcome of a computer science student project. It is also important to carefully consider who works with what in the project. Computer science student projects would therefore gain from considering different ways to divide the work in the project. These should be evaluated based on the desired learning outcome with the project. Hence, the mechanism for work allocation is a feature to consider when designing computer science student projects.

6.1.2 Connection to External Stakeholders

As described in section 2.2.1, our computer science student projects sometimes have connections to external stakeholders. Often these represent the software industry. The projects are connected to the external stakeholders by letting an industry partner contribute with tasks, knowledge on planning models and sometimes funding. More than one external stakeholder can be involved in the project at once.

Barker (2005) argues that the involvement of external stakeholders can lead to perceived pressure to finish the computer science student project. This may result in increased learning, but may potentially lead to the opposite. An external stakeholder can share their aim with the students involved in the project, or they can have a mismatch in their different intentions. The function of the external stakeholder can also vary considerably.

In Paper B, the experience of decision-making shows that the external stakeholder has a strong influence in the project. The position of the external stakeholder can be so strong, that it has the final say in decisions, even though the student project group has a different opinion. Category 6 from the study about decision-making in Paper B, describes experiences where the external stakeholders interaction highly influences the decision-making process. A statement from a student, Ann, also illustrates a problematic relation with the external stakeholder:

> **Ann**: We should have more time to communicate with the company in order to understand what kind of product they want in the end. Also, in sometimes you have to assume that what they want, you have to assume something in your requirement, but it is still a key problem that the communication is not enough in this case, in the project I think.
> **Interviewer**: Ok, so how could the communication be better?
> **Ann**: Mm.
> **Interviewer**: Or, not better, but more communication.
> **Ann**: The problem here is they are from the company and we

> are the student in, in university, they have their business to do. We, I think we, we would better set up some better way of communication other then e-mails, they was like, we write some, write some e-mails to them but they response quite late and it is not efficient.

The involvement in computer science student projects from external stakeholders can be beneficial in a number of ways. It connects the student with a feeling of reality in their project, it contributes with ideas for the projects, puts different requirements on the project etcetera. However, as stated in, for example, Paper B and Barker (2005) the involvement means that students' adjust their decision-making process as well as their goals based on the external stakeholders needs. This can be beneficial, but it is needed to be closely controlled in order to design rewarding projects.

6.1.3 Focus on Result or Process

The result of a computer science student project is often described by some kind of product. This product, or resulting artefact, can be seen as the ultimate goal which students' effort will be measured against. Alternatively, it can be seen as a strategy to help students' focus in their project work.

Holland and Reeves (1996) presents results that computer science student teams can strive for different things: produce elegant software; fulfil course requirements; or focus on the challenges of team dynamics. Paper C concludes that Swedish engineering students, of whom computer science students form a sub-set, see themselves as creative problem solvers. Evidentially, this tells us that their self-image includes problem solving as a central part (Wiggberg & Dalenius, 2008). Paper B shows how the groups organized themselves according to the task given. To a large extent, they also appointed people to different roles based on previous experience and skills of those appointed. In the cases described in Paper A and Paper B, the product did not need to be fully completed in order to pass the course. The process of working on the product was the focal point. Focusing on the process instead of the resulting artefact is not unusual in a learning setting, e.g as expressed by Säljö (2000):

> Pupils in western educational systems are often encouraged to be "experimental" and to "be creative" when they work in school. To tray and fail are seen as important components of learning in modern education. To mimic and copy as an apprentice often does is looked upon with suspicion by us. The reason for harboring such an attitude is that what is produces is generally of little value outside the learning situation. (Säljö, 2000, p. 45)

In the study presented in Paper B, the tension between focusing on the result or the process is described by several students. Viktor reasons about how he tries to optimize the outcome of the project:

> **Viktor**: Well, it very much my character that I want to do what's good for the project, that's the attitude I have. Eh, I think that some.. if one put someone that didn't know all that much before about, say, writing documents, then I think that person would probably learn more in that case.
> **Interviewer**: Yes.
> **Viktor**: Than the person I assigned to the writing document task. But, I feel that it is the best for the project to put him in this position, eh, I am a bit selfish, so I, don't distribute positions in order for people to learn, but so that we will do a good project.
> **Interviewer**: Right, and then we get into what you, what you see as the result with, with this project.
> **Viktor**: Eh, yeah, it is to succeed, eh, produce what we have specified in our requirement specification, which is my goal.

If the students chose to focus on the result, it will eventually lead to a situation where the most skilled in different areas also takes care of tasks within those areas. Students lacking those skills do have fewer options when choosing a task. It also shows how one student's priorities affect a fellow student's learning experience. This mechanism has a clear impact on the learning outcome of the project. Awareness of it is hence of importance when designing computer science student projects.

6.1.4 Level of Freedom in Task

The definition of the task to fulfil in a computer science student project varies. The level of freedom with which students' can decide about the task is therefore different in different projects.

The level of freedom in the task can differ and is typically low in ordinary courses in computer science where teachers determine the task and expect results. The task given in computer science student projects contains a part where the students are assumed to make substantial contributions to the design of the task. Teachers and industry partners might set other parts of the task. Participating students contribute with the final requirements of the task. Planning of the work is then something that is a responsibility of the group itself. In the computer science student project studied in Paper B, the following description of the freedom in a task can be found:

> Although the technical goals were given by the industry partner and the team of teachers, the specific shape of the technical goals,

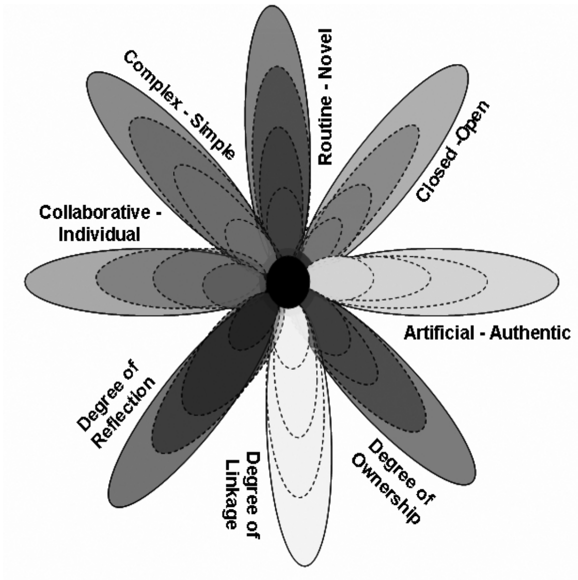

Figure 6.1 – Typology for describing task features (Carbone, 2007, p. 61).

> as well as design and implementation issues, were left to the project teams to decide. Faced with a somewhat vague design, the project teams had to interpret the task and develop a system design, a requirement specification, and an implementation plan. (Wiggberg, 2008, p. 4)

This feature might have a substantial impact on the content and aim of the task. It captures the level to which students' can influence content and aim while running the project. The level of freedom in task is something that the students or teachers needs to consider when choosing how to allocate the work.

6.2 A Proposed Framework for Analysis and Design

Carbone (2007) has by revision of earlier literature and own empirical material, presented a comprehensive study about how student learning of programming is influenced by the nature of task features, by individual factors, and by the learning environment (Carbone, 2007). One of the major results from the study is a task topology providing a framework for investigations into programming tasks, see figure 6.1. In this thesis, four important features for the learning outcome are presented, namely:

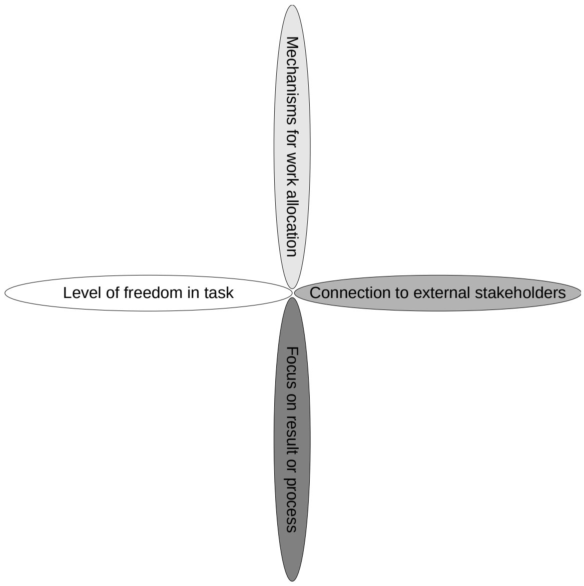

Figure 6.2 – A proposed framework for analysis and design of computer science student projects. Each field contain a feature recognized as important in such projects. Inspired by earlier work of Carbone (2007).

- mechanisms for work allocation,
- connection to external stakeholders,
- focus on result or process, and
- level of freedom in task.

Inspired by Carbone (2007), a framework based on the important features for the learning outcome of computer science student projects is proposed, see figure 6.2. The framework provides a tool for which design and analysis of computer science student projects can be made. Each of the four fields contains a feature of a computer science student project shown earlier to be of importance. By taking each of the fields into account when analysing or developing such a project, a better or more insightful grip with the situation will be achieved. The analysis aspect is especially interesting for the computer science research community. This framework is proposed as a generalization from the studies in this thesis, and will be developed in detail in the next step of the Ph.D. project.

An example of using the proposed framework is to set up a follow up study of relations between learning outcome and decision-making and influence in project groups, which are interesting as a factor for understanding different outcomes of learning. Results of such a study will give further clues in the field of learning in software groups in addition to those presented in this thesis.

6.3 Future Work

The processes involved in computer science student projects need to be investigated further. Role taking, goal setting and goal congruence between teachers and students, are all areas that teachers who uses computer science student projects as pedagogic models would benefit from a deeper knowledge in. Some of these issues will be investigated in the remaining parts of my Ph.D. research project.

The proposed framework for analysis of computer science student projects is a start. Each feature included needs to be investigated and motivated carefully. The influential features need to be verified as useful. Establishing their connections to the learning outcome of computer science student projects is another area to investigate. The proposed framework as a whole should be developed and different dependencies studied. The theory's ability to support pedagogical choices needs also to be tested. These issues will be addressed in the work towards my Ph.D. thesis.

Chapter 7

Conclusions

How students make decisions is an important aspect for the outcome of a computer science student project. Two processes that are influential for how decisions are made are identified in this thesis. The first relates to competence, or rather the perceived competence of a student among other students in a project group, which affects the personal influence that students has in the decision-making process. Three qualitatively different ways of experiencing competence have been identified: presumed skills; prior demonstrated skills; and demonstrated skills. The second process identified in the thesis relates to the decision-making itself and the investigation identified six categories of how the students understand decision-making. The level of sophistication differs between the categories, where the first describes an experience of decision-making as individual decisions too small and unimportant to be handled by anyone other than the individual. At the other end is the experience of decision-making as a democratic process involving both the full group and the context in which the group acts.

What students identify as being "engineering" is important to understand in order to be able to motivate the students, and computer science student project courses are considered as important components in many engineering education programs. Analysis of a large study of Swedish engineering students identifies "problem solving" as by far the most central conception about what engineering entails.

Based on the conducted studies four features have been identified as important, namely: mechanisms for work allocation; connection to external stakeholders; focus on result or process; and the level of freedom in the task. A framework is proposed and it is intended to aid in considering these four features into account when designing and analyzing computer science student projects. The framework identifies important features of such a project and the presented findings provide knowledge about the features as a starting point for the design. For example, students might benefit more from their learning experience in a computer science student project by considering the four features, individually and together in the group, before the project starts. By doing so, the goals and choices of students can be contrasted to the characteristics, as told by the four features, of the project.

By analyzing the four features, or dimensions, it is possible for instance to balance the external stakeholders' interests in the project. Another implication of the proposed framework is the possibility to level the focus on the result of the process in order to achieve the desired learning among the students. Knowledge about students' conceptions of engineering is essential for practitioners in engineering education. By having access to information about students' conceptions, the approach when teaching can be tailored to reach students given their particular mindset of the engineering field. Program managers with responsibility for the design of engineering programs would also benefit using information about students' conceptions of engineering. Courses could be motivated and contextualized in order to better connect with the students.

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Appendices

Appendix A

Are the Results Reliable?

The quality of results presented in research relies heavily on the quality of the methodology and approach to produce them. In this appendix, a walk-through evaluation of one of the papers in this thesis is presented. The aim is to present an argumentation for the quality and soundness of the methodology and approach in the research presented in this thesis. The tool for the evaluation is Klein and Myers (1999) seven principles for interpretative field research.

The research question underlying this evaluation is: how does my current research reflect Klein and Myers (1999)' seven principles for interpretative field research? The research question is carried out by applying each principle to the study or by explaining why a specific principle is not applicable.

The rest of this chapter is organized as follows. The next section presents the design of the analysis. The project reported in the article that is analyzed is explained together with a short presentation of the research approach. The empirical section contains a walk-through of each of these principles and its application in the current study. Finally, a short conclusion discusses the overall result of the principle based evaluation.

A.1 Study Design

The design of this evaluation is straightforward. By using Klein and Myers (1999) set of seven principles for interpretative field research, I will evaluate the research reported in Paper B. In turn, each principle will be revised and applied to the study and at times illustrated with examples from relevant sections. Implications and conclusions will be drawn after each principle is applied. Finally, a short summary of the resulting evaluations will be presented as well as an answer to the research question.

The intention with this study is not primarily to judge the reported research as good or bad, but to elaborate on its quality and soundness in order to improve future research.

A.2 Evaluated Research Study

The research study in focus is intended to understand the ways in which students experience the process of decision-making in computer science student projects. It also investigates the ways the student group works to make decisions. The empirical setting for the study is a semester-long project with final year computer science students (Wiggberg, 2008). It is a qualitative study where data is gathered using interviews and analyzed using phenomenography (Marton & Booth, 1997).

The result of the study is the discovery of six categories describing how students experience the process of decision-making in computer science projects. The level of sophistication differs between the categories where the first describes an experience of decision-making as individual decisions too small and unimportant to handle by anyone else than the individual; at the other end is the experience of decision-making as a democratic process involving both the full group and the context in which the group acts. The other four categories are situated between these two extremes (Wiggberg, 2008).

An overall goal in the current study is to identify, on a collective level, the process of decision-making in a computer science project within a student cohort (Wiggberg, 2008). A phenomenographic approach (Marton & Booth, 1997) has been used to reveal different ways of experiencing how students go about to make decisions. Phenomenography is a research framework for revealing the qualitatively different ways in which people experience a phenomenon.

A phenomenon, such as the process of decision-making, can be experienced in many different ways. Marton and Booth describe the rationale behind phenomenography as a way to find and describe the outcome space that consists of the different ways of experiencing a particular phenomenon (Marton & Booth, 1997). An important characteristic of a valid phenomenographic outcome space is the relationships between the categories. Berglund and Wiggberg (2006) describe this:

> Since the categories illustrate different aspects of the same phenomenon, they are logically related to each other. Were they not, they would describe aspects of different phenomena. In general, some categories offer a wider or richer perspective and often come to embrace others in an inclusive structure. [...] the more embracing categories are generally more desirable. (Berglund & Wiggberg, 2006, p. 266)

Phenomenography helps us reveal the experience of learning something. In this study, the decision-making process is the focal point for the experience of learning.

To be able to use the seven principles as a perspective for evaluation of the reported study relies on if it belongs to interpretative research or not. According to Klein and Myers (1999), required properties of interpretative research can be formulated like this:

> Interpretive research does not redefine dependent and independent variables, but focuses on the complexity of human sense making as the situation emerges (Kaplan and Maxwell 1994); it attempts to understand phenomena through the meanings that people assign to them. (Klein & Myers, 1999, p. 69)

The phenomenographic research framework, as described by Marton and Booth (1997), fits well into this definition of interpretation since it deals with how people, in this case students, experience and understand a phenomenon. Hence, the current study based on phenomenography can be analyzed using the suggested seven principles.

A.3 The Seven Principles Applied

I will walk through the seven principles by first stating my interpretation of them. After that, each principle is applied to suitable parts of the study in focus. Finally, when it is appropriate, I will criticize parts of the current study based on the presented principle.

The presented principles are collected and presented by Klein and Myers (1999) although they originate from different sources. I will refer to the main contributors, as stated by Klein and Myers, in the presentation of the principles.

A.3.1 The Fundamental Principle of the Hermeneutic Circle

Although Klein and Myers (1999) suggests that all seven principles together constitute a set for evolution of interpretive research, the fundamental principle of the hermeneutic circle is significantly important. The principle states that interpretative research, or human understanding of something, is best done by iterating between the full picture and the parts. By analyzing parts and letting them form a whole, the understanding of the new whole gives a better understanding of the interdependence between the parts and vice versa. The principle therefore suggests a continuous shift in focus between the whole and the parts of which it consists (Gadamer, 1976).

In the current study, how students understand decision-making in the computer science project group can be classified into six different categories, each describing an experience of decision-making. Together the categories forms a whole that tells something about the students' experience of decision-making. Full understanding of the phenomenon in focus, decision-making, is not possible without considering all categories.

> Six categories have been identified describing how students experience the process of decision-making in computer science projects. The level of sophistication differs between the categories where the first describes an experience of decision-making as individual decisions too small and unimportant to handle by anyone else than the individual. At the other end is the experience of decision-making as a democratic process involving both the full group and the context in which the group acts. The other four categories are situated between these two extremes. (Wiggberg, 2008, p. 1)

An iterative analysis was used to derive the six categories. Tentative categories were constructed from empirical data. The profile describing the core of each category was compared with the full set of empirical data. Adjustments were made to the categories and the set of new categories was again compared with the empirical data.

The reasoning behind this principle, where identified parts form a whole and that whole gives a base for refining of the parts, is comparable to a phenomenographic research approach. In phenomenography the outcome space, as defined by categories, forms a whole.

In the current study, another set of findings is also present. These findings are not connected to the six categories, but contribute to the secondary research question. These findings helt to make the picture more complete in a way

The fundamental principle of the hermeneutic circle is applicable in the current study, and the current study well meets its core features.

A.3.2 The Principle of Contextualization

This principle points to the importance of a broad picture when research is presented. More precisely, the contextualization principle states that the social and historical context should be presented alongside the current results. The context described is focused on the object of study. The reason for bringing the historical and social context to the fore is to let the reader follow how the situation described has emerged (Gadamer, 1976).

In the current study, this principle is reflected in the background description of the project course. Here, the study program, the participating students' background, and organization of the interviewed students are presented.

Firstly, the project course is described. Its aim, position in the study program, and pedagogical motivation are presented in order to situate it in the curricula of computer science education. A historical perspective is also present, albeit in a more limited scope.

Secondly, the groups of students are presented. Their nationality, which study program they are enrolled in, how they applied for the course, and the number of students in the two different groups are all taken up.

Thirdly, the organization of the students in groups as well as their internal organization is described.

Contextualization of the different parts studied aims to give a broad picture of the project course and participants. Less effort is spent on in-depth descriptions of the interviewees themselves. For instance, the cultural aspects of a mix that includes exchange students is mentioned but not explored. Neither the external stakeholders nor the team of teachers is presented in-depth. It is also hard to know their background and their level of presence in the project work, hence it is not impossible that a deeper understanding of their backgrounds would be necessary to increase the value of the study.

The concept of context in phenomenographic research can be interpreted in a number of ways. In Adawi, Berglund, Booth, and Ingerman (2002) the concept of context is elaborated on. The stated research question shows a gleam of the diverse concept of context in phenomenographic studies:

> *When we speak of context in phenomenographic research, whose context are we speaking of? Who is experiencing the context? How can we describe and account for context in a phenomenographic study where the prepared context is apparent but the experienced context is lost in the analysis? How can the researcher work towards an awareness of the context during the stages of the phenomenographic study?* (Adawi et al., 2002, p. 84)

Phenomenography is aimed at describing the experience of a phenomenon as it is experienced by a group of people, in this case, a student cohort (Marton & Booth, 1997, p. 114). My main interest as a phenomenographer when analysing is thus the collected experiences, not the context from which it originated. This does not mean that the context is unimportant when the results are analyzed. Indeed, the context of the study is connected to the result of the analysis by a description of the empirical setting, the researcher's methodological choices etcetera.

Some description of the context exists in the current study. Perhaps it would have benefited from a deeper description of the interviewees cultural background, the external stakeholders and the teachers involved in the course.

A.3.3 The Principle of Interaction Between the Researchers and the Subjects

This principle follows a tradition in social research, for example Kahn (1989), where the data is seen as a construction based on social interaction between the researcher and the participants. The principle suggests a view where the participants can be seen as both analysts and interpreters. The former is apparent when participants alter their actions during the scope of an interactive data collection because of changed horizons. The latter is apparent when they change their horizons while influenced by concepts used by interacting parties. Participants and their relation to the researcher, being part of the analytical and interpreting processes, need to be understood based on their historical context.

Assuming that the principle of interaction between the researcher and the subjects holds in this study, two things are important. First, becoming aware of this effect and trying to avoid its pitfalls, and second, treating the results respectively. In relation to the first requirement, the study has used a research approach that allows for this. The phenomenographic research approach is a second order research perspective, which means that it tells the researcher something about other peoples' experience of the world (Marton & Booth, 1997). The witnessed experience can be influenced by the researcher's methodological strategies, but phenomenography still treats this as the subject's experience.

The requirements on the phenomenographic outcome space, the result after analysis, are a set of categories that together describe the different ways of experiencing the particular phenomenon (Marton & Booth, 1997). An important characteristic of a valid phenomenographic outcome space is therefore the relationships between the categories. Cope (2002) describes this:

> One of the consistent findings of phenomenographic studies is that a group of individuals will experience the same phenomenon in a limited number of distinctly different ways. Importantly the different experiences have been found to be related hierarchically based on logical inclusiveness and increased level of understanding. (Cope, 2002, p. 68)

Another way of dealing with the interaction between the researcher and the subjects is to moderate the method for data collection. In the current study semi-structured interviews (Kvale, 1997) have been used. The mechanisms of this interview technique are described as:

> Kvale (1997) describes semi-structured interviews as interviews where central themes and openings for relevant questions are prepared beforehand, but where it is also possible to adjust the order and formulation of the questions during the interview. The central themes and prepared questions can be seen as a desired structure, with the remainder of the interview comprising follow-up questions on interesting lines of thought from the initial answers. (Wiggberg, 2008, p. 4)

This means that central themes are covered while follow-up questions are posed in order to get more information from the interviewee. The follow-up questions are neutral in their wording and serve as a way to explore the themes. Using this approach, a minimal set of new and possible leading directions was introduced. On a meta perspective, the act of deciding when to ask follow-up questions or not naturally interferes the information collection process.

Being a researcher and at the same time a teacher at the same department means that the posed questions are influenced by my role as a teacher. Even though not involved in the teaching of the particular course, my role might interfere what kind of experiences the students' converse.

The choice of research approach and data collection method in the current study supports the claim that this principle is taken into account.

A.3.4 The Principle of Abstraction and Generalization

The matter of generalization and abstraction is widely discussed in the area of interactive research, see for instance Heidegger (1962); Husserl (1970, 1982). It is often argued that human affairs cannot be governed by culturally interdependent natural laws. This principle argues that the validity of the interference drawn from a particular study at least can vary. Moreover, it depends on the " "plausibility and cogency" of the logical reasoning used in describing the results form the cases, and in drawing the conclusions from them" (Klein & Myers, 1999, p. 75).

Theory plays an important and critical role in interpretative research. By using relevant theory to support findings, develop concepts and draw specific implications the results are supported. Any abstractions and generalizations should be connected to the details of the field study (Walsham, 1995).

The current study presents one set of different ways of experiencing decision-making in the computer science project course. In coherence with the principle of abstraction and generalization, the empirical results are carefully described with illustrations as they are presented. This should serve to clarify the logical reasoning behind the results. To support the results, they are connected to a theoretical framework of studies about decision-making. Earlier results from areas close to those investigated are also compared to the current results.

The research approach is also presented in detail. The main research question is connected to the research approach in order to argue for the feasibility of the choice of research approach.

Klein and Myers (1999) reports on four different types of generalizations:

> Walsham argues that there are four types of generalizations from interpretive case studies: the development of concepts, the generation of theory, the drawing of specific implications, and the

> contribution of rich insight [(Walsham, 1995)]. (Klein & Myers, 1999, p. 75)

In the current study, the last and second last types of generalizations are possible. The contribution of rich insight is present in the current study. The drawing of specific implications can be claimed to some extent, assuming that the contexts in the compared studies are alike.

A.3.5 The Principle of Dialogical Reasoning

In contrast to positivistic reasoning, this principle assumes prejudices as a necessary starting point for new or increased understanding of something. By letting our prejudgment become visible to ourselves, we can deal with it in a constructive way. The prejudices based on the philosophical viewpoint should be contrasted to the empirical findings. By doing so, the bias should become transparent to the researcher as well as the reader (Gadamer, 1976).

The current study assumes that decision-making happens in the student project groups and that it is traceable. Despite my preconception, that decision-making happens in the project, it is possible to have a viewpoint where most important decisions are already set by the task description and team of teachers.

Another prejudice that is bound to the philosophical viewpoint phenomenography is the assumption that there exist an outcome space and that all collected experiences can be found there (Marton & Booth, 1997, p. 125).

Am I as a researcher then aware of my prejudices, and do I discuss them in the study? In the choice of phenomenography, I elaborate on the appropriateness of that specific research approach:

> To address the first question we required a research framework that helps the researcher understand the experience of the student. Phenomenography is a second-order research perspective: it tells the researcher something about other people's experience of the world, whereas a first-order research perspective makes statements about the world itself (Marton & Booth, 1997). Thus phenomenography was chosen as research framework to explore how students experience the process of decision-making. (Wiggberg, 2008, p. 2)

Even though I motivate the research approach, I still assume that decision-making is happening in the justification of the research approach. On the other hand, I do find decision-making in the data, which concludes that my preconception was correct. The interesting question left then is what I would have done if my preconception did not hold, i.e. no traces of decision-making were found? Even though this question was not dealt with, I think that the principle of dialogic reasoning is well taken care of in the current study.

A.3.6 The Principle of Multiple Interpretations

This principle assumes that human actions are restricted by a context in which multiple agents exist. Thus, the researcher must consider the examined results influenced by this context. Finding out, documenting and reasoning about such context bias in the empirical findings is therefore necessary in order to follow this principle (Ricoeur, 1981).

The principle of multiple interpretations is similar to the principle of dialogic reasoning in its seeking of conflicting interpretations based on conditions of the study. The difference is that the current principle argues for seeking different interpretations of the participants. Thus, the focus here is the participants, not the researcher.

In the current study, this principle can be applied as a tool to learn about and confront the different interpretations done by the interviewed participants. The participants all share some context. They have applied for the same course, worked on the same (i.e. two) project task etc. At the same time, they carry different contexts. Some have background in a study program at the same department as the project course is given, and some are exchange students from China.

When I collect data by interviewing students, it is possible and indeed likely that their answers are affected by these different contexts. Relative questions or statements, for instance regarding influence, are probably interpreted in the individual student's own context. Therefore, answers collected may vary in their semantic meaning even though they, as part of the data, look similar.

Another important context dependent issue is that I am myself a researcher. What is told and not may be affected by the individual student's relation to me as an interviewer. Some of the participants have had me as teacher in earlier courses. A few of them have been involved in teaching as teaching assistants in courses held by me, and for some of them I am a complete stranger.

How could I then use this principle to acquire better data? One way is to ask for definitions or individual interpretations of given experiences. This is partly done in the current study by using follow-up questions. Clarifying answers to the follow-up questions have been a part of the experience, and thusly influenced the interpretation.

A.3.7 The Principle of Suspicion

The principle of suspicion, as stated by Ricoeur (1981), argues that false preconceptions easily sneak into an analysis. A systematic approach for finding these misconceptions needs to be undertaken. It is mainly the narratives from subjects that must be analyzed for these false preconceptions. This principle is questioned by interpretative researchers since some argue that social research can not be critical, for example Deetz (1996).

In the current study, I have seen some experiences that might be questioned as surface experiences. The following statement from Jake is a possible example of this:

> **Interviewer**: And the first thing I want to ask is how a decision is made in your team?
> **Jake**: Yes, it is very democratic, eh, it is definitely not so that I decide everything, instead we discuss everything together.
> (Wiggberg, 2008, p. 8)

However, as Jake continues, he reminds himself about minor decisions that was not made up in a democratic way:

> **Jake**: Eh, some minor decisions have been taken together with me [...] But that was just things that, eh, well, the time plan and such things and then it was not so that all wrote the project plan, but all big decisions about how we shall, eh, make the game and such things, all are part of it.
> (Wiggberg, 2008, p. 8)

When I interviewed Jake, I noted this during the interview. After a while, I decided to return to the same issue, but from a different angle and with different questions. By doing so, I made Jake explain his statement about democracy in a more elaborated manner.

The principle of suspicion was not easily applicable in the current study, and it is hard to judge whether it has be taken care of or not.

A.4 Conclusions and Implications

Based on the walk-through of the seven principles, it possible to apply all seven principles to the current study. The level of applicability varies of course, but all could be applied in some way.

The fundamental principle of the hermeneutic circle is well taken care of in the current study. The principle of contextualization could be better taken care of by describing the interviewees' cultural background more carefully. Another way to improve the current study using this principle is to give details on external stakeholders and teachers involved in the course.

The principle of abstraction and generalization could perhaps be dealt with better by using other research methods to generalize the results. On the other hand, the current study aims to understand the ways in which students experience the process of decision-making in computer science student projects, which does not necessarily imply generalization as a goal. In order to generalize from the current results, a second step where similar project courses are investigated based on the result from the current study could be performed.

Some effects of the principle of multiple interpretations could have been more carefully handled. My, the researcher's, relation to different participants would have been worth exploring and dealing with in a more thorough manner.

The principle of suspicion was hard to apply in the study in focus. Perhaps it is in fact hard to be suspicious about told experiences. It can also be that I could use the reasoning behind the principle to more carefully doubt the participants' experiences.

To conclude, this evaluation shows that the applicable principles have been taken care of to a reasonable extent. The evaluation has also raised the aspiration of the current research.

Paper A

Paper A M. Wiggberg. (2007). *"I Think It's Better if Those Who Know the Area Decide About It" – A Pilot Study Concerning Power in CS Student Project Groups.* In A. Berglund & M. Wiggberg (Eds.) Proceedings of the 6th Baltic Sea Conference on Computing Education Research, Koli Calling. Uppsala University, Uppsala, Sweden. Also available at `http://cs.joensuu.fi/kolistelut/`

“I Think It’s Better if Those Who Know the Area Decide About It” A Pilot Study Concerning Power in CS Student Project Groups

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February 27, 2008

Abstract

In the light of an emerging interest in project work within the CS curricula, research about projects is gaining importance. In the current work I investigate a full semester CS project course, where focus is on how power is distributed within a group of students. CS skills are shown to be a contributing factor when it comes to power. Using a phenomenographic research approach, a way of researching some aspects on power within CS projects groups is demonstrated. Finally, three qualitatively different ways of experiencing CS skills of other students, and thus power, are revealed.

1 Introduction

In this work I examine a method to study students’ understanding of CS skills, later on referred to as perceived competence, and the relationship between perceived competence and power within student project groups in CS. This pilot study focuses in particular on the role of perceived competence as a power base. In the light of the emerging research on collaborative student projects in higher education in CS, for example Barker [1] and Berglund [3], extended knowledge about social skills and their interactions are shown to be desirable. This is especially true when one of the motivations for doing projects within the CS curriculum is the linking of social and technical

[0] The title is a citation from the interviews by Lukas.

skills. The collaborative teaching form also offers a deeper understanding of the context in where the technology is supposed to be implemented [11].

Open Ended Group Projects (OEGP) [10], like the one explored in this study, are becoming increasingly popular. They offer a learning environment where social components are important. Authority, roles and hierarchy all have an influence on the learning process [2]. Therefore, it is important and relevant to question the role and impact of power in these student projects. This study does not just take a step in the direction of knowledge about power interaction within student projects, but also develops a method for doing such research.

OEGP has a component of social interaction [10] where the current research project has a contribution to make. The literature within the field of CS education research consists of only a few studies remotely close to this subject (see for example Barker [1] and Berglund [3] for a note-worthy exception) which also stresses the need for further research.

The point of departure in the current study is a full semester project course for final year IT engineering students in collaborative project work, aiming at designing and implementing an advanced robotic system. The technical level of the resulting robotic system is specified in advance, but the design of the final system depends on the students' own choices.

1.1 Research Questions

The main research question of this pilot study is how the students become aware of competence of other students in the CS project group. To put it more precise, *what makes CS students experience fellow students as being competent within the subject area?* Thus, the phenomenon investigated is the manner in which CS students experience their fellow students as competent. This question is to be seen as an initial probe for the feasibility and relevance of research in the more general area of power within student project groups.

2 Related Work

2.1 Definitions of Power

A classic definition of power, which is the one used in the reported study, is that of Dahl: "A has power over B to the extent that he can get B to do something that B would not otherwise do." (p. 203) [7]. Moreover, Provan [16] argues that power can be divided in potential and enacted power. Potential power, on one hand, is for instance based on position, formal authority and membership in groups having control over key decisions. On the other hand, enacted power is the "demonstrated ability to affect organizational outcomes" (p. 7). This means that Provan makes a distinction between shown, or demonstrated, power and power that comes with a position in a certain place.

Furthermore, power can have many faces. French & Raven identify five different forms of power; coercive power (the power to force someone to do something), reward power (the ability to ask people to do things in exchange for something they want), legitimate power (power connected to a role), referent power (the power given by someone who adores you and wants to be like you) and finally, expert power (when someone has knowledge and skills that someone else requires) [17].

2.2 Project Work Among Students

The issue of project work as an educational setting in engineering and CS has been investigated in several papers, for instance Brown and Dobbie [4], Coppit and Haddox-Schatz [6], Newman et al. [15] and Leeper [13].

Seat and Lord [18] emphasize the importance of practicing interpersonal skills like communication and teaming. They refer a program for teaching interaction skills to engineers with the aim of increasing the efficiency of their technical skills. The approach for teaching those soft skills was to let the students adopt a simple set of general principles and apply them to their own context. From there, the students could play and interact in supervised groups with the possibility of getting feedback.

The students' motives for learning within a project environment are elucidated by Berglund [3] where the social dimension, academic achievement and project skills are identified. Berglund has investigated and reported on the control structure of CS teams in a very similar social context to the current study. Tensions or contradictions in the groups have also been identified and exposed as a part of the social game within the group.

Barker [1] sheds light on how unclear aims in projects have a negative influence on the learning environment and pedagogic outcome of the project model. Even though performed in another social context, Barker presents findings worth considering. One of the more noticeable results from that study is the unawareness of the effects of knowledge asymmetry, which happens when one group member is more skilled in a topic than the others are. Knowledge asymmetry can be used for peer tutoring, a beneficial situation for both parties. But, when students select their own roles in the group, they often tend to choose task where they already are more skilled in and by that lose the major impact of the peer tutoring in collaborative work. This also implies that in a group allocating tasks themselves, improved learning does not automatically follow. Barker also argues that only when group processes are made explicit, can activities lead to enhanced learning.

3 Phenomenography

In order to explore the complex question of why somebody has a stronger position in the CS project group, I take a phenomenographic approach. Phenomenography is a research framework for revealing the qualitatively different ways in which people experience a phenomenon. The approach is a second order research perspective that tells something about other peoples' experience of the world. The opposite, a first order research perspective, makes statements about the world [14]. Thus, in order to learn about how students experience competence of others, phenomenography is an appropriate approach.

A phenomenon can be experienced in many different ways. The rationale behind phenomenography is to find and describe the outcome space which consists of the different ways of experiencing the particular phenomenon [14]. An important characteristic of a valid phenomenographic outcome space is the relationships between the categories. Cope [5] describes this:

> "One of the consistent findings of phenomenographic studies is that a group of individuals will experience the same phenomenon in a limited number of distinctly different ways. Importantly the different experiences have been found to be related hierarchically based on logical inclusiveness and increased level of understanding." (p. 68) [5]

The concept of awareness of a phenomenon can be understood as its meaning and its parts and their relationship [14]. Together these two aspects create a whole. Berglund [3] has an example of this:

> "A coin of one euro can serve as an illustration: To get a full picture of such a coin, both the meaning (a currency in many European countries; that is, a legal tender) and its shape (round, consisting of two different metals) must be known." (p. 40-41) [3]

4 The Study

The empirical data was collected from a CS project course in the final year of the IT engineering program at the Department of Information Technology, Uppsala University. The course duration is one semester. The students together carry out a task of designing and building a power line inspection robot [9]. The project course usually involves two 12 person teams with support of 2-4 teachers. An earlier instance of this course is described in Daniels and Asplund [8].

The student cohort was analyzed by study background, stated interests and project roles. From that analyze, eight students representing a great variety concerning those variables where selected. Those eight students where then interviewed. The interviews were transcribed verbatim. An iterative process of identifying and categorizing the experiences followed, where sorting and resorting piles of excerpts was a major activity. Finally, an unambiguous distribution of excerpts in categories where found and thus the iteration ended.

5 Empirical Results

The study shows two results. Firstly, perceived competence, presumed or demonstrated, leads to increased influence. Secondly, three different ways of experiencing competence can be found in the project group: presumed skills, earlier demonstrated skills and demonstrated skills.

5.1 Perceived Competence as Contribution to Influence

All interviews conducted indicates that perceived competence is a contributing factor when it comes to influence within the student project. One typical example is the excerpt from Emil [1].

> **Interviewer**: Are there some [students] whose opinions get more attention?
> **Emil**: Yes, those who have competence. It feels like William and Lukas have most.
> **Interviewer**: And people listen to him?
> **Emil**: Yes.

This result is expected and in line with French & Raven's discussion about expert power and increased influence; by expressing yourself as competent you increase your influence.

5.2 Experiencing Competence

Three qualitatively different ways of experiencing competence of fellow students within the current student project have been identified. These three categories constitute the phenomenographic outcome space. Since the three presented categories build on each other and each of them contributes with a qualitatively difference, they are connected.

5.2.1 Category One: Presumed Skills

This category holds expressions that support a presumption of competence. The expressed thoughts about someone's competence are not founded upon

[1]To preserve the anonymity of the students, their names in all excerpts are replaced by fake ones.

any evidence thereof, but rather on presumptions. The following excerpt from Emil illustrates the category.

> **Interviewer**: And what is it that makes people listen to them?
> **Emil**: That they seem to know what they talk about.

Another student, William, emphasizes this when he talks about how he was appointed a certain task.

> **Interviewer**: Why do you think Oskar appointed you?
> **William**: Because he thought I knew what I was talking about.

5.2.2 Category Two: Earlier Demonstrated Skills

This category holds expressions of skills demonstrated in earlier settings. Experiences of someone's abilities to solve problems, not within but close, to the current project focus are articulated. Thus, presumptions about someone as competent are based on evidence, but not from the same area as the project deals with. Again Emil helps us with an example of this category.

> **Interviewer**: Then competence is something one takes into account?
> **Emil**: Yes, I definitely think so. It's not like one puts someone that doesn't, sort of isn't used to, having responsibility for a server to have it. One rather takes someone that has it, already have responsibility and experience from before.

5.2.3 Category Three: Demonstrated Skills

This category describes that someone's acting during the current project work constitutes the bases for fellow student's interpretation of the competence of him/her. Showed skills within the present project are interpreted as evidence of competence. The category implies that the subject is presumed to be competent, but now with evidence from the current project. The difference is that the evidence for the presumed competence is from the project setting where the competence is needed. Let us hear how Erik explains the core feature of this category.

> **Interviewer**: Did he get responsibility at the start, [...]. To decide this much?
> **Erik**: I don't think he decided all that much in the beginning, it sort of grew. He has proved himself competent several times. And the more he come through as competent, that he made the right decisions, the more we others allowed him.

5.3 Discussion

The initial result that perceived competence contributes to influence in student projects in CS is emphasized in all of the interviews performed. This is therefore the starting point for the data driven phenomenographic analysis that leads to the second result.

The result concerning how students experience the competence of their fellow students is summarized in table 1. The table differentiates between the meaning of the categories and the relationship between them.

Focusing on the differences, the inclusiveness between the categories can be elaborated. The first category and the second category have its main difference in the expressions of skills in earlier CS projects.

Let us listen to a continuation of the last excerpt from category one, where William gives an example of the inclusiveness and the difference.

> **Interviewer**: Why do you think Oskar appointed you?
> **William**: Because he thought I knew what I was talking about.
> **Interviewer**: There was thus a presumption...
> **William**: Yes, we have also worked together before.
> **Interviewer**: You know each other?
> **William**: Yes, everyone in the project has more or less worked together before except Lukas and Alexander.

In the next category, demonstrated skills, the qualitative difference is that the demonstrated skills are from within the current project. However, still the experience of competence is based on evidence from earlier projects and then increased with experiences of skill from the current one. Emil, who first expresses an earlier demonstrated competence and later also states experiences from the current setting as indications for competence, describes the differences for us.

> **Interviewer**: Did he come in with this responsibility [..] What made you presume, to understand, to know, that Lukas mastered it?
> **Emil**: At the start it was just because he studied at the Electronic engineering study programme. And the... it has become clear that he is very competent. That he does good things.

Thus, the categories are getting more and more detailed with respect to their requirements about skills relevant to the current project.

6 Conclusion

Two important conclusions can be drawn from the study. First, perceived competence contributes to personal influence in the student project groups.

Category	**Meaning**	**Characteristics**
One	Presumed skills	Expressions that support a presumption of competence.
Two	Earlier demonstrated skills	Expressions of abilities to solve problems not within, but close to, the current project. Presumptions about someone as competent are based on evidence, but not from the same area as the project deals with.
Three	Demonstrated skills	Someone's actions during the current project work constitute the basis for fellow student's perception of his/her competence. Gradually shown skills within the particular field of application are interpreted as evidence of competence. The category implies that the student is presumed to be competent, but now with evidence.

Table 1 – Categories of description of what makes CS students experience fellow students as being competent within the subject area.

Second, three qualitatively different ways of experiencing competence among other students have been identified.

The first result about perceived competence has obvious similarities with results from other studies regarding the value of competence. For instance Grant et al. [12] concludes in an article regarding the importance of technical competence to project managers that: “A majority of respondents in the sample, regardless of personal or situational factors indicated technical competence is extremely important or absolutely essential” (p. 17). Barker and Garvin-Doxas [2] emphasize that status is something you earn in the classroom by giving evidence of skills: “status is informally accorded to those who display their ability to write 'elegant programs', display ability to reason well [...] or provide other needed information” (p. 16).

How well these different studies are comparable with the current study is of course an issue for discussion. Being studies of another context (the defence acquisition) or other settings (classrooms), they still could support the current finding.

The second result is in accordance with the work about potential and enacted power of Provan [16], someone's possibility to control project decisions is based on competence and not formal positions. Thus, competence as a source for power in the current study can be identified as leading to enacted power.

6.1 Open Questions

There is an emerging focus on team work in the CS curriculum. Despite this, the research that is performed on human power and the effects of power on the learning outcome in students' teams in CS are still limited. With respect to those circumstances and the indications derived from the current study that power is an influencing factor, the following initial research questions are proposed for further research;

- in what ways are influence and responsibility as well as the organization of the teams related to the learning outcome,
- are there other ways of distributing influence than perceived competence,
- is the distribution of influence in the teams related to the students' perceived competencies of CS, and
- what can be learned about influence and responsibility in order to prepare rewarding project settings?

The presented work also opens up for several relevant methodological and legitimacy questions connected to my Ph.D. work, where I am especially interested in;

- how well phenomenography can be used for investigating influence, and
- how power and social interaction research has its application within CSED?

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Paper B

Paper B M. Wiggberg. (2008). *Experiences of Decision Making in Computer Science Student Project Groups.* This paper appeared at the Seventh Baltic Sea Conference on Computing Education Research (Koli Calling 2007), Koli National Park, Finland, November 15-18, 2007. Conferences in Research and Practice in Information Technology, Vol. 88. Raymond Lister and Simon, Eds.

Computer Science Students' Experiences of Decision Making in Project Groups

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February 27, 2008

Abstract

This paper describes a study intended to understand the ways in which students experience the process of decision-making in computer science student projects. It also investigates the ways the student team works to make decisions.

The empirical setting for the study is a semester-long project with 22 final year computer science students. It is a qualitative study where data are gathered using interviews and analyzed using phenomenography.

Six categories have been identified describing how students experience the process of decision-making in computer science projects. The level of sophistication differs between the categories. The first describes an experience of decision-making as individual decisions too small and unimportant to be handled by anyone other than the individual. At the other end is the experience of decision-making as a democratic process involving both the full group and the context in which the group acts. The other four categories are situated between these two extremes.

1 Introduction

Learning in computer science project courses is affected by, among other things, how the project is structured. Structures for decision-making among the students in the projects are thus important in order to design good learning environments. According to Desanctis & Gallupe (1987) a decision-making team is

> [...]two or more people who are jointly responsible for detecting a problem, elaborating on the nature of the problem, generating

> possible solutions, evaluating potential solutions, or formulating strategies for implementing solutions. (Desanctis & Gallupe 1987, p. 590)

The perspective of the student project team as a decision-making team brings new questions to the fore. In this context, it is relevant to consider how students experience decision-making.

Largely, universities today organize education so that teamwork becomes an integral part of students' education. In computer science, this is manifested in the important role of teamwork in the ACM Curriculum (The Joint Task Force for Computing Curricula 2005), as well as in many study programs. The Masters program in Information Technology at Uppsala University is one example where projects are emphasized as a model for learning approaches.

The study reported here on decision-making experiences is related to previous studies, e.g. on power structures (Wiggberg 2007). The intention is that the results from the various studies will be combined to form a cohesive contribution to the area of project approaches in computer science education. Regardless of the differing focuses, the unit of analysis in all is the collaborating student project team.

The students' own experience of their learning related to the aforementioned issues is explored with qualitative data analysis. The research framework in the current study, as in the initial study, is built on phenomenography. Marton and Booth (Marton & Booth 1997) provide a general discussion of phenomenography, and Berglund (Berglund 2005) of its applications within computer science education.

Learning outcome is defined by Berglund (2005):

> The learning outcome that is sought is that which is actually learned from the point of view of what is meant to be learnt. (Berglund 2005, p. 39)

Exploring the relationship between learning outcomes and decision mechanisms in computer science project courses can help us to understand different outcomes of learning. Knowledge about this relationship will give new and potentially valuable clues in the field of learning outcomes in software teams. A possible contribution to practitioners in the field of computer science education is a set of guidelines for defining and communicating learning purposes in practitioners' teaching.

1.1 Research Questions

Investigating the distribution of power in a computer science student project (Wiggberg 2007), it is clear that decision-making is a visible structure that determines much of the work in projects. That is also the rationale for studying the structure of decision-making mechanisms in the student teams.

By talking to students and reading through interviews from previous research, two different research questions became apparent. The first one, the primary, can be called "decision-making processes" and concerns

- how the student experiences the process of decision-making.

This question was the driving force in the study. During the investigation, a second question became apparent:

- in which ways does the student team work to make decisions?

The two research questions differ not only in their content but also in their perspectives. The first question is about a student experience, while the second concerns a structure for decision-making. The decision-making processes question is about the student experience of a certain phenomenon at a collective level. The question of structures for decision-making regards the manner, or the structure, of the process of decision-making. This question does not concern student experiences as such, but rather looks at the system within which people experience things. These two questions therefore have different perspectives and require different approaches. The first question asks for answers from the student's perspective, while the second asks for the perspective of an outsider observing the students. These differences led to the use of different methods for analyzing the data. For the first question, we analyzed the data using phenomenography; for the second, we simply categorized and summarized our findings. A discussion on these two follows in section 4.

To address the first question we required a research framework that helps the researcher understand the experience of the student. Phenomenography is a second-order research perspective: it tells the researcher something about other people's experience of the world, whereas a first-order research perspective makes statements about the world itself (Marton & Booth 1997). Thus phenomenography was chosen as research framework to explore how students experience the process of decision-making. The second question, on the other hand, requires a first-order research perspective.

Another advantage of phenomenography is that it aims to gain knowledge on the collective level. The individual experience is important, but only as part of the whole student cohort. Regardless of how the students have divided themselves within the project, for this study they constitute a single data set.

This study is restricted to learning about the decision-making experiences and structures identified by the students in the project. It does not focus on such questions as why the decision-making structure looks as it does or why the experiences came about.

2 Related Work

Related work in connection to the research questions considers both theory on structures for decision-making and research in educational settings for project work. Firstly, a walk through of some of the major theoretical and analytical views on decision-making structures will be done. Secondly, studies on projects as educational settings within or close to computer science will be presented.

2.1 Decision-Making Structures

Organizational decision-making is a complex process involving several different steps. The rational decision-making model divides the process into six analytical steps: identify the problem to be solved; choose the best decision style; develop alternative solutions; choose among the solutions developed; implement the selected alternative; and evaluate the effect of the choice. It is important to notice that the rational model does not support how people and organizations make decisions, but gives the analytical frame for analysis of such decision-making (McShane & Glinow 2005). The rational decision-making model is by no means universally accepted; see, for example, Simon (1955). In this paper, the analysis of decision-making will be limited to steps three and four, developing and choosing between solutions.

Barker et al. (1991) suggest five strategies for team decision-making: force, majority vote, compromise, arbitration, and consensus. No single strategy is thought to be best for all teams. Instead the most appropriate team decision-making strategy is likely to depend on the particular group phase, time constraints, and other such factors (Barker et al. 1991).

Wickens & Hollands (2000) extend the discussion on decision-making with domains of decision-making, a model proposed by Shanteau (1992). In this model, the value of practice and experience in a field is questioned in certain domains. Einhorn & Hogarth (1978) have then added understanding of feedback to the model. The model presents the characteristics of good and poor decision-making domains. A good domain is dynamic, involves decisions about things, has decomposable decision problems, and provides feedback. A poor domain is static, involves decisions about people, gives no or poor feedback, and does not provide decomposable decision problems (Shanteau 1992). The conclusion is that in poor domains, decision-making is hard even for experienced people.

Wickens & Hollands (2000) note that an important component of effective decision-making is situation awareness, the understanding of the situation, often by diagnosing which possible state the world is in (Swets & Pickett 1982).

McShane & Glinow (2005) reason on effective team decision-making and state that in many situations teams potentially make better decisions than individuals. However, many group mechanisms can impair the effectiveness of the group. Janis (1989) suggests that no team member, including the leader, should be too strong or influential. Fiest (1997) points out the importance of keeping the team size on a moderate level: big enough to do necessary work and small enough not to consume too many resources.

2.2 Projects as an Educational Setting

The issue of project work as an educational setting in engineering and computer science has been investigated in several papers, for instance Brown & Dobbie (1998), Coppit & Haddox-Schatz (2005), Newman et al. (2003) and Leeper (1989).

Seat & Lord (1998) emphasize the importance of practising interpersonal skills such as communication and teaming. They refer to a program for teaching interaction skills to engineering students with the aim of increasing the efficiency of their technical skills. The approach for teaching those soft skills was to let the students adopt a simple set of general principles and apply them to their own context. From there, the students could experiment and interact in supervised groups with the possibility of getting feedback.

Berglund (2005) explores students' learning within a similar project environment. Among other things, Berglund identifies three different motives for taking the course in focus: academic achievement, project and team working capacity, and social competence.

Barker (2005) reports on how perceived pressure to finish a project for clients, together with poor understanding of how to work well in groups, has a negative impact on the learning environment and pedagogic outcome of the project model.

> When students are allowed to select their roles based on expediency or comfort, it works against the benefits of collaborative learning, particularly in the case of IT education. While this approach may seem eminently practical and efficient, it does not provide any of the students with a new learning experience, but instead practice of existing skills. (Barker 2005, p. 279)

Hence, when students select their own roles within the team, they tend to choose tasks for which they already have well-developed skills, and through that choice lose the major impact of the peer learning exchange expected in collaborative work. Barker also argues that only when group processes are made explicit can activities lead to enhanced learning. Even though performed in different cultural and social context from the current project, Barker's work presents findings worth considering.

An earlier study investigated a full-semester engineering project course at the Department of Information Technology, Uppsala University, with many similarities to the current course. The focus of the study was on how power is distributed within a group of students. The students taking the course were in their final year of the IT engineering program. The course duration was one semester (Wiggberg 2007). The students worked on the task of designing and building a power line inspection robot (Danielsson et al. 2006). The study showed, as expected when it comes to expert power (Raven & French 1960), that computer science skills are shown to be a contributing factor when it comes to power within the group. Finally, three qualitatively different ways of experiencing other students' computer science skills are revealed: by presumed skills, by earlier demonstrated skills, and by skills demonstrated in the actual project.

Waite et al. (2004) have reported from a study of computer science students in undergraduate project courses where there are indications that the students perform poorly in group skills. By ethnographic observation and in-depth interviews of students during projects, they attempted to discover why using the project model did not give the students these skills. They state:

> In order to improve the students' collaborative skills, we need to change some of the characteristics of their occupational community. This cannot be done by teaching a course in group work or telling them to work in groups to solve a problem. It has to be done by understanding the enculturation process, and establishing conditions that favour development of a collaborative culture. (Waite et al. 2004, p. 14)

Waite et al. emphasize the importance of not just adopting the project model, but instead carefully designing the project course in order to achieve the desired learning outcome.

The same study concludes that group decision-making is often experienced as an ineffective and time-consuming process. Two characteristics of the decision-making process contribute to this: team members' predilection for their own opinions and their distrust in the rationality of using decision-making methods. By experimentation, the authors developed a viable group decision-making exercise that helps students to retreat from favoring the individual choice in decision-making situations (Waite et al. 2004).

Entwistle (1977) discusses the need for reflection on group methods and points at the importance of group methods in higher education:

> What may, however, be necessary is to think more clearly about the functions of large-group and small-group methods in relation to the particular intellectual skills, or cognitive style, they are expected to foster and whether the assignments and examination questions given to students provide sufficient encouragement for deep-level processing. (Entwistle 1977, p. 235)

Even though computer science project teams have been researched in recent years, there is still a gap in the knowledge of the impact of decision-making. This study can therefore, among other things, contribute to the body of research on the learning process within computer science student projects with information on how students experience decision-making. By revealing this information, we can learn more about one of the factors in project structures.

3 The Setting

The computer science project course studied was held in the final year of the Computer Science Masters program at the Department of Information Technology, Uppsala University, between August 2006 and January 2007. The course was taught in English.

The course duration was 20 weeks, 10 weeks part time in parallel with another more traditional course and 10 weeks full time.

Participating students work with one project for the full duration of the course. The product, which varies somewhat by course instance, is not specified with any exactness. Instead, the students are expected to formulate the requirement specification themselves from an initial idea proposed by the team of teachers in cooperation with the participating industry partner. Students do not need to complete the product in order to pass the course, since the focal point is the process of working on the product. This project falls within the framework of Open Ended Group Project courses (OEGP) (Faulkner et al. 2006).

The number of distinct projects varies with the number of students. In the current course, 22 students participated and were divided in two project teams where they carried out either (1) a task involving designing the software for a game for cell phones (Nilsson et al. 2007) or (2) a cell phone positioning task (Back et al. 2007). The industrial partners also contributed to the project as mock customers.

Essentially, the same course has been run for over twenty years. The tasks have varied greatly. Examples from the past five years include football robots, map-making systems, real-time middleware for robots, distributed mobile games, and GPS systems (Pettersson 2006). Daniels & Asplund (2000) and Wiggberg (2007) have described earlier instances of this course.

3.1 The Physical Environment

The physical environment of the project plays an important role in a project (Jaques 1995, p. 120). During the project the students worked in two project rooms. Each team sat in a separate room, but the rooms were located close together. Collaboration between the project teams was encouraged. The work environment was an open-plan office where people located themselves close to the other members of the smaller groups they ended up working in. Each student was given a workspace and a computer. The room was equipped with whiteboard, printer, and some other hardware. The teams were asked to use software for keeping track of bugs, version handler, content management system and personal diary software (Pettersson et al. 2006).

The students were expected to work 8 hours a day during the second half of the semester, and presence was compulsory from 9 am to 4 pm (Pettersson et al. 2006).

3.2 Project Teams and Their Tasks

Twenty-two students participated in the course. Five of them were exchange students from Tongji University, Shanghai, China, who had completed two years of computer science in China and one year at the department prior to the project course.

The other 17 students were Swedish and were all enrolled in the Computer Science Masters Program. They had completed approximately two years of compulsory courses and one year based on individual preferences. Both the exchange students and the Swedish students voluntarily applied for the course [1].

Two different project teams, with different tasks, were formed at the beginning of the project course. Despite the difference in tasks, there was a high level of collaboration between the teams.

The project team Point of Interest (POI) was assigned the overall task of designing and implementing a mobile positioning system based on information provided by the GSM [2] network and GPS [3]/WLAN [4] when available. The second part of the task was to create a map on which points of interest could be displayed (Back et al. 2007).

Project team Teazle Goes Mobile (TGM), was assigned the task of implementing a distributed multi-player game for mobile devices. The game was originally developed in 1997 and called Teazle (Nilsson 2006).

Both tasks were rather complex and involved a client and server solution as well as a graphical web front end.

Although the technical goals were given by the industry partner and the team of teachers, the specific shape of the technical goals, as well as design and implementation issues, were left to the project teams to decide. Faced with a somewhat vague design, the project teams had to interpret

[1] Anders Berglund, Director of international undergraduate collaboration, Department of Information Technology, Uppsala University, private communication.

[2] Global System for Mobile communications, GSM, is today the most popular standard for mobile phone systems.

[3] Global Positioning System, GPS, is a satellite-based positioning system allowing you to determine your geographic position with an accuracy of some meters.

[4] Wireless Local Area Network, WLAN, is a standard for linking two or more computers using a wireless network device.

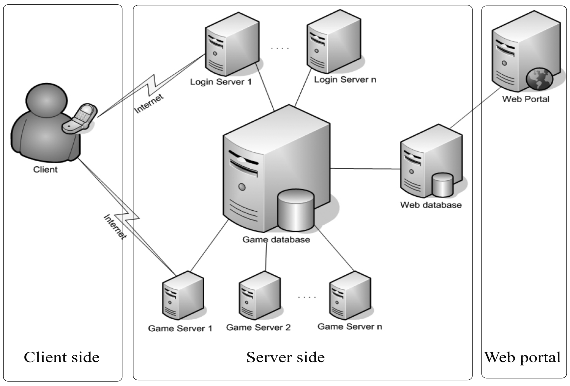

Figure 1 – A system overview of the TGM project (Nilsson et al. 2007)

the task and develop a system design, a requirement specification, and an implementation plan.

The team members originally organized themselves around the three major development areas. The TGM areas, based on figure 1, were client side, server side, and web portal. POI organized themselves similarly, although the software components looked slightly different. The server side sub-team, with four members, took care of the login server, the game server, the game database, and the web database. The client side sub-team, with five members, took care of the mobile application. Finally, the web portal sub-team had two people working on the game's web interface.

Project managers for each team were appointed by the teaching team following applications from team members.

Additional responsibilities for all three sub-teams included lead programmer, testing manager, system administrator, configuration manager, bug manager, final report manager, user interface manager, and requirement specification managers (Nilsson 2006).

4 Research Design

4.1 Data Collection

Semi-structured interviews (Kvale 1997) were used to collect information on how students experienced the process of decision-making in the course.

An important requirement of the data collection method was that it should provide a rich data set where clues about the decision-making process could be found without exactly knowing in advance where to start looking for them. Semi-structured interviews are also well suited to a second-order research perspective.

Kvale (1997) describes semi-structured interviews as interviews where central themes and openings for relevant questions are prepared beforehand, but where it is also possible to adjust the order and formulation of the questions during the interview. The central themes and prepared questions can be seen as a desired structure, with the remainder of the interview comprising follow-up questions on interesting lines of thought from the initial answers.

An important goal with the phenomenographic research framework is to get the broadest possible set of experiences under the actual time constraints. The group for interview is selected not to capture all understandings, but to sample as broad as possible a range of experience in order to provide a rich data pool containing a wide range of experiences of the phenomenon. You cannot get all the understandings, since you can never see inside the minds of the group members. Students' backgrounds were surveyed in order to carefully choose the interviewees. Their academic records were examined to give a picture of their previous courses and achievements. The students were also asked to complete a questionnaire regarding their motives for participating in the project course, their expected achievements, and the personal skills they considered important. The gathered information was used to construct a profile of each student participating in the project course. Some of them turned up with similar academic background, personal skills, expectations, and motivations. Based on the assumption that diverse profiles were more likely to contribute to diverse experiences, 18 students were selected for interviews, four of whom were exchange students. This means that all but four students were selected for interviews, which certainly fulfilled the desire of a broad data set.

Decision-making processes might be different in the different project teams, therefore the students' experience is perceived differently. Since the phenomenon in focus, how the student experiences the process of decision-making, regards the full project course, this difference is a part of the expected variation in experiences.

The interviews were performed in three sets of six interviews each over the duration of the course. The aim with this was to catch experiences from early, middle, and late team phases in the team development, as described thoroughly by Jaques (1995).

The interviews were held in either English or Swedish, according to the interviewees' preferences. The interviews were then processed and analyzed in their original language. Published excerpts will be presented in English and hence some translation is necessary.

The students investigated have different nationalities and genders. Although these factors might influence the empirical data, they have not been considered as a difference with regard to the analysis. Due to the integrity of the students, the fictitious names used in the excerpts might not suggest the same sex and nationality as the names in the original transcripts.

A final important note is that the study is not longitudinal. No comparisons were made between individual students or over time. This is consistent with the phenomenographic framework.

4.2 Analyzing Data

The full interviews were recorded on digital recorders. These methods for recording data during the interview are in accordance with how Kvale (1997) describes methods for collecting data from interviews. The recorded interviews were transcribed verbatim. An iterative process of identifying and categorizing the experiences followed. In this process, the researcher places statements from students in different categories, which are at first tentative. As the sorting process continues, the categories form their own contexts, giving a meaning to the different statements. The statements are continually re-sorted during this iterative process, since each newly added statement changes the meaning of the full set of categories. Finally, a set of categories is formed, each of which can be given a meaning in the researcher's own words.

Once this process was complete, the final categories were shown to a second researcher in order to establish their soundness. The categories and their meanings were also compared to the full interview transcripts in order to check their consistency.

4.3 Phenomenography and Learning

To reveal different ways of experiencing *how* students go about making decisions, a phenomenographic framework (Marton & Booth 1997) was used. Phenomenography is a research framework for revealing qualitatively different ways in which people experience, or learn about, a phenomenon.

A phenomenon, as the process of decision-making, can be experienced in many different ways. Marton and Booth describe phenomenography as a way to find and describe the outcome space that consists of the different ways of experiencing a particular phenomenon (Marton & Booth 1997). An important characteristic of a valid phenomenographic outcome space is the relationship between the categories. Berglund & Wiggberg (2006) describe this:

> Since the categories illustrate different aspects of the *same* phenomenon, they are logically related to each other. Were they not, they would describe aspects of different phenomena. In general, some categories offer a wider or richer perspective and often come to embrace others in an inclusive structure. [...] the more embracing categories are generally more desirable. (Berglund & Wiggberg 2006, p. 266)

The complex process of learning is multi-faceted. In order to offer a framework for analyzing learning, phenomenography introduces a distinction

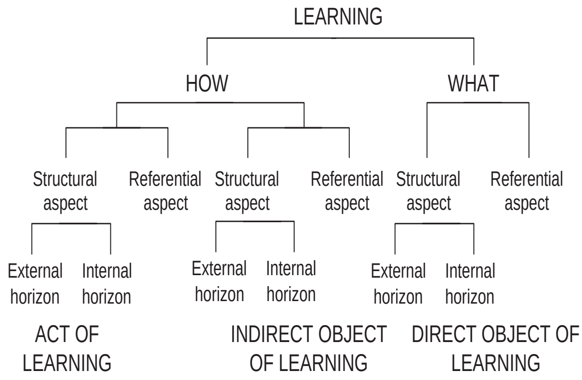

Figure 2 – An analytical view of the experience of learning something Marton & Booth (1997, p. 91)

between two aspects of learning:

> (1) the *what* aspect of the learning, describing the content of the learning (for example a network protocol) and (2) the *how* aspect, describing how the students go about learning, or how they tackle their learning. While the first normally is referred to as the *object of learning*, the latter is labelled the *act of learning*. This distinction is, as Marton & Booth (1997) point out, purely analytical: the aspects can only be "thought apart" for research purposes and do not represent different concepts. (Berglund & Wiggberg 2006, p. 266)

Hence, even though the experience of learning something from the students' perspective is a whole process, phenomenography analytically helps us to analyze the process in different parts, the *what* and the *how*. The former deals with the content of learning, often referred to as the *direct object*, and the latter the *act of learning*.

The analytical distinction between *what* and *how* can be taken a step further by dividing the *how*-branch in two different parts, the *act of learning* and the *indirect object of learning*. The *act of learning* refers to how the students experience the learning. Berglund (2005) explains this *act of learning*:

> The term "act" should here be interpreted in a broad sense, beyond the physical acts that a student performs in order to learn, such as reading a book, solving a problem and asking a friend. The term "act of learning" also includes abstract aspects, such as how students go about achieving their aims. (Berglund 2005, p. 42)

The *indirect object of learning* is about the quality of the act of learning, or what the act of learning aims at. This can also be seen of as the motive for learning (Berglund 2005).

While the above described terms form the main analytical separation in the experience of learning, the *act of learning*, *indirect object of learning*, and *direct object* can each in turn be divided in a *structural* and a *referential* aspect. The former denotes the structure by which we identify or recognize the phenomenon, and the latter refers to the meaning of the experienced phenomenon. Again, this is just an analytical separation. The structure identified helps clarify the meaning, and the meaning helps us find the structure. A final analytical separation of the *structural* aspect helps to distinct between the phenomenon itself, its *internal horizon*, and its surroundings, its *external horizon*. Marton & Booth (1997) phrase this distinction like this:

> That which surrounds the phenomenon experienced, including its contours, we call its external horizon. The parts and their relationships, together with the contours of the phenomenon, we call its internal horizon. (Marton & Booth 1997, p. 87)

See figure 2 for a summary of the analytical framework.

In this study the phenomenon is the process of decision-making, with a focus on *how* students experience that phenomenon. How students go about deciding things in the project is a strategy they adopt to be able to learn. This strategy can be seen as one of the "capabilities the learner is trying to master" (Marton & Booth 1997, 84) and thus the indirect object of learning.

A final remark on phenomenography is that it aims at gaining knowledge on variations in experiences on the collective level and not individual experiences. Marton & Booth (1997) put it like this:

> [...] phenomenography focuses on variation. The objective of a study is to reveal the variation, captured in qualitatively distinct categories, of ways of experiencing the phenomenon in question, regardless of whether the differences are differences between individuals or within individuals. (Marton & Booth 1997, p. 124)

4.3.1 Different Approach on Question B

Question B, addressing the kinds of decision structure that occur in the project, was a result of information that emerged during the data collection. Regarding question B, no particular analysis of the material has been performed, but the identified strategies have been categorized briefly. Answers to question B are presented in the empirical section as a collection of methods used by groups to make decisions.

5 Empirical Results

The empirical results consist of two sets of findings. For the question of how the student experiences the process of decision-making, a categorization is produced. Findings regarding the second question on structures for decision-making are also summarized. Together those set of findings describe the ways that students experience the process of decision-making as well as giving examples of the ways the group go about making decisions.

The first set of findings describes six categories that differ in their 'richness' or quality. The differences between categories include the size of the decision-making unit, the level of formalization of the decision-making process, and the level of involvement of people external to the group.

The categories are described in detail and illustrated by excerpts from the interviews. The presented excerpts are examples of the excerpts behind each category, and should give the reader an impression of the data supporting the category.

5.1 Question on How Students Experiences Decision-making

The phenomenographic outcome space consists of six different categories describing different experiences of how the group handles decision-making. The categories all have different meanings (which phenomenographical terminology calls referential aspects), that give each of them a unique profile within the outcome space. Table 1 gives an overview of the referential aspect of each category.

We shall now describe each category in turn, giving examples of excerpts from each. Their focus, or structural aspect, and their meaning, or referential aspect, will also be described.

Cat. 1: Decisions by Individuals

In this category, individual decisions are expressed. That means that the decision either is too small or involves too few people to be handled by any means other than the individual first encountering the decision. The individual perceives the unimportance of the decision and therefore it becomes a private issue.

As an example constituting the base for this category, let us listen to Emma who states that most of the decisions are individual:

> **Emma**: Most decisions have probably been made individually, [...], well there are lesser design decisions, maybe one, two or three persons have sat down in small groups and discussed how to design this or that thing, and it is these little decisions, small changes, [...], that in the end have created this project, then I think that many such decisions have been made individually,

	Label	**(Referential aspect) Decision-making is understood as...**	**(Structural aspect)The focus is on...**
1	Decisions by individuals	... too small or involving too few to be handled by any means other than the individual first encountering the decision. The individual perceives the unimportance of the decision and therefore it becomes a private issue.	...one person and that individual's decisions.
2	Decisions by individuals with preferential right of interpretation	...an informal right to interpret and make decisions even though the decision might involve other people.	...the knowledge that the decision may be of importance to other people in the project, but still it is recognized and treated as an individual decision.
3	Decisions by small group discussions	...a mutual agreement in a smaller group. The decision matters for more than just one individual and therefore automatically involves opinions from more people.	...on the smaller group and its discussion.
4	Decisions by group discussions supported by a facilitator	...group discussions supported by a facilitator.	...the facilitator and the small group.
5	Decisions by democracy in full team	...a democratic process in a formalized full team setting.	...the team as a formal body where strategies for structured decision-making are present.
6	Decisions by mutual agreement between team and external stakeholder	...democratic involving the full team, but in the same time the 'reality' is involved in some way.	...the full team and its context, namely the surrounding stakeholders and their interaction with the team.

Table 1 – Categories describing the outcome space for how students experience the process of decision-making

> simply, that the largest absolute amount of decisions in the end have been individual.

In this excerpt, Emma goes on to describe different kinds of strategy for decision-making during the project, but indicates that the majority are individual.

Oscar continues by giving a reason for this when he tells us that those decisions often regard minor changes or minor things.

> **Oscar**: Who'll be affected, really, is it a decision that just concerns, affects one [...], if it is just a small function in what one is about to construct, then it is not necessary, maybe not to send it all the way up, it is not really anyone interested except the two that are implementing the detail.

It is worth noting that Oscar explains the informal way of making decisions where most of the issues are too small to bring up in whole group. Following this discussion, the focus in this category is therefore on one person and that particular individual's decisions.

Cat. 2: Decisions by Individuals with Preferential Right of Interpretation

This category expresses an experience where a specific individual, namely the one who has responsibility for the result of something, also has the preferential right to decide. The decision-making therefore stays with that specific student. Edison gives us an explanation:

> **Edison**: And for example for, I am, I am doing the communication with the client side and if the server goes wrong, and I am in charge of every... everything, and I, of course I have the, the right to decide, eh, the architecture and stuff like that.

In this excerpt, Edison is clear on the link between responsibilities and decision-making.

Another note to make is that some kind of unspoken formal structure leads to the preferential right to decide, but that formal process is not agreed in advance. Courtney illustrates this in the interview:

> **Courtney**: It is not formal, but it is like, eh, everybody, I do not know, eh, we, it is not written anywhere, but it is like we are working, because everyone, in charge of different things, you, of

> course, this is your job, and you, you, of course you should have the, eh, [decision/right to decide].

Another important characteristic of this category is the awareness that the decision might involve, or have an effect on, other people's work. The focus here is therefore the knowledge that the decision may be of importance to other people in the project, but still it is recognized and treated as an individual decision. This also implies a wider description of the decision-making process than in the previous category since the decision is now understood as something that will affect others. Even so, the individual makes the decision herself.

Cat. 3: Decisions by Small Group Discussions

This category contains experiences comprising small discussions at the workplace, often while people are still sitting at their computers. Pairs or small groups reason around specific issues while they work. The groups are limited in size and decisions, and the full group is not a part of this category. The focus is therefore on the smaller group.

Let us hear how Eaton describes the core feature of this category, small group discussions:

> **Eaton**: Yes, it depends on the way we work, very often we work in pairs, or perhaps in threes, and then we reason with each other to come up with a good solution and, eh, since we all sit in the same room.

The small group discussions are often centred on specific issues and seem to be task-oriented. Decision-making is therefore experienced as mutual agreement in a smaller group. The decision discussed is also something that matters for more than just one individual and therefore automatically involves opinions from more people. This makes the category wider than the previous one.

Ashley illustrates a situation where two different pairs of the project group had to solve something:

> **Ashley**: And then when there has been things that are associated with both parts, or with the both parts in the project, then we may have had a meeting about this and then we've sat down and discussed it and thus have reached a joint decision.

As Ashley states, the decision affects more than just one person, and this is something that is acknowledged. The groups meet informally, though, and there are no traces of formal structures to choose between different options that arise from the discussions. Instead, the one arguing best wins.

Cat. 4: Decisions by Group Discussions Supported by a Facilitator

This category describes decision-making experiences where the project manager is involved, not as someone who works with the particular issue in focus, but as a facilitator for the discussion. The group that gets facilitating support can be of any size. Ashley will help us again by describing such a situation to us:

> **Ashley**: And she was also sort of part of the discussion, tossed ideas and such, since she's kind of well situated in everything.
> **Interviewer**: Yes.
> **Ashley**: But she said that, look, we have kind of discussed this for 15 minutes and, it was just a tiny detail. Because this was something that would take like between 5 and 20 minutes to implement. And then she sort of said that enough is enough.

The category involves situations where a group discusses a particular issue. The discussion need not be formalized or planned, but more than one person is involved. Harold gives another example from this category:

> **Harold**: [The project manager] has been there as a mediator if there hasn't been a solution [...] and then we've been forced to make a decision. And that is, has functioned well, I think.

The facilitator is here described as a driving force or arbitrator. The role is also emphasized as important for the progress of the project. The facilitator's involvement makes this category wider than the previous one, which involved only the small group.

Cat. 5: Decisions by Democracy in Full Team

This category contains experiences of decision-making as a democratic process. The team has formalized a process in order to make decisions that people can recognize as fair. This category includes descriptions of formalized discussions where pros and cons are elaborated on. The focus is on the team as a formal body where strategies for structured decision-making are present.

Jake will start by telling us how he experiences the decision-making:

Interviewer: And the first thing I want to ask is how a decision is made in your team.
Jake: Yes, it is very democratic, eh, it is definitely not so that I decide everything, instead we discuss everything together. Eh, some minor decisions have been taken together with me [...] But that was just things that, eh, well, the time plan and such things and then it was not so that all wrote the project plan, but all big decisions about how we shall, eh, make the game and such things, all are part of it.

Examples from this category make clear references to democracy. The interviewees give us a picture of formalized whole team processes. Let us listen to Alfred who describes one example of this process:

Interviewer: And then, did you open up for a general discussion or...
Alfred: Oh, ok, yes, yes, everyone can speak for free, can, give their own opinion about the specific, the scope, and maybe we, eh, how you say, we, kind of vote, voted.
Interviewer: Voted.
Alfred: Yes, voted, kind of.
Interviewer: Ok. So, you voted finally, everyone had a possibility to say something.
Alfred: Yes.
Interviewer: And then you voted.
Alfred: Yes, that is, tradition.
Interviewer: Ok.
Alfred: In our team, everyone can say something.

In this illustration, the level of formalization is high and the team has adopted a system of voting to make the decision. In other cases, thorough analysis of the situation is the experienced strategy to let everyone be a part of the decision:

Interviewer: Right... When you say democratic, then you mean that...
Isac: That, eh, we, well, we sort of discuss it, we propose, eh... pros and cons sort of, okay, this should be the best, sort of. Just logic, like that. Not, yes but I'm best, I'm right. You are wrong.

To conclude this category, decision-making is understood as a formal and democratic decision-making process within the full team.

Cat. 6: Decisions by Mutual Agreement Between Team and External Stakeholder

This final category describes experiences of decision-making where the decisions are not just the team's, but involve some external person. This means that the decision has to be taken by the team and agreed on by some external stakeholder. Decisions in this category are still democratic and involving the full team, but in addition, the 'reality' is involved in some way. This is a wider view on decision-making since it includes not only the team and its formal process but also an external person. Leslie starts to illustrate this:

> **Leslie**: But then we had to change it again recently, because we thought, or Patric [external stakeholder] thought that, eh, Nok.. some Nokia phones we had chosen may not be so good so we had to deselect them and choose something else, so now it's surely decided, but that, that, that is the type of issue that took a long time.

Thus, the external stakeholder plays an active role in the decision. Furthermore, the external stakeholder may disagree with the project team, regardless of where in the process the team is. Let us listen to an example of this.

> **Isac**: [...] we sat and discussed for surely two hours yesterday.. And in the end we agreed on some things.. and then he [the external stakeholder] sent a mail later in the evening or this morning, and he said that he had changed his mind about things we had agreed about.

Another characteristic of this category is the experience that the external person has a strong mandate, not to mention the final say in a decision. Two excerpts from the interview with Jake illustrate this:

> **Jake**: Because, eh, he is the customer and he wants to have things done his way and we want things our way, so within the group it has been fairly easy to make decisions together. We have been fairly unanimous, well I think we have, eh... but, yeah, it is just Chris [external stakeholder] that becomes like this, sort of compensating, then [...]
> **Jake**: Because, or well it is in the end his product... although... but I don't agree with his decisions...

	Decision-making strategies
1	Small group meeting
2	Outside meeting
3	Full team meeting
4	Lottery
5	Voting

Table 2 – Categories describing different strategies for decision-making

This veto on the external person's side is an important factor in the understanding of this category. Even though decision-making is performed with the full team and democratic processes, the external party has the final say and can therefore override the team.

Focus in this category is on the full team and its context, namely the surrounding stakeholders and their interaction with the team.

Despite the external interaction, the experiences in this category indicate that the whole team contributes to a formal decision-making process.

5.1.1 Structural Aspect

As mentioned earlier, the structural aspect holds the categories together and provides them with an order. This is an important characteristic of a valid phenomenographic outcome space (Berglund & Wiggberg 2006, Marton & Booth 1997). The focus, or structural aspect, of the categories is on different aspects of the team or its members and context. The rightmost column in table 1 presents these different focuses.

As can be seen in table 1 the focus of the categories grows from the individual project member via the smaller and the full team to the team and its context. According to this categorization, the least sophisticated way to make decisions is to make them on your own. The most sophisticated is to include not only the full team but also its context, in this case the client. An important note here is that the least sophisticated strategy for decision-making can very well be adequate at times.

5.2 The Ways Student Team Works to Make Decisions

Regarding the question of what ways the student team works to make decisions, the empirical results form five categories. Each presented category describes a strategy to make decisions that can be observed by a person outside the team. The categories are simply describing different ways to make decisions that the students have revealed in the interviews, and no connections between the categories are claimed. In the presentation, excerpts from the interviews exemplify the categories. The different strategies are summarized in table 2.

Cat. 1: Small Group Meeting

Depending on the effect on the project, subgroups of the team may handle the decision. Decisions regarding complex matters are sometimes best suited for small subgroups. Oscar explains:

> **Oscar**: It also depends on, eh, there are different types of decisions, we have for instance split up in server and client groups, six in each, where there are two sub-project leaders, call it, and they have functioned exactly as I within their groups, like, eh, well, like project leaders in general for client and server respectively and how they've made decisions, it is up to them but they have simply often discussed in smaller groups of at most six persons, for decisions that now have been their part, when we will take big decisions that involve the whole project we can either be twelve persons discussing together [...]

Cat. 2: Outside Meetings

In unusual cases, decisions are made outside the formal meetings. People with higher presence more often get the opportunity to attend these meetings. Roberta explains:

> **Roberta**: It is like when everyone is, during lunch-time someone is drinking coke, someone is having their lunch and they just talk freely during this process they gain some decision.
> **Interviewer**: So it is in the formal gathering of people?
> **Roberta**: Yes. Also, not everyone, are, I mean, not everyone there, (?) talk with each other...

Cat. 3: Full Team Meeting

Here planned meetings, formalized by the formal structure of a project manager, are present. Rules exist about the structure of the meeting and the project manager takes an active role in the meeting. Bob describes this:

> **Bob**: Yeah, then it was more like a meeting, with the whole team, and then we sat and discussed tossing up a lot of ideas like that, and then it ended up with us making a decision concerning some of them.

The formal structure is emphasized by Roberta:

Interviewer: So tell me a little bit about those Monday meetings, eh, when you are discussing something, like a decision on design or something like that, how, how is the, how is the structure of the discussion. How is the decision made?
Roberta: Structure, as to the structure...
Interviewer: Is everyone giving his or her opinion and then the leader decides or is it in some other way.
Roberta: The leader always stands in front of that whiteboard.
Interviewer: Ok.
Roberta: And, he writes what we are going to discuss, the, the points, all the points and topics and he lists that on the whiteboard and everyone discuss the topics one by one. Eh, some of the members they maybe not, I mean, they talk not, not, not that much, but most of the members they give their opinion.

Cat. 4: Lottery

This category consists of people's testimonials of lottery as a decision-making strategy. Lottery is often used in decisions regarding roles, i.e. when choosing between two persons. Donald gives an example of this strategy:

Donald: [...] and also happened some time before that one got a day to think about what one was interested in, but then during the decision process we were all gathered together and then we had the opportunity to say what we were interested in, eh, and if several wanted the same position there was a draw [...]

Cat. 5: Voting

Voting as decision-making strategy happens in full team meetings when making decisions that do not directly regard people. Alfred gives an example of this category(the excerpt is also used for illustration above):

Interviewer: And then, did you open up for a general discussion or...
Alfred: Oh, ok, yes, yes, everyone can speak for free, can, give their own opinion about the specific, the scope, and maybe we, eh, how you say, we, kind of vote, voted.
Interviewer: Voted.
Alfred: Yes, voted, kind of.
Interviewer: Ok. So, you voted finally, everyone had a possibility to say something.
Alfred: Yes.

Interviewer: And then you voted.
Alfred: Yes, that is, tradition.
Interviewer: Ok.
Alfred: In our team, everyone can say something.

6 Conclusion and Implications

The current study investigates how computer science students experience the process of decision-making in computer science projects. Six categories have been identified, describing how the students understand decision-making. The level of sophistication differs between the categories, where the first describes an experience of decision-making as individual decisions too small and unimportant to be handled by anyone other than the individual. At the other end is the experience of decision-making as a democratic process involving both the full team and the context that the team acts in. The other four categories are situated between these two.

The level of sophistication in the experience of decision-making does not necessarily connect to reasoning on what is better or worse. A programmer in the team has to make a lot of small decisions, and being forced to bring all those to the table would create an untenable situation and diminish the progress in the project. The other extreme, to let one single person decide everything, is not good either. Another implication is that one individual team member can make decisions that affect not only the project, but also other people's work in it as described in category 2.

According to Barker et al. (1991), no single strategy for decision-making is thought to be best; instead the choice depends on team process factors. The current results presented therefore fit well with that result. The frustration in excessively static processes for team decision-making as reported by Barker et al. (1991) does not seem to apply to the teams we studied. Instead, they experienced a decision-making scheme that adapts to different situations.

One question worth looking into is how the design specification of the project affects the decision-making process. Does the design specification decide the implicit line between category 2 and 3? In addition, if so, are the students aware of that?

Situation awareness is an important component for decision-making (Wickens & Hollands 2000). The categories found show that in some cases, when people experience decision-making as an individual process, perhaps the situation awareness might be lower since only a single perspective is involved.

According to the categories that we have found, it seems that the nature of the decision determines how people experience decision-making. The number of different experiences, six, also shows a richness in how the team goes about its decision-making. A comparison of these conclusions with discussions presented by Shanteau (1992) on domains in decision-making is interesting. The categories found point at a decision-making process that would be identified as belonging to the good domain. The conclusion here, following Shanteau (1992), is that decision-making in the studied project is not necessarily hard and therefore might work well.

The full picture of the categories gives an interesting view. Some decision-making is done individually (category 1-2) and some is recognized as subject for team discussions (category 3-6). There is a fine line between these different strategies, and which way to go seems to be a decision for the individual project member.

The second result of this study, how the student team works in order to make decisions, shows diversity in decision-making strategies. This diversity is denoted as positive in Barker et al. (1991) since it helps the team to make decisions in different situations.

Decision-making is shown to be an active part of the computer science student project. Decision-making is an important part of running a project and thus it seems likely that what decisions are made, and how, will have substantial implications on the learning environment, and thus is a factor to consider. Exactly in what ways decision-making is related to the learning outcome is still an open question, but some important inferences can be drawn at this stage.

Different decision-making situations require different decision-making strategies and these end up in some of the six categories presented. As said, it cannot be considered better or worse to be in a certain category, but it affects the level of interaction in the process of decision-making. This means that the decision-making processes chosen affect the desired level of interaction among the students. Hence, decision-making processes likely determine the possible peer learning in the student project groups and therefore play an important role. Thus, learning what decisions are made and how the processes of decision-making are constructed is something that could contribute to peer learning and make it possible to configure more rewarding project settings.

By getting more knowledge on how decision-making processes occur, teachers can be aware of the possible learning outcomes of their project course design. Decision-making will also be a parameter to consider when setting up the project courses. The different project methodologies and software development methods used in student project courses also play a role in how much and what decision-making will occur among the students.

Decision-making in computer science student projects may be influenced by the interpreted goal of the project. One opening for further work is an investigation of students' interpretation of goals with a project. A phenomenographic analysis of how students experience the goal of this computer science project course is currently under way.

7 Acknowledgements

Many thanks to UpCERG research group at the Department of Information Technology, Uppsala University, Sweden, and to the COMPSER group, Helsinki University of Technology, Helsinki, Finland.

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Paper C

Paper C	M. Wiggberg & P. Dalenius. (2008). *Bridges and Problem Solving - Swedish Engineering Students Conceptions of Engineering in 2007.* Submitted.
Comment	First author. I have contributed with, roughly half of the different sections.

Bridges and Problem Solving - Swedish Engineering Students Conceptions of Engineering in 2007

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February 26, 2008

Abstract

Swedish engineering students' conceptions of engineering is investigated by a large nation-wide study in ten Swedish higher education institutions. Based on data from surveys and interviews, categories and top-lists, a picture of students conceptions of engineering is presented.

Students' conceptions of engineering, are somewhat divergent, but dealing with problems and their solutions and creativity are identified as core concepts. The survey data is in general more varied and deals with somewhat different kinds of terms. When explicitly asking for five engineering terms, as in the survey, a broader picture arises including terms, or concepts, denoting how students think of engineering and work in a more personal way. For example, words like hard work, stressful, challenging, interesting, and fun are used. On the other hand, it seems like the interviewed students tried to give more general answers that were not always connected to their personal experiences.

Knowledge on students' conceptions of engineering is essential for practitioners in engineering education. By information on students' conceptions, the teaching can approach students at their particular mindset of the engineering field. Program managers with responsibility for design of engineering programs would also benefit using information on students' conceptions of engineering. Courses could be motivated and contextualized in order to connect with the students. Recruitment

officers would also have an easier time marketing why people should chose the engineering track.

1 Introduction

Engineering education in Sweden faces several challenges today. New groups of students are entering higher education (Furusten & Lundh 2007) which challenges both the design of education and the pedagogical methods. In addition, the number of applicants to engineering programs has decreased during recent years (Inkinen et al. 2007). At the same time, several stakeholders see an increasing need for engineers (Maury 2004, Kungl. Ingenjörsvetenskapsakademien 2003).

The gap between the growing need for engineers and the shrinking group of applicants raises several questions. What do students think of engineering education, why do they choose to enter an academic engineering program and what makes them finish their studies? To explore questions regarding why students enter engineering programs, it is interesting to know what conceptions of engineering Swedish engineering students have. Thus, the aim of this study is to *find and describe what conceptions of engineering education Swedish engineering students have in 2007.*

Finding out what conceptions of engineering the students have requires a huge investment in data collection. Our empirical data comes from the nationwide Stepping Stones project, organized by CETUSS [1].The Stepping Stones project was a unique data collection experience where researchers from ten Swedish higher education institutions were collaborating and gathered data from more than 500 students.

The the article is organized as follows. An introduction to the area is given through a literature review presenting material relevant to the current study. The data collection framework Stepping Stones is presented followed by a section presenting and explaining the method used. Some key results from the analysis are then given and discussed. Finally, conclusions are drawn and directions and further work are suggested.

2 Related Work

There is a growing body of literature on college students' understanding of engineering and engineering practice. The conception of engineering among student populations promises to be an important aspect, since it is likely that it contributes to knowledge on motivation among engineering students and perhaps the reluctance to undertake an engineering education.

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[1] `www.cetuss.se`

Mosborg et al. (2005) studied what advanced practicing engineers ranked as key concepts of design activities in engineering. Among other results, problem formulation and communication were ranked highest, while building was ranked among the least important activities. Creativity was ranked as neither important nor unimportant.

The Extraordinary Women Engineers Coalition (2005) reports from the Extraordinary Women Engineers project, a national US initiative that targets the question 'Why are academically prepared girls not considering or enrolling in engineering degree programs?'. Using online focus groups, in-person focus groups and online surveys they primarily targeted high school girls to learn about what they think about engineering, their career motivators and influences, and received and desired information about engineering. Findings from the study show that engineering is perceived to be a male field. The high school girls would like their jobs to be fun and at the same time they would like to make a difference. High salary and flexibility are also important. Finally, they want to get information on how identified important career motivators can be met by choosing the engineering track. This is not recognized to be the case at the moment (Extraordinary Women Engineers Coalition 2005).

Conceptions of engineering of engineering students at the senior level have been investigated at the Center for Engineering Learning and Teaching at the University of Washington. In a word-association task technical knowledge was more recognized than issues such as communication, multidisciplinary teams, and global and societal context issues (Turns et al. 2000).

Goel & Sharda (2004) had both engineering students and professional engineers rank a list of activity verbs. Students were asked to sort the words according to how well they thought the activities increased their learning, engineers according to the activities' perceived importance for students. Words expressing activities that require higher order cognition (e.g. analyze, design) were ranked high in both groups. Another group of students rated the same words according to their frequency of use in teaching. Among the top words in this ranking, most concerned simpler activities (e.g. calculate, explain). Goel and Sharda draws the conclusion that while students and professional engineers agree on which activities an engineering education should focus upon, in reality the educational programs do not foster creativity, innovation and critical thinking enough.

Loui (2005) reports from a study where students in a course in Engineering Ethics were asked for the characteristics of an ideal professional engineer. Their answers fell into four categories: technical competence, interpersonal skills, work ethic and moral standards. Typical responses in the first category included creativity, innovation, solve problems and scientific knowledge.

We believe that the body of literature in this area lacks studies aimed at identifying students' conceptions of engineering. This is especially true for Sweden and Europe, and this is where our study fits in.

3 The Stepping Stones Initiative

The Stepping Stones project is an extensive multi-researcher, multi-institutional study which aims to contribute in the area of engineering education research. The Stepping Stones project investigates how students and academic staff perceive engineering in Sweden and in Swedish education. The Stepping Stones study is situated uniquely in Swedish education and allows for exploration of a Swedish perspective on conceptions of engineering. The Stepping Stones project was based on a model of research capacity-building previously utilized in the USA and Australia (Fincher & Tenenberg 2006).

The Stepping Stones data collection consisted of four tasks, two of which are used by this study. A web based survey, a critical incident interview, a photo elicitation interview, and a concept map task (Novak 1998) were carried out using the explanogram technique (Pears et al. 2003). One aim with these different data collection approaches was to produce both quantitative and qualitative data with the intent to provide a basis for triangulation of data as a means to improve the quality of the results. Another important aspect was that by using different data collection methods we could get a richer data set. In the study reported in this article, where we want to acquire information about students' conceptions of engineering, we used two parts of the Stepping Stones data: interviews and survey responses.

4 Method

4.1 Data Collection

During 2006 and 2007, data was gathered by a web-based survey and through interviews from ten Swedish institutions. Students from different engineering programs where asked to fill out the survey and to participate in an interview session. Some students participated in both an interview and a survey, while others participated in only one of them.

The web based survey was adapted from the Academic Pathway Study (APS) survey (Eris et al. 2005). The survey consists of questions about factors that may be of importance in engineering. Examples of such factors include skills, identity, and education.

The survey has been used in many institutional contexts in the U.S. and has been analyzed for its validity (Eris et al. 2005). The survey was adapted to a Swedish context. Words were changed to Swedish equivalents, background questions not making sense in a Swedish context were removed and some new questions added. A pilot run of the modified survey was trialled prior to the full scale survey (Adams et al. 2007).

Nationwide, 521 students filled out the survey and 94 students participated in the interview session. The student cohort represented both freshmen and more senior students. The sample investigated corresponds to approximately 1.5 % and 0.3 % respectively of the total number of students in Swedish engineering programs autumn 2006 (SCB 2006).

The participating students were widespread among different engineering disciplines, and in total 21 different engineering disciplines [2] were involved in the study.

For this study, we used only a small part of the empirical data from the Stepping Stones project and the analysis was divided into two different threads. The first thread concerned data from the interviews. Here the interviewee's own words and conceptions about "real" engineering were analyzed. The second thread of analysis concerned the conceptions of engineering displayed in the surveys. Word frequencies and categories, or sets with similar concepts, are identified and reported.

4.2 Analysis of Answers from Interviews

Qualitative data used in this analysis was collected exclusively from the critical incident interviews. The critical incident interview starts with questions recalling a specific experience from the interviewee's past. A number of questions are then posed, aimed at revealing more information about the experience as well as its meaning for the interviewee. Critical incident interviews have previously been used by Flanagan (1954), Klein et al. (1989), and Klein (1999).

A semi structured interview approach was used to elaborate on the answers given. Thus the interview began with a set of specific questions followed by opportunities for the researcher to probe or follow-up on responses from the participants (Kvale 1997, p. 117).

The Stepping Stones interview script contained, among others, two different questions regarding conceptions of engineering at different points in the interview:

1. In a few words, what would you say real engineering is?
2. After everything we have talked about, what would you say engineering is for you?

In order to get as broad answers as possible to the question of conceptions of engineering, we have taken answers to questions 1 and 2 together as one data source, except in one particular case where we focus on the impact of

[2] Aerospace eng., bio-inspired and agricultural eng., biomedical engineering, chemical eng. (and chemistry), civil eng., computer eng., computer science, electrical eng. (and micro-electronics), geological eng., information technology, materials science and eng., mathematics, mechanical eng., interaction design, software eng., physics (and technical physics), systems in technology and society, energy eng., industrial economics, construction eng., other (less than 5 respondents in total, for example cognitive science and transport and logistics).

the interview. As these questions appeared at the start and towards the end of the interview, conceptions of engineering recalled during the interviews are collected.

The answers to the two questions analyzed were extracted from the transcripts and a simple categorization of the transcripts followed. The method was inspired by qualitative text analysis, which is a standard method for analyzing text systematically, although the concept is used to describe a wide set of methods (Hsieh & Shannon 2005). The general aim with qualitative content analysis is to “provide knowledge and understanding of the phenomenon under study” (Downe-Wamboldt 1992). Qualitative content analysis is therefore more involved than merely counting word frequencies in a text (Weber 1990). Qualitative content analysis has earlier been used in similar projects, for instance Dolde & Götz (1995) and Eckerdal (2006). Among many others Mayring (2000) has described qualitative content analysis and especially inductive category development, which is the method of finding categories that we have used in this study.

By analyzing the transcripts in a systematic manner, forming tentative categories centred on the research question of conceptions of engineering and revising them within a feedback loop, we deducted a set of well defined categories describing experiences of the phenomenon. No quantitative aspects where considered. Revision of categories in the feedback loop included testing the validity of categories and definitions by applying the tentative categories to the data. Categories were also merged and divided up during the analysis. Another researcher then verified the categories by the same procedure. The same categorizing process was used for question 2 and after some discussion, we found that the same categories as in question 1 also held for responses to question 2.

4.3 Analysis of Survey Answers

For this study, we have chosen to focus on one particular survey question dealing more explicitly with conceptions of engineering:

1. In the space provided, list 5 terms you would use to describe “engineering”.

Based on the responses provided, we cleaned the data and translated answers given in Swedish to English. Following this, the approximately 1400 answers were clustered in order to make the grouping easier. Terms with close semantically meaning were first put together. For example 'solving problems' was grouped with 'problem solving', 'creativeness' with 'creativity' etc.

5 Empirical Results

In this section, we present empirical results from the survey and the interviews.

5.1 Engineering Terms from the Survey

The most frequently stated engineering terms from the survey are presented in table 1. Since the survey question did not offer any fixed terms to chose between, the number of different terms is huge. Hence, only terms with an occurrence of 1 percent or more, i.e. there being at least 14 listings of the term, are included in the table.

The terms stated by the participant in the survey, describe many different aspects of engineering. Personal aspects, *open minded, stubbornness* and *respected*, descriptions of the everyday life of an engineer, *frustrating, individual work* and *time consuming* are present side by side with terms describing the aim with engineering, for instance *constructing, inventions* and *developing.*

Problem solving is by far the most common term used to describe engineering with more than twice as many occurrences as the runner up *creativity.* Among the top words, most are abstract descriptions general aspects of engineering. There are also a number of words describing the everyday work from a more personal perspective: *interesting, hard work, fun, high salary* and *challenging.*

Mathematics is ranked as third, but accounts for only 4.8% of the whole set. Apart from that, there are few occurrences of academic subjects, *physics* with 1.1% being the second most common word of that category. Words describing engineering processes include *developing* (4.1%), *analysis* (1.9%) and *designing* (1.1%). Aspects of engineering work include *team work* (2.5%), *project work* (1.3%) and *leadership* (1.4%).

5.2 Answers from Interviews

The categorization of answers to the interview questions is presented in table 2. The percentages indicate how many of the participants' answers matched each category. The differences between the top three categories are small, but the span between the top and the bottom is large enough to justify comparisons.

Problem solving (cateogory A) is the most common concept and it is discussed by more than one third of all participants. It is closely followed by category B that includes concepts related to construction, e.g. building physical objects, and category C including development and improvement.

The impact of engineering on society is also important and this aspect is discussed by 31% of the participants. Related to this is the answer in

Engineering term	**Mentioned (%)**
problem solving	12.5
creativity	5.5
math	4.8
developing	4.1
inventions	3.1
technical	2.8
team work	2.5
research	2.3
hard work	2.2
interesting	2.0
fun	2.0
analysis	1.9
calculation	1.9
constructing	1.6
important	1.5
leadership	1.4
project work	1.3
science	1.3
computers	1.2
thinking	1.1
physics	1.1
designing	1.1
high salary	1.0
challenging	1.0
(other)	38.8

Table 1 – The most frequently stated engineering terms in the survey. Presented as percentages of all stated terms in the current set.

category E stating that engineering is about being innovative, thinking for the future and contributing with something never done before.

22% of the participants use different academic subjects to describe engineering (e.g. maths, physics) and 13% talk about the intellectual activities connected to engineering. Teamwork is the least frequent category. Only 9% of the participants discuss teamwork in connection with engineering.

6 Discussion

The results from the survey and the interviews gives us two ways of pinpointing students' conceptions of engineering, and these two angles both support and complement each other.

To some extent, the words from the survey and the answers from the

Category	Description	Typical words used	Percentage
A	solve problems	solve problems	36
B	realizing concrete products	construct, implement, building, realizing, physical things, hands-on	35
C	improving something that already exists	develop, improve, optimize	34
D	social impact of engineering activities	changing society, ease everyday life, impact on human beings	31
E	contributing with something qualitatively new	innovation, new ideas, thinking for the future, something not built before	29
F	being creative and explorative	create, design, discover, explore, put things together	27
G	static knowledge connected to engineering	knowledge, mathematics, technology, natural science, physics	22
H	intellectual activities	thinking, curious, understanding, challenges	13
I	engineering can be a lot of things	complexity, many things	11
J	teamwork	teamwork, working together, collaborate	9

Table 2 – Categorization of answers to interview question 1 and 2, and frequencies of answers.

interviews paint the same picture. Problem solving stands out as the most important aspect of engineering, being at the top of both lists. It is also possible to find terms from the survey that match each of the other categories from the interview. Categories B and C relate to construction and development. Both of these terms are found in the survey, but not as frequently as in the interviews. On the other hand, innovation and creativity (category E and F) are the second and fifth terms in the survey list, which is much higher than in the interviews. Overall, all of the aspects of engineering covered by the interviews are also present in the survey, even if the relative importance is different.

A categorization, like the one performed on the interview transcripts, of the terms from the survey would be difficult to perform since the survey terms have no context. While the categories from the interviews give us a richer, more cohesive view, the terms from the survey complement this view.

The terms from the survey (table 1) differ in level of detail compared to the categories from the interviews (table 2). The survey data is in general more varied and deals with somewhat different kinds of terms. When explicitly asking for five engineering terms, as in the survey, a broader picture arises including terms, or concepts, denoting how students think of engineering and work in a more personal way. For example, words like *hard work, stressful, challenging, interesting*, and *fun* are used. On the other hand, it seems like the interviewed students tried to give more general answers that were not always connected to their personal experiences.

Another interesting observation is that academic subjects, like *mathematics* and *physics*, do not appear in any of the top positions. Even though mathematics is third in the list of terms from the survey, it represents only five percent of the terms, and the second highest ranked subject, physics, represents only one percent. In the interviews, the category including academic courses is the seventh most frequent category of a total of ten. We believe that this tells us something about the contrast between the subjects that constitute an engineering education and the application of these to engineering problems. According to our results, students value the latter aspect higher.

The results from Mosborg et al. (2005) on key concepts recognized by advanced engineers, partially supports our findings. Problem formulation, in our study *problem solving*, is ranked high in our study as well as in Mosborg et al. (2005). Creativity is ranked as neither important nor unimportant in Mosborg et al. (2005), but in our findings the picture looks somewhat different. Our participants rank creativity rather high, both in the survey and the interviews, which seems to indicate that engineering students connect engineering with creativity to a larger degree than professional engineers.

In Turns et al. (2000) technical knowledge was ranked higher than concepts like communication, multidisciplinary teams, and global and social issues. Our findings, especially from the interviews, show the same pattern for teamwork (category J). This is the lowest ranked category in the interviews and, although in the top twenty list of terms from the survey, it represents only 2.5% of the terms. At the same time our results for category D, social impact of engineering, show a contrast to Turns et al. (2000), where in our findings technical knowledge does not stand out as being among the most important aspects. Some of these differences might be attributed to the different educational systems.

The career motivators that Extraordinary Women Engineers Coalition (2005) found among high school girls matches several of the most frequent terms from the survey, e.g. *fun*, *important*, and *high salary*. Even though these words are generic, this indicates a great potential for broadening the recruitment to engineering programs. As stated by Extraordinary Women Engineers Coalition (2005), one of the problems is that it is hard for high school girls to see that their motivators can be met by choosing engineering.

7 Conclusion and Further Work

Swedish engineering students see themselves as creative problem solvers. They feel that engineering has both a general and abstract side, as well as a real, physical manifestation.

We believe that we have a good picture of students' conceptions of engineering, but it would be even more interesting to compare this with the views of professional engineers. Goel & Sharda (2004) indicates that students and engineers use the same words to describe how to study engineering, but what about the engineering profession? Will the students' views change when they graduate and start working as engineers? With answers to these questions, engineering programs could be adapted to better prepare students for the engineering profession.

Loui (2005) concludes that students get their views of engineering professionalism from relatives and friends. It would be interesting to investigate where Swedish students get their conceptions. The Stepping Stones survey data is a rich source that can be analyzed as a step towards an understanding of where Swedish students receive their conceptions. It would also be valuable to see how students are affected by education and to what extent engineering in general is actually discussed in engineering programs. How do the teachers and educational institutions address engineering? Is there a premeditated way of communicating what engineering is, and if so - what does it look like?

The reported results are not presented with a low level of detail regarding different engineering disciplines can be traced. An interesting thread to follow up is what the conceptions look like in different engineering disciplines. Is there, for instance, a difference between engineering physics and information technology? If so, what does that difference mean in terms of recruitment?

No studies on conceptions of engineering among active engineers have been performed recently in Sweden, and producing one would be a valid contribution to the field. A comparison between the students' engineering conceptions and active engineers' would be useful in order to determine if there is a difference.

Knowledge on students' conceptions of engineering is essential for practitioners in engineering education. By information on students' conceptions, the teaching can approach students at their particular mindset of the engineering field. Program managers with responsibility for design of engineering programs would also benefit using information on students' conceptions of engineering. Courses could be motivated and contextualized in order to connect with the students. Recruitment officers would also have an easier time marketing why people should chose the engineering track.

Another question, regarding the implication of the conceptions, is if there exists a right, or more efficient, way to view engineering in the education? If there is one, how could we adjust educational planning in order to achieve this more efficient view?

8 Acknowledgement

The Stepping Stones project was funded by Rådet för högre utbildning (the Swedish Council for Renewal of Higher Education) and by Myndigheten för nätverk och samarbete inom högre utbildning (the Swedish Agency for Networks and Cooperation in Higher Education). It was run within the context of the Nationellt ämnesdidaktiskt Centrum för Teknikutbildning i Studenternas Sammanhang project (CeTUSS), a national centre for pedagogical development in technology education in a societal and student oriented context. Any opinions, findings and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of any of these supporting bodies.

We thank the Stepping Stones participants for their contributions to this project. In addition to the authors, those are Robin Adams, Jürgen Börstler, Jonas Boustedt, Gunilla Eken, Sally Fincher, Tim Heyer, Andreas Jacobsson, Vanja Lindberg, Bengt Molin, Jan-Erik Moström, and Arnold Pears.

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