UPPSALA
UNIVERSITET

*Digital Comprehensive Summaries of Uppsala Dissertations from the Faculty of Science and Technology 722*

# Computer Science Project Courses

## *Contrasting Students' Experiences with Teachers' Expectations*

MATTIAS WIGGBERG

ACTA
UNIVERSITATIS
UPSALIENSIS
UPPSALA
2010

ISSN 1651-6214
ISBN 978-91-554-7741-7
urn:nbn:se:uu:diva-120081

Dissertation presented at Uppsala University to be publicly examined in 2446, MIC Polacksbacken, Lägerhyddsvägen 2, SE-752 37, Uppsala, Friday, April 16, 2010 at 10:15 for the degree of Doctor of Philosophy. The examination will be conducted in English.

**Abstract**

Wiggberg, M. 2010. Computer Science Project Courses. Contrasting Students' Experiences with Teachers' Expectations. Acta Universitatis Upsaliensis. *Digital Comprehensive Summaries of Uppsala Dissertations from the Faculty of Science and Technology* 722. 189 pp. Uppsala. ISBN 978-91-554-7741-7.

Including small or large project courses is widely recognized as important in preparing computer science students for a professional career. Typical examples are the capstone courses, which often are seen as the jewel in the crown since this is where students will bring their previous knowledge and skills together to show mastery of their craft. These courses are, however, quite complex with often contradictory ideas about how to actually run them in order to reach the learning objectives. This thesis deals with the contrast between students' experiences and teachers' expectations of such courses.

The research presented in this thesis contributes to the field of knowledge of computer science project courses by investigating processes that are of importance in relation to the desired practices that the students' should experience.

A method is developed, based on the theory of communities of practice and an identification of key features in project work, for evaluating project courses in terms of setting up a learning environment suitable for its learning objectives. The method is focused on capturing the students' experiences, which then are mapped onto desirable outcomes, as seen from the teachers' point of view and expressed in terms of communities of practice theory. The result of the analysis is stories capturing the strengths and deficiencies that can be observed in computer science project courses.

Key findings are that rewarding learning environments are not automatically created by following the project model; unclear goals and priorities, for example the choice between focusing on the result of the project or the learning process, can confound, or hinder, the learning outcome. Students may experience a difficult choice between using the project course as a way to become more specialized in a particular area or to develop skills that broaden their knowledge.

The method developed throughout the thesis is a result in itself, allowing academics and institutions to reason systematically about the aims and learning outcomes of project coursework. The strength of the method lies in the insight gained from combining the concept of communities of practice with a series of studies that identify key features of project courses, in order to reveal and explain why students' experience processes and learning outcomes in particular ways.

*Keywords:* computer science education, computer science student projects, computer science projects, computer science education research, phenomenography, learning, higher education, communities of practice, capstone projects, constructivism

*Mattias Wiggberg, Division of Computer Systems, Box 337, Uppsala University, SE-75105 Uppsala, Sweden*



ISSN 1651-6214
ISBN 978-91-554-7741-7
urn:nbn:se:uu:diva-120081 (http://urn.kb.se/resolve?urn=urn:nbn:se:uu:diva-120081)

*To my father Anders Wiggberg*

# List of papers

This thesis is based on the following papers, which are referred to in the text by their Roman numerals.

I 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.*, pp. 132–135.

II M. Wiggberg. (2008). Computer Science Students’ 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, Raymond Lister and Simon, Eds. Conferences in Research and Practice in Information Technology.*, volume 88.

III M. Wiggberg & P. Dalenius. (2009). Bridges and problem solving: Swedish engineering students’ conceptions of engineering in 2007. *Proc. 1st International Conference on Computer Supported Education. Institute for Systems and Technologies of Information, Control and Communication.*, volume 2:5–12.

IV M. Wiggberg & M. Daniels. (2008). Reflecting on running large scale student collaboration projects. *Proc. 38th ASEE/IEEE Frontiers in Education Conference. IEEE*, pp. 8–12.

V M. Wiggberg. (2010). A method for analyzing learning outcomes in project courses. *Accepted for, and submitted to, stage 2 peer-review to FIE 2010.*

Reprints were made with permission from the publishers.

# Comments on my participation

I Sole author.

II Sole author.

III First author. I have formulated the general idea, contributed with data collection, analysis and writing of roughly half of the different sections.

IV First author. I have formulated the general idea in my licentiate thesis and writing of roughly three fourths of the different sections.

V Sole author.

# Other publications

- A. Berglund and M. Wiggberg. (2006). Students learn CS in different ways: Insights from an empirical study. *SIGCSE Bulletin: inroads*, volume 38, 3:265–269.
- T. Danielsson, M. Olsson, D. Ohlsson, D. Wärmegård, M. Wiggberg, and J. Carlström. (2006). A climbing robot for autonomous inspection of live power lines. *Proceedings of ASER2006 3rd International Workshop on Advances in Service Robots*.
- R. Adams,S. Fincher, A. Pears, J. Börstler, J. Boustedt, P. Dalenius, G. Eken, T. Heyer, A. Jacobsson, V. Lindberg, B. Molin, J-E. Moström, and M. Wiggberg. (2007). What is the word for "Engineering" in Swedish: Swedish students' conceptions of their discipline. *Technical report / Department of Information Technology, Uppsala University.*.
- M. Wiggberg. (2008). Unwinding Processes in Computer Science Student Projects. *Licentiate Thesis / Department of Information Technology, Uppsala University.*

# Svensk sammanfattning[1]

Inom högre utbildning i informationsteknologi är det idag populärt att inkludera projektkurser som en förberedelse för studenternas kommande professionella karriär. För att kröna de kunskaper och färdigheter som en IT-utbildning gett brukar ofta en längre *Capstone*-kurs i form av ett större projekt ingå i slutet av de fleråriga utbildningsprogrammen. Vid institutionen för informationsteknologi finns projektkurser som sträcker sig över en hel termin och vardera engagerar mellan 12 och 22 studenter. Uppgiften i dessa projekt är att skapa en avancerad IT-lösning till ett problem med flera komplexa dimensioner. Räddningsrobotar, positioneringstjänster, spel för mobiltelefoner och fotbollsrobotar är exempel på uppgifter. Dessa kurser är mycket komplexa lärandemiljöer. Inte sällan finns det flera och motstridiga uppfattningar om hur de ska genomföras för att nå de uppställda lärandemålen. Den här avhandlingen ägnas åt kontrasten mellan studenternas erfarenhet från-, och lärarnas förväntningar på dessa projektkurser.

Den övergripande forskningsfrågan i avhandlingen är *hur vi kan planera och genomföra projektkurser, baserat på vetenskapligt framtagna erfarenheter, inom informationsteknologi i syfte att bidra maximalt till studenternas utveckling och till utbildningskvalitet*.

För att svara på forskningsfrågan har en metod för att analysera processer i projektet utvecklats. Dessutom har ett grundläggande arbete utförts för att undersöka vilka nyckelprocesserna i relation till lärandeutfallet är. Metoden bygger på teorin om gemensam praktik (community of practice) genom att kombinera den med de nyckelprocesser som tidigare identifierats i projekten. Metoden fokuserar på att fånga studenternas erfarenheter och koppla dem till önskade lärandemål. Erfarenheterna beskrivs sedan i ljuset av den gemensamma praktiken. Resultatet av metoden är berättelser som beskriver erfarna styrkor och svagheter i projektens uppläggning och genomförande.

Två resultat som visar på intressanta erfarenheter från projekten är dels att tillämpa en projektmodell från industrin ger inte nödvändigtvis de önskade lärandet, och dels att oklara mål och prioriteringar förbryllar och hindrar de önskade lärandeprocesserna. Speciellt finns det en slitning hos studenterna mellan att uppnå det önskade resultatet med projektet och prioritera lärandet under projekten. Svårigheterna att lyfta lärandet som viktigt påverkar alla medlemmar i projekten och deras möjlighet till ett gott lärandeutfall. En annan motsättning är den mellan att fördjupa sig inom ett arbetsområde eller bredda

[1] Summary in Swedish

kunskapen genom att ta sig an en mindre van uppgift i projekten. Denna motsättning är inte ett val vars effekt är privat, utan även ett val där möjligheten till gemensamt lärande i projekten påverkas.

Avhandlingen bidrar till det informationsteknologiska fältet genom att undersöka viktiga och centrala processer i projektkurserna, och hur dessa relaterar till de praktiker som studenterna väntas få erfarenhet från. Metoden som utvecklas i avhandlingen är ett resultat i sig själv. Den möjliggör inte bara för pedagoger och akademiker att utveckla lärandeutfallet i projektkurser, utan kan också bidra till att analysera projekt i lärandeorganisationer där det finns en önskan om en långsiktig utveckling av kunskapen hos deltagarna. Metodens styrka ligger i att kombinera empiriskt baserade erfarenheter, formulerade som nyckelområden, med etablerade modeller för lärande som gemensam praktik, med målet att belysa och förklara lärandeutfallet hos studenterna.

Avhandlingen utgörs av fem olika vetenskapliga artiklar. Artikel I undersöker hur inflytande och makt fördelas inom en projektgrupp. Uppfattad kompetens hos medlemmar i gruppen ger inflytande, och tre olika sätt att förstå någon som kompetent har identifieras. Artikel II redovisar sex olika vägar som beslutsfattande går till på i projektgruppen. Alltifrån individuella beslut i mindre frågor till uppfattat demokratiska processer i helgrupp återfinns bland studenternas erfarenheter. Artikel III undersöker uppfattning av begreppet ingenjörskap hos ingenjörstudenter i Sverige. Bland annat är problemlösande och kreativitet identifierade som centrala begrepp. Artikel IV sammanfattar erfarenheterna från de tidigare artiklarna genom att föreslå fyra nyckelprocesser som analysverktyg för att förstå lärandeutfall i projektkurser. Avvägningen mellan projektprocessen och resultat från projektet, fördelningen av uppgifter i projekten, den upplevda friheten i projektuppgiften, samt kopplingen till externa intressenter är de fyra områden, nyckelprocesser, som identifierats som viktiga för lärandeutfallet. Artikel V presenterar metoden som utvecklats för att, med hjälp av teorin kring gemensamma praktiker, och de identifierade nyckelprocesserna analysera och utvärdera projektkurser som lärandemiljöer. Metoden fokuserar på studenternas erfarenheter och kopplar dessa till de önskade lärandemålen. En berättelse används för att illustrera ett antal intressanta områden där lärandet skulle kunna utvecklas ytterligare.

Resultaten i avhandlingen kan användas för att utveckla lärandemiljöerna i projektgrupper. Det är framförallt tre lärdomar som är centrala. För det första behöver lärandemålen få en central roll i projektens planering, examinationsmål och den motivation som kommuniceras under projektet. Att försöka minimera den upplevda stressen i projektgrupperna är också viktigt då denna leder till att lärandemekanismerna delvis åsidosätts. Slutligen föreslår jag att lärandedelen i projekten ges en framträdande roll under hela projektet, gärna genom en dialog kring detta med studenterna i projekten. Att medvetandegöra de lärandeprocesser som ligger till grund för projekten och legitimiteten i dem, skulle i många fall skapa en betydligt högre verkningsgrad i fråga om lärandet i projekten.

# Acknowledgements

Kerstin Nyström Wiggberg and Anders Wiggberg told me that education was important [2]. Formal education opened doors and the advice was always to make sure I could enter as many of these doors as possible. Their advice, together with endless love and support has been of infinite value to me.

To become a Ph.D. is a journey with many challenges: to be accepted is the first. Despite the odds[3], I was given this significant chance by Per Gunningberg and Aruna Seneviratne.

Anders Berglund provided valuable help in the challenge to find a suitable research area and formulate a research project.

Maybe the most challenging part during this Ph.D. journey has been to cope with its intellectual considerations; endless work towards hard deadlines; uncertain decisions from peer-review processes; doubt in self-confidence; and writer's block. These are some of the challenges. With a never ending belief in my abilities, low-voiced and with a certain feeling for diplomacy, my supervisor Mats Daniels has supported me throughout the process. Mats' excellent knowledge in educational research in general and project work in particular has provided me with a unique insight into the research area.

My co-supervisor Lecia J. Barker has been providing very valuable insights with her expertise, extensive knowledge, and encouragement as well as strengthening the theoretical side of the work.

Ivan Christoff is one of a kind and his warm belief in me has helped me to hang in there and to find my way at the department, which has been precious. Håkan Lanshammar's assistance in administrative matters and his supportive leadership has indeed contributed.

Arnold Pears has been a supportive colleague during the journey. Arnold's helpfulness has spanned from inspiring teaching to extensive and professional proofreading. Justin Pearson subtle sense of humor and his language support has been a nice contribution. [4]

Erkki Sutinen, being the excellent opponent of my licentiate thesis contributed with relevant questions to the quality of this final work.

[2]My parents were right. In the OECD Member countries educations is among the most important factor for high earnings, high employment rates, and good health standards (Organisation for Economic Co-operation and Development (OECD), 2009).

[3]My odds were less than half to get in compared to graduated fellows with parents holding Ph.D:s, but almost double compared to graduated fellows with non-graduated parents(Gillström, 2010).

[4]Any errors or misuse of the English language are however entirely my own.

Uppsala Computing Education Research Group has been a fruitful resource during my development. Jonas Boustedt, Åsa Cajander, Anna Danielsson, Liselott Dominicus van den Bussche, Anna Eckerdal, Elina Eriksson, Rebecka Janols, and Michael Thuné are all people contributing in the group with welcomed feedback and by creating a fun and challenging research atmosphere.

A great share of this work has been spent with students. Interviewing, reading their words, listening to their voices, and sharing their beliefs on the subject. Their contribution to this work cannot be overestimated.

The Hedin family, and all my other relatives for their love and providing me with a platform in life.

Britt Magnusson and Per Wahlström, mentors of life, for their contribution to clarity and ease.

I also would like to thank friends and colleagues whose attention and personalities has contributed. I let this extensive group be represented by Jim Wilenius, Magnus Ågren, Richard Bengtsson, Joel Malmqvist, Mats Nordenborg, Petra Ornstein, and Pelle Rödin.

Anna Ardin's precious support and love has been, and is, deeply felt.

At this very end of this thesis, it is with great humbleness I would like to express my deepest honor to all women and men, in past and present times, devoted to work for an equal, top-class, free of charge, educational system. This Ph.D. thesis is just a small evidence of your success. I am looking forward to learn more and to challenge beliefs of myself and others through scientific work. To be curious, is to be human.

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

# Contents

# Part I:

# Introduction

This part introduces the topic of the thesis, provides the motivations behind my research from a professional and a personal perspective. The research questions and an overview of the research project are presented.

# 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.(Wiggberg, 2008b)

What is a good computer science student project? How could such learning environments be an effective learning experience? In contrast to its educational purpose, the project setting may mislead teachers and students causing them to focus on other aspects than the desired learning component. The aim of this thesis is to increase our knowledge of student project work as computer scientists. Especially, I would like to research which features influence the learning outcomes. My varied educational background and my interest in applications of information technology, is my rationale for this interest.

This chapter introduces computer science student projects, the subject of my research. I also present my own background and personal motivation, as it is an essential factor in this research. I conclude with a short overview of the remainder of the thesis.

## 1.1 The nature of computer science student projects

Student collaboration projects, small or large, have been used in higher education, and especially in computer science education programs in, e.g. capstone classes, for a long time. 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 (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 done that highlights the learning outcome of group work, e.g. by relating to the group processes during learning situations in computer science to learning outcomes (with the exception of recent work by Berglund (2005), Kinnunen and Malmi (2004), Barker and Garvin-Doxas (2004)). This thesis contributes to the development of an im-

[1]An excerpt from an interviewed student in Wiggberg (2008a). All names have been changed to preserve the anonymity of those interviewed. More on this in section 11.2.1.

proved understanding of the relationship between group process and learning outcomes in the context of group project work in computer science.

There are many aspects to consider in running these projects. One aim is to create an environment where students can experience professional practice as a part of their education. We define professional practice to include technical skills, but more important, aspects of team work in large projects with complex tasks to solve (Fincher, Petre, & Clark, 2001).

Analyzing learning in capstone classes is a complex task. Social interactions among the participants are intermingled with domain knowledge. Collecting empirical data can also be challenging and time-consuming. Professional skills often are a form of learning goal, with which neither students nor teachers are familiar with. This can raise significant obstacles to crafting effective learning settings for project work. Nevertheless, is it important to find suitable tools to assist with analyzing learning in project settings.

Problem-based educational models has been used to address questions in the area. It is also an established framework for introducing more student driven pedagogical models. Kolmos (2002) is a good example of use of problem-based educational models in learning environments in computer science education research. In this work, I have studied a more open approach to learning environments.

Communities of practice is a social theory of learning created by Lave and Wenger in 1991 (Lave & Wenger, 1991). The theory assumes that learning is an integral part of everyday life and denotes participation as a learning strategy. In this thesis, I describe how projects can be analyzed using communities of practice. The subject of the study is groups[2] of computer science students studying at an advanced university level.

## 1.2 Rationale

Growing up in the 1980s meant being an active or passive part of a massive trend towards electronic information storage and delivery. 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 glimmers of early applications such as pocket calculators and digital watches, and it was not until high school 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

[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 fulfill a common goal. When referring to other work, *team* might be used if that is the choice of the original works.

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 a place where my different interests, learning, work processes, and information technology found a natural meeting point.

## 1.3 Thesis organization

This thesis is a summary with an extended kappa. That means the articles upon which it is based are extended by several chapters that further the subject and provide more details. The thesis also provides new data, more results and text that are still to be published. In that sense, the kappa resembles a research monograph. In figure 1.1 a schematic overview of the research design in this thesis is presented in order to provide readers with a guide to the thesis. The guide uses a model of doing design presented in figure 1.2 (Clear, 2009) to illustrate the structure of the research design.

**Part I**

**Chapter 1-2** In this project the general research questions have been used to design the project. That is, methods, empirical choices and research designs in the subparts, are all based on the need formulated by the research questions. This step corresponds to *determine the research questions* in figure 1.2, but also to help formulate and *select the research framework*.

**Part II**

**Chapter 3-7** Starting in the literature, a subfield for research not fully investigated, was found. An initial set of three different investigations Wiggberg (2007, 2008a); Wiggberg and Dalenius (2009) were performed in order to research project courses in order to identify essential issues in running them. In those three studies, different experiences where collected. This step corresponds to *investigate and identify* in figure 1.2, but also to *apply data analysis technique*.

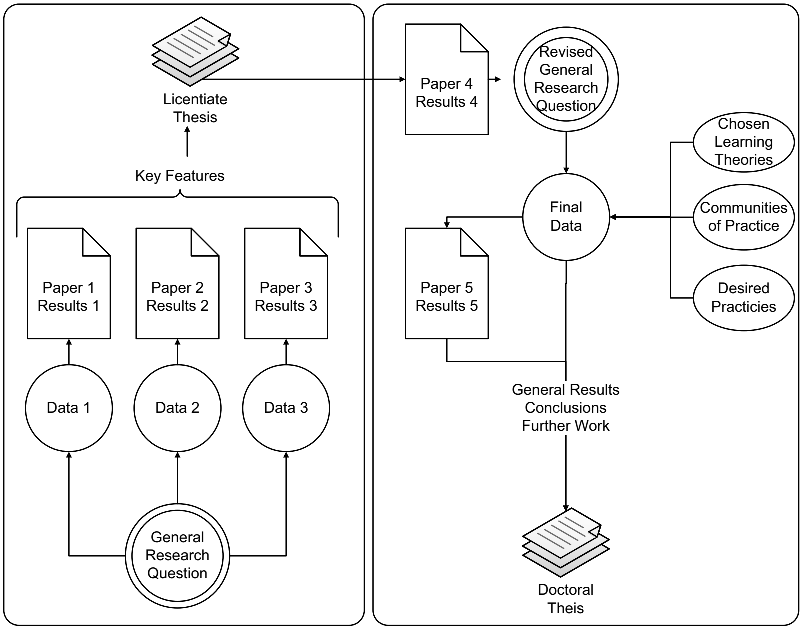


*Figure 1.1:* Organization of the research project. Two final books are produced.

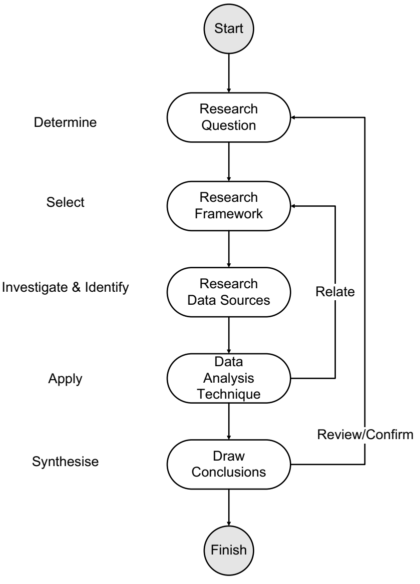


*Figure 1.2:* A diagrammatic representation of a research process (Clear, 2009).

The analyzis and results were synthesized and reported in Wiggberg (2008b). This summarize what has been learned so far, and relate the intermediate results to the research framework as shown in figure 1.2.

A more mature analysis and model of interesting key features to use as a filter when performing a deeper investigation of the main research question more deeply, were presented in Wiggberg and Daniels (2008). This step corresponds to *select a new research framework* in figure 1.2.

**Part III, can be seen as similar to chapters in a monography.**

**Chapter 8-10** My learning perspective is described and it is shown how it relates to the studied projects. Communities of practice are introduced as a theoretical framework to relate the key features to the model in order to address the research questions. These relations are described in chapter 11. This step enhances the step of *selecting a new research framework* in figure 1.2 by extending it with an additional theoretical model. Desired project practices where also investigated.

**Chapter 11-12** The method for combining communities of practice with the key features as a lens on the data is described in chapter 11. Final results are also described. This step corresponds to *applying data analysis techniques* in figure 1.2. These chapters contain results and other material that is to be published, in part, in paper V.

**Part IV**

**Chapter 13** Conclusion and further work is presented. This step corresponds to *synthesising and drawing conclusions* in figure 1.2.

# 2. A road map to the thesis

This chapter introduces my research interest. Elaborating on that interest, detailed research questions are developed. The multi disciplinary aspect of computer science education research is discussed briefly. The results of the initial part of my thesis work are presented in part II, and are related to the computer science education research field. These results are then used as a stepping stone to find and develop appropriate methods to learn more about my research questions. This part of my work is presented in part III of this thesis.

## 2.1 Research interests

My interest in learning 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 influence the effectiveness of the project model as a pedagogic method in computer science. My experience of being part of teaching groups in project courses lead me to conclude that there was much more to learn about how to structure and run computer science student projects.

The pedagogic motivations for teaching using projects are interesting in many ways. Computer science folk pedagogy [1] holds that projects present an extra challenge to students, and prepare them for working life. Adding known development methods from industry emphasizes the reality component, and improves 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 student projects. It seems widely accepted within education programs that project work is a valuable experience. Typical approaches combine components such as, use of technical skills, and training in the needs, difficulties, opportunities and complexities of project work. All of these outcomes are seen as essential to becoming an IT-worker(Fincher et al., 2001).

There are pedagogical challenges with computer science student projects. An example is the mismatch between intended and real outcomes that can be found in one of the studied projects. The learning purpose with using a project

[1] the term 'folk pedagogies' is coined by Bruner (1996) and introduced to the computer science education community by Lister (2008).

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, at the beginning of the course, described the goal of the course on an abstract level, where process and technical knowledge was emphasized (Pettersson, Gällmo, Hessel, & Mokrushin, 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 was supposed to deliver. Learning purposes (Back et al., 2007; Nilsson et al., 2007) were not clearly identified, or discussed by students.. This example illustrates a potential disparity between teachers' intentions and students' experiences that I believe warrants further investigation.

The learning outcomes attained through student projects are often 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. The argument is that this is not a problem, since the students will learn something useful from the student project regardless of their role. In Säljö (2000),this is discussed [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 out 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 such that 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)

## 2.2 Research questions

The starting point in my Ph.D. research project is connected to the reasoning above, namely the interest in how different processes in computer science student projects contribute to the learning outcomes. This general goal is captured in the following overarching research question:

> *how can we design and set up computer science projects in order to make them contribute maximally to students' development and educational quality, based on a firm research foundation?*

In order to address this question, I needed to investigate what processes contribute to learning in computer science student projects. This initial research question is the focus of the work presented in Part II of this thesis. A secondary question, pursued in the initial phase was, to identify if there are any features that are highly influential for the learning outcome, with respect to the processes identified?

The idea is that pursuing the overarching research question can be based on the identified features. Furthermore, taking a clear theoretical stance regarding learning, identifying a context in which to evaluate learning, and designing studies are all driven by needs identified as essential for addressing this question.

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 critically influence the learning outcome of computer science student project. If so, could a pilot framework based on identification of these features be derived and used as a basis for analysis of the studies included in this thesis, and thus address the overarching research questions.

## 2.3 Conducting discipline based research

One may wonder if questions regarding project work, group performances, collaboration etcetera can be effectively investigated by a researcher within the field of computer science. The one major argument here is that a computer science researcher, as with every discipline based researcher, is a part of the his or her own discipline. The internal perspective is both a strength and a weakness. The study plan for the computer science education research graduate study program reasons about this issue as follows:

> 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 endeavors. (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 them at a considerably higher level than an outsider. Understanding of the subject, culture, and discourse are most likely easier from an insider perspective. The ability 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 issues in a discipline 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 interpretation 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 from the social sciences. Even though using methods and theories from the social sciences, I will still lack the deep and extensive understanding of a person with solid experience in social sciences.

The work in this thesis is computer science education research and the results are restricted to computer science education. However, the research questions draw on general mechanisms and the results are likely to be informative also in other disciplines.

## 2.4 Initial answers to the research questions

This thesis contributes to the field of computer science education in several ways. The papers included investigate different aspects of processes in computer science student projects.

**Paper I** 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 are identified.

**Paper II** investigates experiences of the process of decision-making in a full semester computer science project course. Six categories describing the experience of decision-making are 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.

**Paper III** investigates Swedish engineering students' conceptions of engineering, where dealing with problems and their solutions and creativity are identified as core concepts. Subject concepts, as mathematics, and physics do not appear in any top position. *Math*, for instance, accounts for only five percent of the total mentioned engineering terms. *Physics*, the second highest ranked subject term, only accounts for approximately one percent.

**Paper IV** proposes four key features for reflecting on how to set up and analyze computer science student projects. The proposal is based on insights from paper I and paper II, which focused on decision-making and experience of competence, e.g. how the perceived level of competence and the decision-making process among students influence the projects. The overall aim with using those key features is to address issues related to the learning outcomes of project courses, and thus be useful for both education researchers and teachers. This paper is also an important intermediate step towards the final proposal in this thesis.

Thus, my background, interest and the proposed research questions led me to start exploring and learn about computer science student projects. I investigated different themes, such as how students perceive other students' competence, decision-making in project groups, and their conceptions of the subject area. Results from these three studies formed a cohesive knowledge contribution in terms of an understanding of some key features in student projects regarding learning outcomes. These results are used as a stepping stone for the final study.

## 2.5 Going further with the research questions

The four key features, presented in Wiggberg and Daniels (2008), are combined with the pedagogical model, communities of practice (Wenger, 1998), to provide a framework, for reasoning about learning in computer science student projects. The aim is to reflect on the use of computer science student projects as a way to integrate students into the larger IT-workers community of practice. Interview data, described in chapter 12.1, are analyzed and presented. When designing those courses, both the four key features and the structure for reasoning about learning, create a systematic approach to reasoning about how learning occurs. The result from the investigation is presented in part III and in **paper V**.

The 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 using a number 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).

Previous research in the field of student projects has contributed various insights and knowledge regarding group processes. The work in this thesis aims to increase the research-based body of knowledge concerning group processes, especially in the field of computer science student projects, in order to elucidate the effects of the key features I have mentioned.

# Part II:

# Background and initial studies

This part is presenting the current research in the field of computer science education research. The underlying educational setting for the researched projects is illustrated. An overview of initial data collected is presented, together with the initial results. Finally, the question of reliability is discussed.

# 3. Related research

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 General categorization

The field of computer science education research is growing and is becoming more diverse. Fincher and Petre (2004) mapped the field of computer science education research identifying 10 main areas:

- Student understanding
- Animation, visualization and simulation
- Teaching methods
- Assessment
- Educational technology
- Transferring professional practice into the classroom
- Incorporating new developments and new technologies
- Transferring from campus-based teaching to distance education
- Recruitment and retention
- Construction of the discipline

This broad categorization can be extended in several layers by adding subcategories, but it provides a useful overview at the present resolution (Fincher & Petre, 2004). The work presented in this thesis mostly fall in the following three areas; *student understanding, teaching methods and transferring professional practice into the classroom.* Another classification based on project courses and research within those, is made by Fincher et al. (2001). Fincher et al. presents a work where a large set of composite studies, compounds of found "standard practice", that exists in the education environment of IT- and engineering departments. Together with an analysis of different mechanisms, for instance the mechanism of allocating students to different project groups, are also presented. In a in-depth third part, Fincher et al. analyses certain real project settings. In all those three cases, the data about projects is data describing the projects from the teachers point of view, collected through a survey to different education departments. That is, students might have been informing teachers, but the major and primarily experiences used are teachers'. This difference is an important distinction from this current Ph.D. study. The final part of the book reasons on how to solve certain and frequent recurring issues when dealing with computer science project work. Allocation of students, examination, motivation etcetera are dealt with in those guides (Fincher et al., 2001). Fincher et al. also presents an overview of different project models. Those are based on the same data set as the composite studies.

- Research
- Product development - design and build
- Software engineering
- Application-based
- Team projects, process based
- Capstone, integrative
- Culminating, demonstrative
- Industrial projects

Reading through the lists of different project models, a first notice is that many of the suggested categories could be involved in the same project. For instance, a capstone project most likely involves some software engineering. In the current projects investigated in this thesis: *product development - design and build, software engineering, team projects, process based, capstone, integrative and culminating, demonstrative* all are reasonable candidates as project models. Fincher et al. goes further in their description of different types of project by introducing three major styles of project work. Project work closely connected with a specific part of the curricula, demonstration of mastery skills in a large project, and large projects where students are mimic the thought reality. In this categorization, the projects discussed in this thesis fall in the latter two models.

## 3.2 Need for improving projects

Several recent reports have pointed out the need for improving work in student projects, and for increased knowledge on how mechanisms work.

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. 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 soft factors and their distribution within the projects. Beranek et al. (2005) identifies four typical group roles:

- Group task roles
- Group building and maintenance roles
- Individual roles
- Typical programmers

Earlier, research also show that computer science student projects can handle their effectiveness in different ways. Hause, Almstrum, Last, and

Woodroffe (2001), for example, compares the effectiveness of distributed teams depending on their communication pattern in the planning phase. Holland and Reeves (1996)'s extensive study on programming teams performing the same task showed that different teams ended up with a broad variation in their priorities. Berglund (2005)'s performance study along the same line as Holland and Reeves (1996)'s, concluded that motives for taking a computer science project course differ greatly (Wiggberg, 2008b). Clearly, there is a need for research on computer science student groups, which is why different researchers address those issues.

## 3.3 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 were 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 is 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 es-

tablishing 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; 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 favoring 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 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 et al. (2001), utilizing 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 between five and six members each, 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 from 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.

## 3.4 Group skills

Seat and Lord (1998) emphasize the importance of practicing 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 (Barker, 2005).

J. 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 J. Brown and Dobbie (1998), leading the study was that J. 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 students' 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 6. 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 behavior 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.

## 3.5 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 fulfill 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 team working 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 was 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.

## 3.6 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.

# 4. Computer science student projects

The main object of research in this thesis is computer science student projects. They constitute the primary research interest, the empirical setting, and a major part of the data source. In short they are an important part of the thesis.

Computer science student projects are also the starting point for students who are becoming integrated into the larger community of practice of IT-workers, described in chapter 9. This means that the projects are important in terms of providing activities, practices in community of practices-terminology, for students. In this chapter I will describe instances of those computer science student projects.

Computer science student projects will here be introduced by an illustration of the project setting used in Wiggberg (2008b), one of the main studies in this work. The aim with the projects, formal goals, and physical environment will be described together with a specific project group and its tasks. Different projects have different settings, but this project contains a wide set of characteristics that make it suitable as an illustration of the concept of computer science student projects.

## 4.1 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, illustrating computer science courses, was held between August 2006 and January 2007. The course instance was taught in English, but the language depends on the students' language (Wiggberg, 2008a).

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 computer science student projects sometimes having connections to external stakeholders. In this particular instance, the external stakeholder is from 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 the course instance described only one external stakeholder was involved in each project, helping out with the requirements of the task. The external stakeholder also contributes to students' exposure to experience from the community of IT-workers. The exact specifications of the product are not set. Instead, the students are required to elicit the requirement specification themselves from an initial idea formulated by the team of teachers in cooperation with the participating industry partner (Wiggberg, 2008a). This connection to the larger community of IT-workers, is one example of this course role, described in section 10, in introducing students into the community.

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 2 projects: 1) designing software for a game for mobile phones (Nilsson et al., 2007); 2) mobile phone positioning (Back et al., 2007). The industrial partners also contributed to the projects as mock customers (Wiggberg, 2008a).

## 4.2 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. Based on those formal objectives, the team of teachers formulated and communicated the following interpretation to the students:

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

The teachers' interpretation is a shortened, but straightforward, interpretation of the formal course description. An important note here is the high level of similarity in interpretation, with the one stated in chapter 10.

## 4.3 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. In projects with just one group, the full group is located in one room. 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 white board, printer and other hardware relevant to the project. The groups were also asked to use software for keeping track of bugs, a version handler, a content management system and personal diary software and some other tools. 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).

## 4.4 Project groups and their tasks

Twenty two students participated in the course. Five of them were exchange students from Tongji University, Shanghai, China, whereof 4 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 seventeen students were Swedish, whereof fifteen were male. 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 them. Members of the different groups discussed common technical challenges and project issues on an informal basis.

As a preparation for the project course, some introductory 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. It is interesting to observe how they tackle the use of the project model The project group Point of Interest was assigned the overall task of designing and implementing a mobile positioning system based on

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

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 [points of interest], comment [on] them, add their own POIs [points of interest] and filter by interest. In addition, support for uploading images with POI [points of interest] 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 4.1. Following the appointment of project manager, the group assigned formal roles and responsibilities among the participants. An analysis of required roles and responsibilities were made 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 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 the 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 man-

[2]Global System for Mobile communications (GSM) is today a 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.

ager. 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 aim 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, 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 turn based 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 defined 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 formulate 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 selections made by the participants in Point of Interest. The Teazle Goes Mobile organization illustrates this in the system overview in figure 4.2. 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.

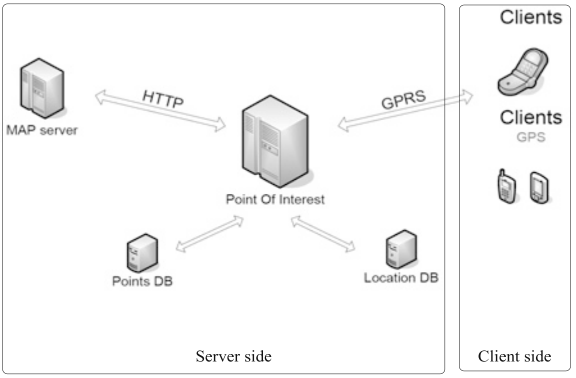


*Figure 4.1:* A system overview of the Point of Interest project (Back et al., 2007).

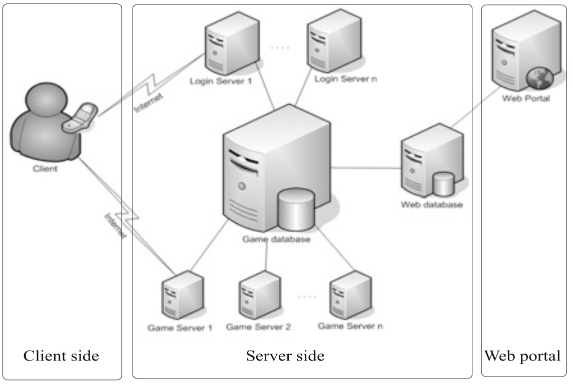


*Figure 4.2:* A system overview of the Teazle Goes Mobile project (Nilsson et al., 2007).

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 re-organization 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.

## 4.5 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, such as 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 Technology. 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), Pears and Daniels (2010), 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 20 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.

## 4.6 Final words on computer science projects

The computer science student project described here illustrates the more general settings investigated in this thesis. As learning environments the projects have many interesting implications: group dynamics; a complex and demanding technical task; the requirement of several external connections during the project work; a needed mix of technical areas in order to solve the problem; etcetera. In the latter section 8.4 a connection between open ended group projects (Newman et al., 2003) and the projects is established. Researching those projects is hence a significant task, and this thesis contribution covers a relatively small area.

# 5. Initial data sets

The first step in this thesis, as described in Part II, is informed by data that has been gathered during the three studies. The data is collected at three times during the duration of two years. This chapter describes those initial data, how they were collected and when they were used. The data collected is described in chronological order. The descriptions have previously been published in studies by the author, and citations are provided for further reading. A summary of the collected data is presented in table 5.1 and the questions used during the data collection is attached in appendix.

## Data set A: Computer science project semester 2006

Eight students from a project group of 12, were selected to be interviewed. The selected students represented a wide variety concerning the variables study background, stated interests and project roles. The interviews were semi-structured and held in Swedish. 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. The interviews where transcribed verbatim (Wiggberg, 2007, 2008a). Each interview were between 31 and 49 minutes long.

The interviewed students participated in a computer science project course in the final year of the IT Engineering program at the Department of Information Technology, Uppsala University. The course duration was one semester and the course started in spring 2006. The students worked together to carry out the task of designing and building a power line inspection robot (T. Danielsson et al., 2006; Wiggberg, 2007).

Data set A was used to analyze power relations between members in project groups. It was also a part of the data used to derive the key features.

*Table 5.1:* Initial data sets.

| Data set | When | Method | Use of data |
|---|---|---|---|
| A | 2006 | Semi-structured interviews | Analysis of power in project. Derivation of key features |
| B | 2007 | Semi-structured interviews | Analysis of decision making in project. Derivation of key features |
| C | 2006-7 | Survey / Critical incident interviews | Analysis of engineering conceptions. Derivation of key features |

| Data set | No. Informants | Male | Female | International students | Cohort |
|---|---|---|---|---|---|
| A | 8 | 8 | 0 | 0 | Full semester computer science course, year 4 |
| B | 18 | 15 | 3 | 4 | Full semester computer science course, year 4 |
| C | 94/521 | | | (see Adams et al. (2007)) | Engineering students in Sweden |

## Data Set B: Computer science project semester 2007

Eighteen students from a project group of 22 students were interviewed. 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 information obtained was used to construct a profile of each student participating in the project course. Some of them turned out to have similar academic background, personal skills, expectations, and motivations. Based on the assumption that diverse profiles were more likely to contribute to diverse experiences, four students were removed from the data collection exercise. Four of the selected students were exchange students. Each interview were between 25 and 44 minutes long (Wiggberg, 2008a).

Semi-structured interviews (Kvale, 1997) were used. The interviews were performed in three sets of six interviews each over the duration of the course. The aim was to capture experiences from early, middle, and late team phases in the team development, as described more thoroughly in (Jaques, 1995; Wiggberg, 2008a). The interviews were held in either English or Swedish, according to the interviewees' preferences. The processing of the interviews was done in their original language.

Data set B were used to analyze decision making in project groups. It was also a part of the data used to derive the key features.

## Data Set C: A national web based survey and interviews 2006-2007

A nationwide data collection, called Stepping Stone, was conducted between June 2006 and May 2007 with the aim of studying engineering students' conceptions of engineering [1]. From this data collection, some data is used to inform studies in this thesis. Only a minor part of the empirical data from the Stepping Stones project has been used in studies connected to this thesis, namely answers to two interview questions and answers to one survey question. Mainly, the data were used to paper III. The full data collection is described in detail in Adams et al. (2007), and the reader is encouraged to peruse it for more details.

Structured interviews were held with 94 students. Web-based surveys also gathered information from 500 and 21 students. Some students participated in both interviews and survey. The survey data was not used in this thesis. The

[1] The data collection was done by the Stepping Stones participants. In addition to the author, 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.

students came from 10 Swedish institutions and represent experiences from a total of 21 different engineering disciplines [2] (Wiggberg & Dalenius, 2009).

The interviews were made using a critical incident model. They started 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), G. Klein, Calderwood, and MacGregor (1989), and G. Klein (1999). Each interview was between 14 and 42 minutes long. 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).

[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).

# 6. Initial results: Key features of computer science student projects

There are many issues to consider when setting up a learning environment for a computer science course based on a student project. Four of them were highlighted as key features in my licentiate thesis (Wiggberg, 2008b) and were further discussed in (Wiggberg & Daniels, 2008). A brief overview of these features is presented in this chapter.

The collaborative projects studied in Wiggberg (2007) and in Wiggberg (2008a), exhibit sets of features that transcend their settings (identifying them as more general in nature), and which influence the processes in the project. Identifying those features, their interdependence and their impact on the learning outcome informs us about the process these projects involve.

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 within a computer science student project ecology. The settings and tools provided in the student projects influence the way in which students work.

Four features of student collaboration projects are of general importance, in the sense that they are all under direct control of the teacher giving the course, and are relevant to the computing education aspect of the course. Before the key features are presented, the research approach, phenomenography, used to derive the former results is revisited.

## 6.1 Initial method: Phenomenography

Phenomenography allows researchers to explore the qualitatively different ways in which people experience a phenomenon (Marton & Booth, 1997). Phenomenography was developed as a research specialization in Gothenburg, Sweden in the 1970's (Marton & Fai, 1999). 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)). I have used the phenomenographic approach to reveal different ways of experiencing processes in computer science student project work. The data analyzed was collected through semi-structured interviews (Kvale, 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 people's experiences of the world. A first order research perspective, on the other hand, makes statements about the world (Marton & Booth, 1997). Phenomenography thusly begins with someone else‘s experience of a phenomenon, in this case the students' in a project group. The variation of experience is distilled into categories. An important feature of these categories is that they can form a hierarchy based on their quality, or level of advancement.

## 6.2 Four key features

### 6.2.1 Mechanism for work allocation

In Wiggberg (2007, 2008a), it has been obvious that some kind of mechanism to allocate work[1] among its members must exist. Waite et al. (2004) report that understanding the enculturation process in computer science student projects is important in order to develop collaborative cultures in the projects. They claim that teaching group process or project models does not solve this issue by default, though it is considered important. Barker (2005) argues further that by letting the students choose their own roles based on expediency or comfort may work against the benefits of collaborative learning in computer science student projects. An example of this from the study described in Wiggberg (2008a) is when Viktor talks about how he suggested a fellow student should work on areas he already knew:

> **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?

[1] *Work* here refers to the tasks necessary to fulfill the main project task.

> **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 results found by Barker (2005) about role allocation also are valid in the computer science student projects I have studied. It also shows how students influence each other's choices. Paper I shows that competence can be demonstrated in a number of ways and influences critical decisions in computer science student projects. In particular by giving students recognized as competent greater influence.

The work allocation mechanism adopted 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 each 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.

### 6.2.2 Connection to external stakeholders

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 may be involved in the project simultaneously.

Barker (2005) argues that the involvement of external stakeholders can lead to perceived pressure to finish the project successfully. 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 because they have different intentions. For example, an external stakeholder can lead to prioritizing the product in the project at the expense of the learning outcome. The function of the external stakeholder can also vary considerably.

In Wiggberg (2008a), the experience of decision-making shows that the external stakeholder has a strong influence on the project. The position of the external stakeholder can be so strong, that they have the final say in decisions, even though the student project group has a different opinion. Category 6 from the study about decision-making (Wiggberg, 2008a), describes experiences where external stakeholder interaction significantly 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 respond quite late and it is not efficient.

The involvement of external stakeholders in computer science student projects can be beneficial in a number of ways. It gives the students a feeling of reality in their projects, it contributes with ideas for the projects, puts different requirements on the projects etcetera. However, as stated in both paper II 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 needs to be closely controlled in order to design rewarding projects.

### 6.2.3 Focus on result or process

The result of a computer science student project is often a product. This product, or resulting artifact, can be seen as the ultimate goal, against which students' effort will be measured. Alternatively, it can be seen as a strategy to help students' focus on aspects of their project work process.

Holland and Reeves (1996) presents results that computer science student teams can strive for different things: produce elegant software; fulfill course requirements; or focus on the challenges of team dynamics. Wiggberg and Dalenius (2009) concludes that Swedish engineering students, of whom computer science students form a sub-set, see themselves as creative problem solvers. We consider this strong evidence that problem solving is central to their self-image. Wiggberg (2008a) shows how groups have organized themselves according to the task given. To a large extent, they also appointed people to roles based on the previous experience and skills of those appointed. In the cases described in Wiggberg (2007, 2008a), 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 artifact is not unusual in a learning setting, e.g. as noted by Säljö (2000):

> Pupils in western educational systems are often encouraged to be "experimental" and to "be creative" when they work in school. To try 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 it produces is generally of little value outside the learning situation. (Säljö, 2000, p. 45)

In the study presented in Wiggberg (2008a), 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 these attitudes is important when designing computer science student projects.

### 6.2.4 Level of freedom in task

The definition of the task in a computer science student project varies. 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 Wiggberg (2008a), 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, as well as design and implementation issues, was 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, 2008a, 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.

## 6.3 Using the four key features

Those four key features provide a tool which can be applied to the design and analysis of computer science student projects. I have presented my reasons for why I see these four as of central importance to the learning outcome of a student collaboration project. There are of course other factors and aspects that influence the learning outcome for the students, not least the general motivational influence of the teacher, but I believe these are special for collaboration projects. They are also aspects that are new to many educators.

The features are important for running projects, and the framework helps teachers address these issues, and thus be more scholarly in their role as teachers. By taking each of the fields into account when analyzing or developing such a project, a better and more insightful grip on the situation will be achieved. Within the computing education community Lister (2008) has long argued for a migration from folk-pedagogies to using a scientific approach, e.g. in his keynote speech at the ACM Australasian Computing Education conference 2008. Boyer (1990) also addressed the issue of scholarly teaching in his book "Scholarship reconsidered: Priorities for the professoriate".

Part of being scholarly is to stand on solid ground in the sense of having knowledge of the teaching situation and about how learning takes place in that setting. Computing education research is thus of significance, and in this case especially so for computer science collaboration projects. The framework lends itself well to structuring analysis of collaboration projects and can thus be of assistance to education researchers. Research structured in such a way is likely to be quite relevant to teachers of such courses.

# 7. Reliability issues

The quality of results presented in research relies heavily on the quality of the methodology, or approach, used to produce them. In this chapter, a walk-through evaluation of one of the papers in this thesis is presented. The aim is to present arguments for the quality and soundness of the methodology and approach in the research presented in the first phase in this thesis.

Lincoln and Guba (1985) provides a theoretical frame for discussions on reliability and trustworthiness in research studies. In the field of educational research, Lincoln and Guba have been used for similar discussions (for instance in Eckerdal (2009, p.32) and A. T. Danielsson (2009, p.89)). However, in this thesis, I have chosen to discuss reliability in a design focus framework using the seven principles for interpretative research by H. K. Klein and Myers (1999).

The question underlying this evaluation is: *how does my current research reflect H. K. Klein and Myers (1999)'s seven principles for interpretative research?* This is carried out by applying each principle to the chosen 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 relevance to the current study. Finally, a short conclusion discusses the overall outcome of the principle based evaluation.

## 7.1 Overview of reliability study

The design of this evaluation is straightforward. By using H. K. Klein and Myers (1999) set of seven principles for interpretative 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 establish the quality of the results.

## 7.2 Evaluated study

The research study examined here attempts 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, 2008a). 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 construction 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, 2008a).

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, 2008a). A phenomenographic approach (Marton & Booth, 1997) has been used to reveal different ways students' experience making decisions. 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 study we must first determine if the study lies in the area of interpretative research or not. According to H. K. Klein and Myers (1999), required properties of interpretative research can be formulated as follows:

> 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. (H. K. 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.

## 7.3 Seven principles for interpretive research

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 principles are collected and presented by H. K. Klein and Myers (1999) although they originate from different sources. I will refer to the main contributors, as identified by H. K. Klein and Myers, as I present each of the principles.

### 7.3.1 The fundamental principle of the hermeneutic circle

Although H. K. 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 important. The principle states that interpretative research, or human understanding of something, is best achieved 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).

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 form 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.

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 help to make the picture more complete.

The fundamental principle of the hermeneutic circle is applicable in the current study, and the current study well meets its core features. Phenomenography itself also shares the hermeneutical roots. The parts in the understanding of categories and outcome space, is understood in relation to the whole (David, 1998, p. 138).

### 7.3.2 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.

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.

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.

### 7.3.3 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, 2008a, 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 permutes 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.

### 7.3.4 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) and 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"* (H. K. 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.

H. K. 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)]. (H. K. 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.

### 7.3.5 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, 2008a, 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.

### 7.3.6 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 etcetera. 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.

### 7.3.7 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, 2008a, p. 8)

However, as Jake continues, he reminds himself about minor decisions that were 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, 2008a, 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. Note that my research interest regards students´ experiences of decision making, not the decision making in itself.

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.

## 7.4 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.

# Part III:
# The final study

The final study[1], which is based on experiences and results from previous studies, is presented here. My learning perspective is stated, together with the interpretative framework communities of practice. Those are tied to the final study. Practices seen as important for the students to practice during the projects are investigated. A method for combining the interpretative framework, the key features, desired practices and data is developed and presented, followed by results and discussion.

[1] A subset of this part, in a reworked form, is presented in paper V.

# 8. My perspective on learning

This chapter introduces constructivism as the epistemological base used in this thesis, and the way it has implications for the research presented. This epistemological standpoint is then tied to computer science, and especially to the scope of student project work trough an investigation of constructivism design principles. An expansion of the epistemological choice and its connections to the theory of open ended group projects (Faulkner, Daniels, & Newman, 2006) is given. Finally, a summary of the epistemological choice and its implications is presented.

## 8.1 Constructivism as my epistemological standpoint

It is essential that the ontology, the way we look upon the world and the reality, and how we can know and reason about that ontology, i.e. our epistemological standpoint, is clearly stated when researching learning. Bringing this standpoint out in the open provides important information about what assumptions that are guiding the researcher when designing the research project and analyzes the results. The value of the results presented can be better judged when put in the researchers assumptions about knowledge. Although views on knowledge are always assumptions (Duffy & Cunningham, 1996), I will provide arguments and background for my epistemological claim.

Constructivism is my guiding theory of knowledge. Constructivism is, in the area of educational science, acknowledged to Piaget (however, George Herbert Mead's work on symbolic interactionism have preceded and informed Piaget) as described in Marton and Booth (1997), in their quest to find out what it takes to learn. Piaget is described in several works, where some examples connected to the educational area are Marton and Booth (1997); Staver (1986); Ackermann (2001); Machanick (2007). Being a constructivist, Piaget did not see knowledge as existing on its own. Nor was knowledge something that could be inserted into people. To Piaget, knowledge wasn't anything that existed in isolation; it was something that was constructed by, and in relation to the self and its previous understandings. Piaget denotes the individuals own actions and interactions as part of the process of constructing knowledge. The key concepts in the theory is *accommodation* and *assimilation*. Assimilation means that new pieces of information are fitted into an existing model, and hence the model becomes more detailed and complex. Accommodation

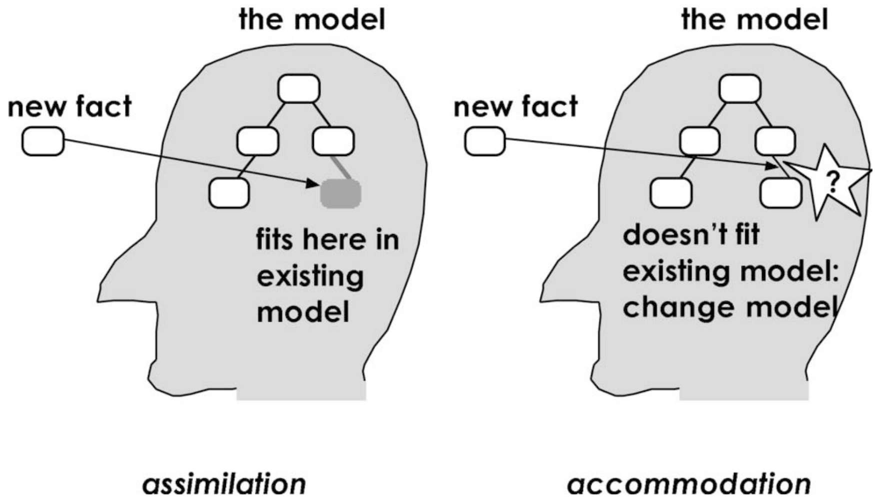


*Figure 8.1:* Learning in constructivism. New facts which fit the existing model are slotted in (*assimilation*); those that do not fit require changes to the model (*accommodation*) (Machanick, 2007, original caption).

on the other hand, means that acquiring new pieces of information leads to replacement of information in the model that the learner is creating (Machanick, 2007). Knowledge construction in an individual is, according to Piaget's constructivist view, explained by more advanced levels of knowledge evolving through the assimilation and accomodation process. Figure 8.1 illustrates the concepts of assimilation and accommodation.

A similar description is made by Marton and Booth (1997), referring to constructivism within the field of computer science education research. Marton and Booth phrases knowledge, in the Piaget constructivist manner, as being:

> [...] constructed by the individual through her acts, through her interaction with the environment, by means of the complementary adaptive mechanisms of accommodation (in which the individual adjusts to the environment) and assimilation (in which the environment is adjusted to suit the individual). (Marton & Booth, 1997, p. 7)

Some work criticizes Piaget's conclusions and theories. O'Loughlin (1992), as one example, argues that educational scientist tend to rely on *"too many unexamined assumptions from developmental psychology and we take for granted the problematic notion that children learn by doing."* (O'Loughlin, 1992, p. 791). O'Loughlin's main critique against Piaget's constructivism is that it privileges only one form of knowledge, the technical rational. O'Loughlin says it ignores *"the subjectivity of the learner and the socially and historically situated nature of knowing"* and *"it denies the* *essentially collaborative and social nature of meaning making"* (O'Loughlin, 1992, p. 791). Constructivism is not including culture, power and discourse in the classroom, according to O'Loughlin. In this work, O'Loughlin's concerns about the shortcoming of constructivism is partly addressed since meaning making, in the context of the projects, is handled. The field of computer science education research has several well cited and trusted sources where collections of constructivist approaches are referred. One example of such trusted source is the earlier mentioned Marton and Booth (1997). Ignorance of the subjectivity of the learner is not an issue in this research project. This is due to the fact that the informants own words are used as primary data source and hence are the informants eventual subjective conceptions also included in the data.

## 8.2 Constructivism in computer science education

Constructivism[1], as the base for understanding learning has been elaborated in the computer science Education field. An early trace is Ben-Ari (1998), who claims that constructivism is the dominant view on learning today (Ben-Ari, 1998, p. 257). Ben-Ari, working in the area of computer science education, presents work where constructivism's influence and usefulness in computer science education is investigated. Ben-Ari starts by defining constructivism:

> This theory [constructivism] claims that knowledge is actively constructed by the student, not passively absorbed from textbooks and lectures. Since the construction builds recursively on knowledge (facts, ideas and beliefs) that the student already has, each student will construct an idiosyncratic version of knowledge. (Ben-Ari, 1998, p. 257)

Ben-Ari illustrates the importance and influence of culture, society, the specific project learning environment, one's fellow learners, the perceived importance of what is being learned in the project, the psychology of the individual, and the team of teachers, in the learning experience. These unavoidable things in the world are perceived differently by the students, and a constructivist perspective recognizes these as important for knowledge creation. Ben-Ari identify activity and interaction as important parts of constructivism. Interaction and construction of knowledge, is significant in the definitions. Each student's knowledge will, according to these definitions, differ from each other.

[1]Several works in the field of computer science education Research refer to a construct*ivism* approach, meanwhile some other refer to construct*ionism*. In short, constructionism can be seen as an expanded version of constructivism, where a contextual insight is included (Papert & Harel, 1991). Crotty defines the difference between those two, as constructionism having *"the social dimension of meaning as it centre stage"*, while constructivism lacks this dimension (Crotty, 1998, p. 57).

Their previous learning students bring into their educational experience, as manifested in their beliefs, knowledge, and ideas, has a vital impact on their learning from the experience.

Ernest (2009) defines educational paradigms, as being comprised of four key components: *ontology* (theory of existence); *epistemology* (theory of knowledge); *methodology* (a way to acquire and validate knowledge); and *pedagogy* (theory of teaching). The contribution of the work by Ben-Ari is not to define constructivism, but to apply it in the computer science education research area. Thusly, Ben-Ari illustrates how constructivism can be seen as an educational paradigm within computer science education research.

Constructivism as educational paradigm implies that there is no absolute foundation of truth upon which to build knowledge. Each individual or student in this case, constructs its own foundation of knowledge. A direct consequence is that knowledge is fallible. The method of learning is to acquire knowledge recursively and combine it with existing knowledge. A pedagogical method, when constrictivism is the pre-dominant view on learning, needs to be active, meaning that the learner has to actively accommodate and assimilate new pieces of information, since each learner will bring her own preexisting framework of knowledge. Only an active learning situation will be able to adapt a preexisting framework of knowledge. Since the knowledge, based on the main assumption of constructivism, is created by the learner, an active learning approach is required (Ernest, 2009; Ben-Ari, 1998).

Ben-Ari claims that many phenomena in computer science Education can be understood and explained using a constructivist approach (Ben-Ari, 1998, p. 259). Ben-Ari argues that constructivism will be a useful epistemological approach, even when computer literacy will become more common among students. Ben-Ari (1998) claims that applying pedagogical methods based on constructivism in the field of computer science education must address the following two issues: a newcomer in computer science has *no effective model of a computer* (a cognitive structure that the student can use to make viable constructions of knowledge, based on sensory experiences such as reading, listening to lectures and working with a computer); and *the computer forms an accessible ontological reality* (a correct answer is easily accessible). These statements about the constructivist paradigm not only fit my view of knowledge creation in computer science, but also exemplify how it can be used within computer science education research. Students entering computer science know different things about the relevant subjects covered by the tasks involved in their educational training. Their set of previous courses differs, as well as their study alignment.

## 8.3 Constructivism and projects

Through collaborative project work, guided by the tasks and the goals, students acquire knowledge. Building upon existing knowledge, they use Internet, books, discussions and other sources to learn more and increase their knowledge on the desired subject. A student participating in a computer science student project needs to be actively involved in order to build knowledge. Since no or very few lectures are held, the participants own motivation to participate and learn by actively involve in the projects activities, helps in order for learning to take place. The project setting is an excellent example of a active learner approach that provide challenging tasks and a high degree of freedom in actions to fulfill the tasks.

Jonassen has used the constructivism perspective on learning in his studies of project work. Jonassens view of constructivism is similar to the view presented in Ben-Ari (1998), as can be seen in the following quote:

> [...] claims that reality is more in the mind of the knower, that the knower constructs a reality, or at least interprets it, based upon his or her apperceptions. (Jonassen, 1991b, p. 10)

The constructivist does not deny the existence of an external reality, but claims that each of us constructs our own reality based on our experiences and interpretations of the external reality (Jonassen, 1991b). Jonassen discuss constructivist learning environments, which in my interpretation should be seen as learning environments suited for a constructivist view on knowledge construction. He consider project as being good examples of such learning environments and summarizes eight design principles for constructivist learning environments Jonassen (1991b, p. 11-12). These design principles are collected from educators and cognitive psychologists, where J. S. Brown, Collins, and Duguid (1989); Collins (1990); Collins, Brown, and Newman (1989); Jonassen (1991a); Resnick (1987); Scriven (1983); Richard Coulson, Feltovich, and Anderson (1988) are some examples. It is worth noting that some of the criteria also address properties not connected to constructivism, but to project work in a more general way.

## 8.4 Relation to open ended group projects

Open ended group projects is a pedagogical tool that introduces open ended problems in education. Problem solving is considered to be a major learning activity (Jonassen, 1997; Davidson & Sternberg, 2003), and Hauer and Daniels (2008) considers the ability to solve problems as central. Based on this assumption Hauer and Daniels uses open ended (ill-structured) problems as a way to create starting points for problem solving. Hauer and Daniels (2008) describes open ended problems as:

> Open ended or ill-structured problems are where goals or bounds are unspecified, unclear or insufficient in various ways; these problems are considered to be more complex, real-world or indeterminate in their end goals in comparison to the well-structured problems [...]. (Hauer & Daniels, 2008, p. 86)

Open ended group projects has, according to Newman et al. (2003, p. 96), several similarities with characteristics of constructivism. For instance, open ended group project is argued to meet requirements of learning suited for learning environments based on a constructivist view on knowledge construction: *"bring about the modification of learner behavior after the experience of learning"*, *"requires learners to be active in their relationship with the material to be learned"*, and *"presupposes the existence of a worthwhile problem that needs solving by the learner"*(Brooks & Brooks, 1999).

Open ended group projects also contribute to learning environments that *"shares knowledge among teachers and students"* and where *"the teacher's role changes from instruction to guidance"*(Kolmos & Algreen-Ussing, 2001), i.e. in accordance to a constructivist view. Newman et al. (2003) define open ended group projects by their benefits compared to other learning environments:

> It is argued that putting students into a "team" context and facing them with a problem for which there is no "right" answer helps them think about what they have been taught, internalize some of the material that has been presented in lectures and laboratories, and develop the "soft" people oriented, skills which are essential in the "real world" The requirement to consider what needs to be achieved and agree it within the group and with the lecturers helps overcome the purely technical image of the subject. (Newman et al., 2003, p. 96)

In this thesis, the project course consists of students who work together in projects in order to achieve both increased learning and a product. Students design parts of their own task and they are together seeking solutions and strategies to achieve the goal. The exact specifications of the product which the project is working to fulfill are not set. Instead, the students are required to specify their requirement specification themselves from an initial idea formulated by the team of teachers in cooperation with the participating industry partner. In a collaborative manner the students work out the plan for the work as well as the organization needed. Their different perspectives, together with the views of teachers and external stakeholders, contribute to an environment where knowledge is constructed. The studied projects can in my opinion be argued as being representations of open ended group projects (Faulkner et al., 2006). The above connections between constructivism and open ended group projects are also some evidence for defining open ended group projects as epistemologically being suited to a constructivits learning assumption.

## 8.5 Summary

This chapter has laid the foundation of my view on knowledge creation, and its relation to social learning environments as constituted by the studied projects. This chapter presented constructivism's relation to the projects that have been reviewed. Narrowing down from projects to the more specific open ended group projects was done by investigating the foundations of open ended group projects and their relation to constructivism. What should be brought in mind from this chapter is my view on learning: how it happens, and each learners own involvement in how knowledge is created in her.

In the next chapter, an epistemologically constructivist (Cox, 2005) theory on learning is presented: communities of practice. Communities of practice is a theory of learning where the interaction and learning in projects is the field of application. Communities of practice is used later in this thesis to analyze projects

# 9. Computer science student projects as communities of practices

This chapter introduces communities of practice, and presents how the concept can be used as an interpretative framework for learning in project based computer science courses. communities of practice is first introduced and discussed in general terms followed by a section discussing communities of practice related to computer science, and particularly student project groups. The issue of learning, and especially learning in a student project group, is addressed.

## 9.1 Communities of practice

In the social theory of communities of practice, learning is thought of as a result of social participation (Wenger, 1998, p. 4). Wenger suggests that learning is a natural and inevitable part of life. Learning in communities of practice opposes the assumptions that learning is an individual process where a uni- or bi-directional communication between the learner and the teacher is seen as an effective way of learning. Communities of practice instead place the participation in a social process, the practice of a community in a certain domain, as the way to learn (Wenger, 1998). Wenger puts it:

> Learning is not refined as an extraneous goal or as a special category for learning something else. Engagement in practice - in its unfolding, multidimensional complexity - is both the stage and the object, the road and the destination.(Wenger, 1998, p. 95)

Viewing communities of practice as a concept, it can be thought of as a group of human beings sharing a common interest, or a set of problems, in a topic. The group increases their expertise in the topic by interacting with each other through certain practices in an ongoing process (Wenger, McDermott, & Snyder, 2002).

Although the perspective on learning assumes it is an ongoing activity, it does not make it trivial by saying that everything is learning in the communities of practice-sense. Learning has to do with the practices and the learners ability to negotiate meaning (Wenger, 1998, pp. 95–97). Connecting learning with practicing is a central assumption in this study.

Communities of practice exist in places where we share our everyday lives, and often we do not recognized them as communities of practice (Wenger, 1998). That is, communities in this context are where we do things together with other people, in a shared domain of interest and with certain practices. A community of practice is a special case of a community and there is a need to clarify what makes it so. Community is a word with many meanings. Wenger put three, crucial, requirements on the community in order to call it a community of practice Wenger (1998). These three characteristics are:

- *Domain* A shared domain of interest exists among the members. Competence in the domain subject differentiates a member from a non-member. This implies a commitment to the domain by the members.
- *Community* Relationships that enables learning from each other. Members of the community share information and helps each other. They are also actively engaged in joint activities and discussions.
- *Practice* Community members are practitioners who work actively in the domain. They develop resources, such as tools, experiences, stories, and ways of addressing recurrent problems in order to enhance their common work. The process of developing resources takes time and requires interaction between the community members.

According to Wenger, a community of practice is recognized by the presence of all these three in combination. The cultivation of the community of practice is also based on development of the three characteristics. Important aspects of communities of practice thus involve shared repertoire, domain, mutual engagement and joint enterprise practice. An alternative way, inspired by Kolikant, McKenna, and Yalvac (2006), to rephrase the characteristics is:

- *What the community is about, its subject* The joint enterprise of the community, as understood and continually renegotiated by its members.
- *How the community functions* The mutual engagement by its members that binds them together into a social entity.
- *What capability the community has produced* The shared repertoire of communal resources (routines, sensibilities, artifacts, vocabulary, styles, and so on) that members have developed over time.

These three dimensions, or requirements, need to be identifiable in a community in order to categorize it as a community of practice.

### Practice

In a community of practice Wenger identifies *practice* and *identity* as key concepts. Wenger states that learning is the outcome of interaction and handling of relations in communities. This collective learning results in practices that become the property of the community (Wenger, 1998).

The concept of practice is essential to communities of practice. Members in the community need to be practicing in their shared domain. A Practice is defined by what a group of people have:

> [...] developed in order to be able to do their job and have a satisfying experience at work.(Wenger, 1998, p. 47)

Included in the practice are both explicit and implicit artifacts of working together. Some examples are language, tools, documents, well-defined roles, codified procedures but also subtle cues, untold rules of thumb, underlying assumptions, shared world views (Wenger, 1998, p. 47).

**Identity**

Identity, the other key concept in Wengers definition of communities of practice, starts from the perspective that development of a community of practice contains the step of building a community where members can relate to each other as participants. Members should also feel connected in the sense that they have a shared meaning for things in the community and feel that they belong to the community. Thus, creation of one's identity in respect to the community and its practice becomes an issue. Wenger refers to creation of identity as a negotiation, which can be silent or more explicit, but in any case participants in the community deals with identity of each other by the way they relate to one another or engage in actions to one another. Building a community therefore also implies negotiation of identity. This is formulated by Wenger:

> Building an identity consist of negotiating the meanings of our experience of membership in social communities. The concept of identity serves as a pivot between the social and the individual, so that each can be talked about in terms of the other.(Wenger, 1998, p. 145)

Identity is connected to practice since developing a practice requires the formation of a community with members that relate to each other. Negotiation of identity may, or may not, be a direct issue in the community, it is nevertheless somehow dealt with (Wenger, 1998, p. 149).

### 9.1.1 Legitimate peripheral participation

A very central mechanism related to identity in communities of practice is the term legitimate peripheral participation and the transition to central participation and the reverse process. Lave and Wenger formulates legitimate peripheral participation as a theoretical description of how newcomers, people who are new to the community, who enter a community of practice can become more experienced members of the community of practice. Starting with less prestigious low-risk tasks, a participant can get acquainted with the communities tasks, cultural expressions, skills and other expressions of the shared repertoire. As time goes by the member becomes more senior in the community and gains access to the more central aspects (Lave & Wenger, 1991). In

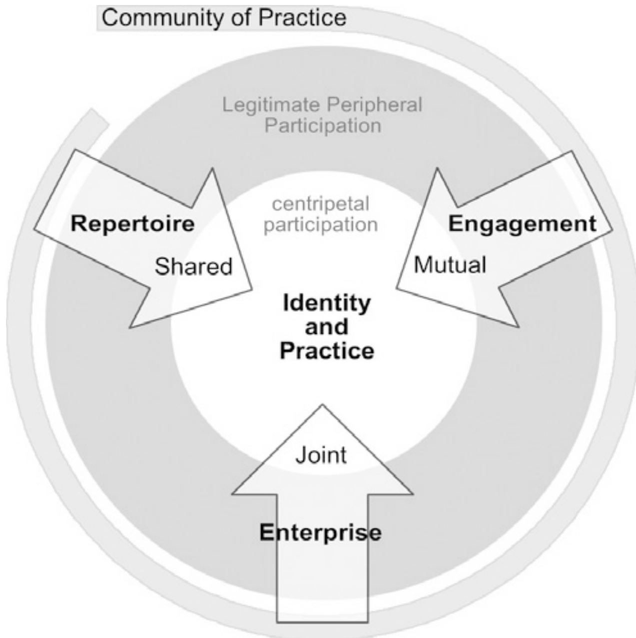


*Figure 9.1:* An overview of communities of practice (Henderson & Bradey, 2008).

figure 9.1 an overview of general idea with communities of practice is presented.

An important observation from the theory of legitimate peripheral participation is that newcomers who gain access to experts and can study their practice, understand their own activities within the community. In contrast, newcomers with less access to the more central members of the community have a more flat learning curve (Lave & Wenger, 1991). Legitimate peripheral participation hence can be used to reflect how members of the community through practice can become more experienced members of the community. Doing that, they will also be more engaged in different practices in the community.

Legitimate peripheral participation, the central theory describing the socializing mechanism in communities of practice, explains the process of going from a being a legitimate peripheral participant to a more central participant. During the journey towards the more central parts of the community, learning takes place through sequences of actions. These actions are an integral part of the journey and define a trajectory from novice to accepted community member:

> Learners inevitably participate in communities of practitioners and [...] the mastery of knowledge and skill requires newcomers to move toward full participation in the socio-cultural practices of a community. "Legitimate peripheral participation" provides a way to speak about the relations between newcomers and old-timers, and about activities, identities, artefacts, and communities

> of knowledge and practice. A person's intentions to learn are engaged and the meaning of learning is configured through the process of becoming a full participant in a socio-cultural practice. This social process, includes, indeed it subsumes, the learning of knowledgeable skills. (Lave & Wenger, 1991, p. 29)

Under the assumption that a community exists in order to evolve and engage in new practices, a process where a participant slides away from the more central parts of the community implies that learning opportunities are lost.

## 9.2 Community of practice in computer science

Community is used to describe a wide variation of constellations of people, and could be somewhat vague. The theory communities of practice is wide spread in different areas of the literature, as well as the definitions used. For instance Roth (1998) gives a more general definition:

> Communities of practice are identified by the common tasks members engage in and the associated practices and resources, unquestioned background assumptions, common sense, and mundane reason they share. (Roth, 1998, p. 10)

Communities of practice have been used in different disciplines, and with slightly adjusted definitions. An example, from the area of language and gender research is Holmes and Meyerhoff (1999). Another example from the domain of biomedical engineering can be found in Kolikant et al. (2006), and yet another from the domain of doctoral training in education Olson and Clark (2009). Similarly, a definition of the computer science discipline can be defined.

### 9.2.1 The project group as a community of practice

Courses based on computer science student project are the focus of this thesis and the community of practice referred to will be a student group in such a course. I will describe how I use the concept of community in relation to how it is defined in Wengers theory of communities of practice.

Communities of practice are referring to two different communities in this thesis, one where a smaller community - the project group - is the one in focus, and one where the larger computer science community is the scope. The default community I refer to throughout this thesis, is the smaller community that is constituted by the computer science student project. That community is hence limited to the project group itself and their closest collaborators such as teachers and industry contacts. The empirical data collected in Wiggberg (2008a, 2007); Wiggberg and Daniels (2008) all belong to the smaller project group. It is in these setting interviews and surveys have been performed, and reports and papers have been produced.

The group formed by the project participants is not a blank sheet. It contains people who have knowledge in different areas thought to be valuable to the project. That means that when the project group is starting to form their community, some members are already more knowledgeable and have a greater opportunity to establish themselves in a more central role in the community. This is a prerequisite for the group to become a functional community of practice. The process of legitimate peripheral participation and the movement from there to more central parts of the activities in the community needs, or at least benefits from, having a variated level of knowledge in the initial phase of the community.

### 9.2.2 Constellations of practices

It is quite reasonable to believe that the smaller project group exists in a larger environment of a more general computer science community. Participants in the project group have connections not just within their class, but also through friends in other similar study programs. Ideas, both related to the students' studies and their general interest in computer science are shared. For computer science students it is also plausible that they have had, or have, contact with industry trough visiting career fairs, industry involvement in other courses, and actually being part time employed. A community of practice is hence more than a community: it provides a base for establishing links to broader communities. Barab and Duffy (2000) concludes on this:

> [...] a community is not simply bringing a lot of people together to work on a task. Extending the length of the task and enlarging the group are not the key variables for moving to the community concept; rather the key is linking into the society - giving the students a legitimate role (task) in society through community participation and membership.(Barab & Duffy, 2000, p. 49)

This means that the project group as a communities of practice also serves as a base for linking the students into the wider computer science community.

As a part of the learning view based on communities of practice, Wenger introduces constellations of practices as referring to interconnected communities of practices (Wenger, 1998). Such constellations of practices can be seen as connected communities even though they may not be particularly close to one another or being of different size. The important feature of constellations of practices in this thesis is the existence of a relation between the involved communities of practice. The project group as a community of practice and the computer science community as a community of practice are seen as related, and therefore treated as of constellation of practices. The reason for the relation is the existence of several similarities. Both communities have shared historical roots, where computer science as subject and its cultural annotations are two examples. They also share artifacts in their working process. The conditions in both communities are also considered to be closely related.

### 9.2.3 Experiences from the The Department of Information Technology

The Department of Information Technology at Uppsala University, Sweden, has within the IT engineering program and the Master in Computer Science program during the past twenty five 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 (Wiggberg, 2008b). Those projects have been studied by several researchers, where Berglund and Wiggberg (2006); Daniels and Asplund (1999, 2000); Wiggberg (2007, 2008a); Faulkner et al. (2006) are some examples.

In the collaborative student projects studied, it has been obvious that some kind of mechanism to allocate work among its members is in place. Waite et al. report that understanding the enculturation process in computer science student projects is important in order to develop collaborative cultures in the projects. They claim that teaching about group process or project models does not solve this issue, though it is considered important (Waite et al., 2004).

Although the studies underlying this thesis do not treat the larger community, the computer science community is interesting to elaborate on. One of the goals with the use of computer science projects is to introduce students into the larger computer science community by training them in practices identified as important in that community. In this thesis we will refer to the larger community as the community of IT-workers.

## 9.3 Supporting framework for interpretations

Communities of practice have been illustrated as a useful and effective theory in the field of computer science education. Strazdins reports from a study where communities of practice was used as the principle for teaching and learning generic research-related principles and skills (Strazdins, 2008). The outcome motivates the author to state:

> The CoP [communities of practice] approach is also quite cost-effective in terms of staff resources, maximizing learning resources by utilizing the students' collective experience.(Strazdins, 2008)

Strazdins continues by elaborating on how communities of practice in general can be beneficial in learning situations:

> Over teaching these skills in a separate course, a CoP [communities of practice] approach has several advantages: the students are more motivated in the context of doing an actual project, they can relate general principles with their current experience (experiential learning), and they seem to appreciate the element of peer review [...]. There is evidence that the students feel the CoP sessions can improve their general understanding and abilities in research skills [...].(Strazdins, 2008)

Communities of practice is not limited to function as method during courses. Instead, the social theory of communities of practice also helps by providing a systematic way of discussing the experience of learning in communities (Wenger, 1998). Doing this, the definition, and its parts, of communities of practice is used as a filter, or glasses[1], to find and show how participants in computer science student projects influence the learning experience. Communities of practice, and the central concept of legitimate peripheral participation, are illustrated below as means for analyzing computer science student projects as learning environments.

## 9.4 Thoughts on use as yardstick

The assumption here is that a communities of practice is created in the specific computer science student project. That community has enough ties to the community of IT-workers, which is also seen as a community of practice. Via the concept of constellations of practice, these two communities have links between them. By using empirical data to analyze how participants contribute or not to constitute the smaller community in the project course, I can unwind actions and behaviors that facilitate or prevent the possibility to become a central member of that community, and hence also belong to the larger community of IT-workers.

By using communities of practice, and especially the concept of legitimate peripheral participation, it is possible to obtain a new understanding of the implications of mechanisms used to allocate work in projects. Participants, who do not engage in legitimate peripheral participation in a proper way and thus stay in a peripheral position in the community of practice, or project, have fewer opportunities to learn trough interaction with the more knowledgeable members of the community. Thusly they risk learning less because of their distance to the core parts of the community.

[1]The terminology, glasses, is borrowed from Ehn and Löfgren (2001).

## 9.5 Summary

Communities of practice can be a useful tool to unwind students and teachers experiences' of learning in student projects. The way work is allocated in a project is used as an example of how relating to communities of practice can aid in understanding consequences of how this is done. The approach to use communities of practice for analyzing effectiveness of a method can be used in the general case as well. Any method used to address any aspect of the learning environment can be analyzed in terms of how it causes students engage properly as legitimate peripheral participation and to move towards the center of the communities of practice or, if not, move away from it. An example of an important aspect in a communities of practice is the level of engagement in social interaction and practices. In this thesis, these kind of analyses will be performed based on interviews from participants in student projects.

# 10. Desired practices in the studied projects

Learning outcomes of the computer science project courses are defined by the formal course descriptions and interpreted by the teachers giving the course. This chapter describes those two processes of establishing learning outcomes, and also present the official desired learning outcomes, which are manifested during the project course. Those practices are later investigated in the analysis of how students become members of the larger community of IT-workers.

## 10.1 Formal course description

The formal course descriptions are in practice set by the board of studies often based on the proposals written by the teachers of the course. These descriptions are made public to students and staff. Teachers of the course are instructed to use them as starting point for the course planning, and the actual implementation is largely up to the teachers. Often, actual course teachers have taken part of the process of writing the proposals. Then it is up to the individual instructor to teach it according to how she feels it should be taught. Although students can read the formal course descriptions, anecdotal evidence indicates that their main source of information is what is said by the teacher responsible for the specific course instance.

### 10.1.1 Analyzing the formal course descriptions

The current formal course descriptions, one from the autumn course and one from the spring course, are presented below.

> **IT-Learning outcomes** [1] **(referred to as 1)**
>
> *Learning outcomes*
>
> After completing this course, students are able to use knowledge and skills from other courses within the IT program to solve a large and complex problem task in the form of a project. This involves being able to...
> -Structure a large task into individual tasks in a large project group

[1] `http://www.uu.se/en/node701?kpid=11639&type=1`

-Identify, obtain and use key knowledge associated with the individual tasks
-Present a realistic design of a complex computer system

**DV[CS]-Formal course descriptions [2] (referred to as 2)**

*Learning outcomes*

The participants should in order to pass the course:
-Be able to account for and have experience with, as members of a project group, the running of a major project from the initial planning to the finishing in the distributed systems area (i.e. systems where the computing resources are distributed and there is a need for synchronization between them).
-Be able to use "state-of-the-art" design principles and programming methods, as well as be able to delimit the assignment and choose applicable components to carry out the work based on an appropriate project methodology and carry out the planning accordingly.
-Be able to handle the fine details of at least one aspect of the construction of a complex distributed system.

These two different formal course descriptions share several aims: some of them are listed and briefly motivated below. I will focus on the learning outcome parts in the descriptions.

- *Use knowledge obtained during earlier phases of the education.* References are, implicit or explicit, given to previously obtained knowledge. The chosen subject “Distributed systems” (2) and “use knowledge and skills from other courses within the IT program” (1) are examples of that.
- *Projects are constituted by complex systems.* The denotation of complex systems as a part of the task is in the formal course descriptions done by the two formulations “aspect of the construction of a complex distributed system.” (2) and “a large and complex problem task” (1).
- *Structuring the task in the project group.* Both descriptions specifies the ability to divide the task into minor pieces, “Structure a large task into individual tasks in a large project group” (1), and plan the work accordingly “as well as be able to delimit the assignment” (2) “and carry out the planning accordingly.” (2)

These three aims are clearly stated as important in relation to the learning outcome of the course.

[2] `http://www.uu.se/en/node701?kpid=18937&type=1`

## 10.2 Teachers aims with the course as central practices

Each teacher responsible for a course has an extensive impact on the manner in which the course is performed. The teacher responsible for the course exercises considerable personal judgment in determining the final content, choice of task and methods, level of direction, communication and other important things of the projects. This implies that each course instance can, and do, vary depending on those variables based on the current teachers influence. Based on the information from interviews, the following is what the two teachers responsible for the studied courses, recognize as being most important in the project course.

### 10.2.1 Teacher A

Teacher A recognizes the aim with the course as fostering computer science- and engineering students into the expected role of an IT-worker. This is done by letting the students experience their expected role.

> **Teacher A**: One of the goals with the courses is to prepare engineering and computer science students for their profession.

Among the practices in the course, teacher A states that the following five, where the first two are more important than the one in the later places, are most central in respect to the formulated aim:

- *Connection to an external company.* It is of high importance that the involved companies are actively taking part in the project.
- *The cooperation among students in the project.* This is especially an important practice during the condition that students entering the projects are heterogeneous.
- *Experiences and skills in tools used in the community of IT-workers.*
- *Complexity in the task.* A high level of complexity in the task creates a project environment were project skills and cooperation is catalyzed.
- *Use of obtained knowledge.* The synthesizing of previously obtained knowledge from earlier courses.

### 10.2.2 Teacher B

Teacher B recognizes the aim with the course as learning to work in a large project, in a work-life manner, where students get the possibility to use knowledge obtained from all previous courses. An important part of practices during the course is the experience of having to re-work earlier sub-optimal decisions. Teacher B formulates this practice like:

> **Teacher B**: If one makes a wrong decision during the development process then one analyzes what went wrong and takes the consequences in terms of changes to the plan, e.g. delayed delivery.

Among the practices in the course, teacher B denotes that the following five are most central in respect to the formulated aim:

- *System integration.* Each participant contributes with a delimitated part aimed for integration with fellow participants' parts.
- *Systematic testing.* Being able to actively prune the system of possible design- or coding mistakes that might cause errors.
- *Handling of unexpected things during a development process.* Being able to take care of unexpected problems connected to the task, that might show up during the project.
- *Planning and follow-up of a complex project task.*
- *Working efficiently and constructively in a large project team of developers.*

The current course responsible teachers, who also have had the responsibility the last four years, have been interviewed on their conceptions of those issues.

## 10.3 Desired practices in a project course

Which practices should the students adopt from a project course? The purpose of this chapter is to answer that question by looking at it from the course responsible teachers point of view. Their view is interesting as such, but also since they are highly influential in what is communicated to the students about the course, due to the fact that most of the face-to-face teaching, presentations and written instructions and supervising is under their responsibility.

Teacher A and Teacher B have somewhat different views on which practices that are of importance. For example, teacher A says that the connection to the external company is of high importance, while teacher B doesn't mention that at all. Nevertheless, I have abstracted the following basic assumption about computer science project courses from the interviews. This is based on their interpretations of the formal course descriptions, their thoughts on important concepts to learn, and to some degree on the formal course descriptions themselves:

> Becoming a member of the IT-worker community of practice is an alternative way to state the learning outcomes of the course. The students will reach this state, and thus fulfill the desired learning outcomes, through being involved in activities identified as essential in the IT-worker community of practice.

The activities they bring up as being essential in this assumption are:

- *Training in working with an external stakeholder, usually an external company involved in the project.* This implies working together with an external stakeholder that is seen as a representative from the community of IT-workers.

- *Working efficiently and constructively in a large project team of developers.* This implies cooperation among students in the project and benefit from different experiences. Skills and cooperation is catalyzed in the project environment.
- *Planning and follow-up of a complex project task, and taking care of unexpected things that might occur.* Being able to take care of unexpected problems connected to the task that might show up during the project.
- *Getting experiences of applying previous knowledge, and learning skillful use of tools used in the community of IT-workers.*
- *Integrating smaller tasks into a larger task.* This involves testing, communication on interfaces, and planning.

The practices above are the ones that will be used later in the thesis for further analysis.

# 11. A method for analyzing learning outcomes in computer science project courses

This chapter presents and discusses the method used to analyze my final data sets. Building on previous research approaches, a way to analyze how learning outcomes are fulfilled is presented. This method is radically different from the ones used in the first phase of my thesis and a brief discussion about, the reliability of the method is given.

## 11.1 Related research approaches

The use of stories, in the shape of biographies describing experiences and attitudes toward computer science, has been used in the field of computer science education by Schulte and Knobelsdorf (2007). Using this method Schulte and Knobelsdorf have been able to:

> [...] not only describe objective events and experiences but relate them to their personality and add personal attitudes and opinions. (Schulte & Knobelsdorf, 2007, p. 31)

Barker (2009) has performed a study on perceptions of undergraduate research experiences in computing. Barker used interviews as data, where undergraduates and faculty mentors were asked about research conditions for students. Barker discovered a wide range of undergraduate research experiences that to a varying extent contributed to, or hindered, the research experience. Although the study in itself reveals interesting results, it is the method for processing interview data that I have used as starting point for the development of my method of analyzing the data set in section 12.1. The approach used in this study is similar to Barker (2009); Craig (2009), which are both approaches to collecting, analyzing, and presenting data. In the study, Barker used interviews as a means for revealing experiences of students and faculty:

> For this study, interviews with both students and faculty were conducted as a means of seeing the research experience through their eyes.(Barker, 2009, 5:6)

Even though Barker didn't set out to relate interviewee's stories, the narrative style emerges as an eminently reasonable chocie when presenting the findings. Barkers approach was semi-structured interviews which allowed the informants to choose more freely what to talk about in certain topics. Examples from the general topics are why interviewees participated in the program, and what activities they and their partners (students, faculty mentors, or graduate students) engaged in.

The semi-structured interviews focused on some categories of experiences. Following those lines of thoughts the interviewer asked open question based on the answers given. Working in this manner it was possible to:

> [...] probe certain issues that might not be easy to write on a survey. (Barker, 2009, 5:6)

Barker's collected interview data was then transcribed and analyzed. The results was in line with grounded theory (Strauss & Glaser, 1967), which is an inductive and iterative process of letting different themes emerge data. The researcher works with the raw data, listening to the interviews twice and reading through the transcripts carefully. Different themes, for instance motivations, perceptions, outcomes, and suggestions for improvement, were then identified in the data. Finally, interview transcripts were coded in the interviews and sorted into different categories (Barker, 2009, p. 5:9). Barker then presents each theme, with a story that serves to illustrate and contextualise it. Both cases and excerpts from interviews are intertwined in the stories.

An educational study of Craig (2009) uses an approach similar to mine. Experiences are collected and combined in order to make new stories describing more complex conceptions on knowledge in knowledge communities. Craig summarizes the approach as follows:

> [...] I temporally assemble relevant narrative excerpts from my existing scholarship conducted in multiple school sites in order to stitch together a new story that examines what teachers cumulatively came to know in their knowledge communities [...]. (Craig, 2009, p. 1040)

An important difference is that Craig is using pieces from different people's experiences and combining those to form a new story. Craigs stories does not reflect an individual's reality, but contribute insight based on the collective experience of the interviewees. Therefore, the stories Craig presents are well-informed fictions, while the stories Barker presents are actual experiences.

## 11.2 Current method

In my study, data was collected in June 2009 from 11 students participating in a computer science project course. The goal of the project course was to design a rescue robot. The project team consisted of 22 students. The students selected for interview represented a great variety in terms of study background, stated interests and project roles. Semi-structured interviews where used. Each interview were between 29 and 48 minutes long (data also described in section 12.1). The method used for the analysis is similar in many ways to that of Barker (2009), but with some differences. The initial step through which the conceptual framework of key features was derived, which now are used to categorize interview data, was performed by an approach similar to grounded theory.

The objective was to get students to talk about their experience in relation to the key features. The categories of questions used in the semi-structured interviews, were informed by the key features described in chapter 6. Hence, questions asked and discussions that arose during the interview process often focused on these key features. This allows me to view how students perceived their engagement, or lack of engagement, in the project practices. Interviews were recorded and transcribed as described in section 12.1. Analysis of the interview data involved both clustering of experiences connected to the key features, and establishing relations between key features and identified important practices in section 10.3.

In the first step of the analysis, the recorded interview data was listened to by the researcher, with the aim of noting the major themes discussed. Transcripts were then read through twice to identify more themes and identify traces of them. The themes that emerged were compared to the key features that emerged from the first phase of the research, in order to establish that the desired discussion of key features was present in the data. With one exception, the key feature regarding external stakeholders, this was the case. Absence of statements relating to external stakeholders should not be regarded as problematic, however, since the studied project did not involve any external stakeholder. The second step was to code the original transcripts using the qualitative coding program NVivo. NVivo helps to automate the tedious work of categorizing large sets of text, in this case interviews. NVivo gives the researcher support in the systematic work of identifying relationships and patterns that exists in the data. Although NVivo provides a systematic approach, it also is specifically designed to support qualitative data analysis, which makes it particularly appropriate for this phase of my research. The coding resulted in a set of codes, equivalent to the earlier found themes. After coding, those sets consist of excerpts from the transcripts supporting the themes and illustrating them. In the third step, I coded the original transcripts based on the identified important practices, presented in section 10.3. The same method as the coding of key features in the second step was used. After the coding, we now have two different set of categories with excerpts illustrating those categories. The fourth step is to combine these sets, in order to obtain useful insights on students' experiences of the tensions and synergies between important practices and the key features.

The analysis in the fourth step was conducted by setting up matrices, where key features were columns and important practices constituted the rows. The two different sets of excerpts were then analyzed in order to find intersections, experiences of key features that influenced important practices or vice versa, between the two sets. Experiences that connected a key feature to an important practice were marked in the matrix. When the two sets had been analyzed, the result was a matrix showing present and interesting intersections. The general matrix is presented in table 11.1.

| | **Mechanism for work allocation** | **Connection to external stakeholders** | **Focus on result or process** | **Level of freedom in task** |
|---|---|---|---|---|
| **Practice 1** | Observed connection | Observed connection | | |
| **Practice 2** | | | | Observed connection |
| **Practice …** | | Observed connection | | |
| **Practice n** | | | Observed connection | |

Table 11.1: *Matrix showing the general idea for finding intersections by combining key features and important practices, real data are not present in this general illustration. Cells are filled by interesting observations from interviews.*

In the fifth and final step of the analysis, excerpts in each column in the matrix are traced back to their original interview. Interviews showing a high presence of findings in a given column are selected as candidates for use in constituting a story.

The stories, illustrate how important practices are connected to the key features, and are told using the collected data excerpts for illustration. Data from different interviews can inform the same story, but patching a story together from the experiences of multiple students has been avoided. Each story is a full story, which means that some context information is repeated in all stories. In total three (the key feature regarding external stakeholders is excluded since no such external stakeholder were present in the project course studied) stories, one for each feature, are told in the following sections.

### 11.2.1 Ethical considerations

Kvale (1997) discusses the ethical considerations associated with interviewing, and especially the confidentiality of the interviewee (Kvale, 1997). In order to preserve confidentiality, the interviewees' names and other personal references are removed from the transcripts presented in the studies. In order to preserve the integrity of the interviewed students, all names have been changed. New names have been randomly chosen without any attempt at 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. An example script can be seen in appendix. In addition to practices adopted from Kvale (1997), the research ethics were closely guided by the recommended rules of ethics from the Swedish Research Council (Vetenskapsrådet, 1990).

## 11.3 Reliability of the current method

Chapter 7 discusses the reliability of the research included in this thesis in detail. The method presented in this chapter will not get such an extensive walk through of its reliability. Nevertheless, it is interesting to discuss if the previously performed discussion of reliability could hold as well for the current method?

Recalling the reliability discussion from chapter 7, the 7 principles for interpretative research presented by H. K. Klein and Myers (1999) were used as probing tools. These 7 principles are: the fundamental principle of the hermeneutic circle; the principle of contextualization; the principle of interaction between the researchers and the subjects; the principle of abstraction and generalization; the principle of dialogical reasoning; the principle of multiple interpretations; the principle of suspicion. I will apply a short reasoning on some of the principles in order to establish the current method as reliable.

The fundamental principle of the hermeneutic circle suggests a continuous shift in focus between the whole and the parts of which it consists (Gadamer, 1976). In the current method, analysis of each interview is a process where parts in the interview are selected. Those are then put together with other interesting parts to form a whole. The whole then enlightens us in terms of understanding the finer details and context.

The second principle, contextualization, states that the social and historical context should be presented alongside the current results. In the current method stories describes both interesting findings and context from the project. The results are reflected in the context and vice versa.

Let us jump to 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. In the current method, an assumption that there exists information in regards to the students experiences of practices seen as important by teachers. This assumption is a necessary starting point for the analysis. This assumption is also clearly presented. Hence it is transparent to the reader as well as possible to evaluate.

The final principle I will use in this discussion, is 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. Revealing, documenting and reasoning about such context bias in the empirical findings is therefore necessary in order to follow this principle (Ricoeur, 1981).

In the current study, not only the interviewed students are seen as data. The teachers' interpretation of the curricula, and the formal course descriptions are also data. These additional data informs the analysis by providing a clear context in which the students' experiences are shaped. This permits us to identify what context the students have been exposed to, and thus more easily avoid the tendency towards biased interpretations.

I argue that this illustration of conformance with key aspects of H. K. Klein and Myers (1999)'s principles in the current method supports the conclusion that this is reliable interpretative research.

# 12. Data and results

In this chapter, collected data is presented together with an analysis and results. The data is analyzed based on the four key features derived in earlier sections. Using the key features as a filter, or sorting tool, for experiences of activities in student projects, provides a deeper understanding of the student interview data. The aim of the analysis is to find out more about the students engagement in desirable practices and how that is connected to the project features and course design.

Guided by the four key features identified in earlier work (Wiggberg & Daniels, 2008), I have interviewed project members about their practice in the project and its relation to the key features. The aim with the study was twofold. Firstly, I wanted to learn how the practices stated as important by the teachers are reflected in students' approach to working within the project. Does the teachers' intention in regard to practice influence the way students engage in practices? Secondly, I wanted to learn in what way the same practices are influenced by design choices related to the key features. Do certain design choices for the project itself affect learning and learner's priorities?

First we present an overview of the collected data. Second, a general introduction to the results, presented as stories, is given followed by three stories. Finally, a summary of the result is presented.

## 12.1 Final data sets

The data included in the two final studies in this thesis is of a varied nature. The data is collected at four points over the course of two years. Before we commence an analysis the final set of data is described; both how it was collected and when it was used. A summary of the data is presented in table 12.1 and the questions used during the data collection is attached in appendix.

## Data Set D: Project surveys from 51 students

A survey on working habits, learning outcomes, contribution and team processes was used as data collection instrument for data set F. The survey was answered during March and April 2008 by 51 participants of the Runestone course. This instance of the Runestone project course had 63 participants

*Table 12.1:* Final data sets.

| Data set | When | Method | Use of data |
|---|---|---|---|
| D | 2008 | Survey | Analysis and design of questions to data set G. Adjusting key features |
| E | 2008 | Survey | Investigating which students to ask for biographies |
| F | 2008 | Biographies | Analysis and design of questions to data set G |
| G | 2009 | Semi-structured interviews | Application of the key features |
| H | 2009 | Semi-structured interviews | Informing the study about teachers views on project courses, and desired practices |

| Data set | No. Informants | Male | Female | International students | Cohort |
|---|---|---|---|---|---|
| D | 51 | 50 | 1 | 28 | Five week computer science course, year 3 |
| E | 17 | 16 | 1 | 8 | Full semester computer science course, year 4 |
| F | 6 | 5 | 1 | 2 | Full semester computer science course, year 4 |
| G | 11 | 11 | 0 | 0 | Full semester computer science course, year 4 |
| H | 2 | 2 | 0 | 0 | Course responsible teachers of the project courses |

from Sweden, USA and Finland. The participants are working in 9 teams of seven students each. The teams were given the task of constructing software/hardware system. Each team had students from two countries. Each team had a team leader that was actively participating in the work. Previous instances of the Runestone course are described in several works, e.g. Hause (2003); Last (2003); Pears and Daniels (2010). The data set D were used as background material for the questions asked in data collection G, and also used to adjust the key features.[1]

## Data Set E: Self-evaluation of capabilities from 17 students

Participants in the same project as described in section 12.1, contributed with additional data in November 2008. This time, the whole group of 24 students were asked to take a survey on self-evaluation of capabilities. 17 answers where recorded. The survey and stated capabilities where inspired by Acuna and Juristo (2004, p. 680). The data set E were used to investigate which students to ask to contribute biographies to data set F.

## Data Set F: Biographies from 6 students

Data set F was collected in September 2008 from six students participating in a computer science project course. The course had two projects related to development of systems for mobile phones, one creating a next generation instant messaging system based on the IP Multimedia Subsystem (IMS) and one location based mobile game that forces the player to interact with the physical, real, world (Ekberg et al., 2009; Monshi et al., 2009). Both projects collaborated with partners from the industry, i.e. Mobile Arts, Ericsson and Green Hat People. The two projects together involved a cohort of 24 participants, divided in two equal groups.

Short biographies were collected by asking the students four questions about their view on participation, freedom, work allocation and focus in the project. Each student participating in the data collection had roughly 40 minutes to answer the questions in written text. They where also asked to write a narrative text, a story, on their views. The data collection method is similar to *computer-biographies*, described by Schulte and Knobelsdorf (2007). The main difference is that computer-biographies mainly ask for computing experiences, while this data collection was about experiences of different aspects of computer science project work. It is important to recall that we are using this method of data collection in order that, students:

[1]The data collection design and some initial analysis were done in collaboration with Petra Ornstein, Department of Statistics, Uppsala University, Uppsala, Sweden.

> [...] not only describe objective events and experiences but relate them to their personality and add personal attitudes and opinions. (Schulte & Knobelsdorf, 2007, p. 31)

Participants in the data collection came from two different groups in the project. Six students were selected, based on their previous interest and experiences in project work, their roles in the current project and their study background. This procedure was aimed at getting such wide experiences as possible. The data set F was used as background material for the questions asked in data collection G.

### Data Set G: Interviews with 11 students in 2009

Data set G was collected in June 2009 from 11 students participating in a computer science project course. The project course was about designing a rescue robot. The project team consisted of 22 students. The students selected for interview had varied study background, stated interests and project roles. Semi-structured interviews were used. The same approach as described in chapter 5 where used to collect the data. Each interview was between 29 and 48 minutes long. The data set G were used for the application of the key features in the communities of practice framework.

## Data Set H: Interviews with course responsible teachers in 2009

Data set H was collected in September 2009 from the two teachers at the Department of Information Technology, Uppsala University. The two teachers were responsible for the project courses investigated in data set A, B, E, F, and G.

The reason for interviewing the two teachers, was to obtain additional information on what is thought of as being the core aspects of the project courses. Together with information from the formal course curricula, data set H was used in the analysis in this thesis. One of the interviews was held face to face, and the second one via e-mail. In both cases a questionnaire with general areas of interest and starting questions was used. The interviewer also came back to the teachers' with one round of follow-up questions. Since the data set H was used as a probe in the analysis and affects the full analysis, it was of importance to get the teachers' views correct. Therefore they got the possibility to read through the conclusions drawn from the interviews.

## 12.2 Project stories

In this section, three different stories collected in data set in section 12.1 are presented. All stories are from students in project HUGE[2] in spring 2009. The aim of project HUGE was to develop rescue robots, and the project involves building upon software and hardware from earlier instances of the project course. To achieve the main objectives of the project, the team needs to build rescue robots that are capable of autonomously locating victims in hazardous environments. This includes using advanced sensor systems as well as advanced communication between robots. An overview of the robot system is presented in figure 12.1. In the final report for HUGE, the project team describes the task as:

> The focus of Project HUGE has been the development of autonomous rescue robots. The robots are meant to be part of a rescue crew, dispatched to an inhospitable environment, such as a disaster site. The robots should be able to map the environment and identify victims. The robot system, consisting of several collaborating robots, is supposed to gather information about the environment and distribute it amongst themselves and the rescue crew. Due to the unknown nature of the environment, the robots must be able to work autonomously and employ robust communication protocols. Should the network uplink break, the system must be able to continue working until communication can be re-established. Additional functionality, such as the ability to determine the condition of the victims, identify hazardous materials or dangers, can be implemented.(Abbasi et al., 2009, p.5)

This project is run in essentially the same manner as the project described in chapter 4. Seventeen students participated in the project. In this particular instance, no company was involved as an external client. Instead, the team of teachers acted as clients, specifying the high level requirements. Students at the course used SCRUM[3] as project method. Despite SCRUM, they had total freedom in setting the organization (Abbasi et al., 2009).

In a section following each story, I discuss experiences connected to the practices I have identified that are relevant to the current story. The practices exercised in the projects should help the students' to move towards the larger community of IT-workers. Let us revisit a summary of the actual identified practices in computer science student projects, that teachers conceive are contributing to this developent:

- *Training in working with an external stakeholder, usually an external company involved in the project.* This implies working together with an ex-

[2]HUGE is a name borrowed from the Nordic mythology, and follows a naming tradition in those courses.

[3]SCRUM is an agile software development framework, where work is structured in cycles of work. SCRUM is hence more process oriented and iterative, than for example the classical and linear waterfall model (Rising & Janoff, 2000).

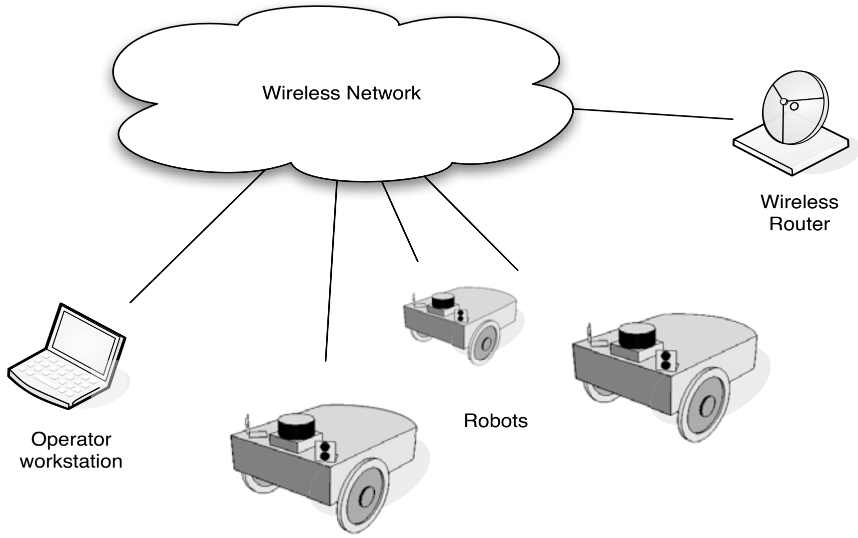


*Figure 12.1:* An overview of the robot system (Abbasi et al., 2009, p. 5).

ternal stakeholder that is seen as a representative from the community of IT-workers.

- *Working efficiently and constructively in a large project team of developers.* This implies cooperation among students in the project and benefit from different experiences. Skills and cooperation is catalyzed in the project environment.
- *Planning and follow-up of a complex project task, and taking care of unexpected things that might occur.* Being able to deal with unexpected problems and situations associated with the task, that might manifest themselves during the project.
- *Gaining experience in applying previous knowledge, and learning skillful use of tools used in the community of IT-workers.*
- *Integrating smaller tasks into a larger task.* This involves testing, communication on interfaces, and planning.

These identified practices will also be discussed in the light of the concepts of legitimate peripheral participation in communities of practice. To remind ourselves, legitimate peripheral participation, presented in section 9.1.1, is a theoretical description of how newcomers, people who are new to the community, who enters a community of practice can become more experienced members of the community of practice. Starting with less prestigious low-risk task a participant can starting to get acquainted with the communities tasks, cultural expressions, skills and other expressions of the communities shared repertoire. As time goes by the member becomes more senior in the community and gains access to the more central functioning (Lave & Wenger, 1991).

The important observation and mechanism from the theory of legitimate peripheral participation, is that newcomers who gain access to experts and can study their practice, understands their own activities within the community. In contrast, newcomers with less access to the more central members of the community have a more flat learning curve (Lave & Wenger, 1991). Legitimate peripheral participation hence can be used to reflect how members of the community, through their actions and shared practice, can become more experienced members of the community. Through "doing IT professionalism", they will also be more engaged in different practices in the community. This reasoning can be transferred to the studied project and connected to the experiences in the stories of the students'.

## A matter of motivation and work allocation

Olof is an engineering student in information technology that would like to work in the IT business. Olof participated in the project HUGE. During the course, Olof and the other participants were expected to experience practices identified as important for the movement into the larger community of practice of IT-workers. These, described in detail for the current course instance in chapter 10, are: working efficiently and constructively in a large project team of developers; planning and following-up a complex project task, and taking care of unexpected things that might occur; gathering experience in using prior knowledge, and learning how to use certain tools used in the community of IT-workers; and integration of smaller tasks into a larger task. Students participating in the course had these practices highlighted by the team of teachers and, to some extent, had also been reading about them in the formal course description?

Olof has attended the student project reasonably motivated. Olof knows his mates from before the project, and feels that he isn't afraid of making himself and his needs apparent to the group. During the project, Olof has been thinking a lot about how the process of work allocation is implicitly and explicitly handled in the project group.

Initially Olof reflected on the number of people in the project. Olof says that his ability to get an overview of different subtasks and work performed was low because of the complexity of the main task. The number of teammates in the project made that situation even harder. He was worried that this would mean that he would have a harder time getting involved in discussions and learning from his fellow students:

> **Interviewer**: How has it worked out in the project, have you worked together... it is a pretty hectic time period with....

> **Olof**: [...] well it could be a disadvantage that we are as many as we are. There is a focus on one's own piece at the cost of not getting an overall image of it all, as one surely would have if there had been fewer in the project. One would have had to know about all the things then.

Since Olof had thought about the course beforehand, he also had developed expectations on the course and the work in the project. During the project course Olof got his expectations of peer learning partly confirmed. Sometimes and in smaller groups, rewarding discussions on technical challenges were held, as will be discussed in more detail later. Sometimes the team had to split both the task and the work in smaller pieces. Olof had the feeling that they had to do that to a larger extent than they initially wished:

> **Interviewer**: How do you collaborate, like do people work with different things, or do two or more collaborate on the same thing?
> **Olof**: We have said earlier, or rather from the start, that we would try to sit down [together] more when doing ordinary programming. But unfortunately this didn't happen as much as we wanted due to lack of time.

Lack of time, the complexity of the task and the stress those two caused are suggested as reasons for less communication among the teammates. The stress led to more solitary work and less interaction between the teammates. Continuing the answer on the question above, Olof describes this situation:

> **Olof**: We needed to divide ourselves a bit in order to manage to do everything. That is a bit unfortunate since one does more mistakes when one work alone and don't have anyone to discuss with except when one is really lost and knows one really has to talk with someone. It thus doesn't get to the same cumbersome walkthrough and ends up with the same feedback as on everything else one does.

These thoughts on stress as a factor for limiting discussion and peer learning are mixed with Olof's impression of how the members of the project chose their tasks. What each person does in the project is decided based on personal interest:

> **Interviewer**: What lies behind where one ends up? I have understood that you have divided the tasks.
> **Olof**: Well, at the start it was by interest. Partly what one might have seen as fun or what one feels one should sort of try out.

Olof thinks that the level of competence should be close to equal since all have similar backgrounds. Starting from an even level, Olof feels that people soon are being specialized into different sections. Discussions are hence less frequent after some time since fewer people have the kind of detailed information needed. In Olof's opinion, each student has the responsibility for his learning during the project. He says that it can't be the teacher's responsibility. This belief that teachers do not have responsibility, has led to some shortcomings in respect to the desired learning since some mates haven't taken this responsibility. Those project members, reasons Olof, have an impact on the rest of the students in the project. Their lack of seriousness affects the learning opportunities in the project, especially for Olof and others who would like to learn much. Ownership, says Olof, is also something that varies accordingly. Those who see the project course just as any another, in terms of credits valuable, course got less ownership. Olof tells that it feels like these don't belong to the project in the same way:

> **Interviewer**: Are there some in the project that belong to it more than others?
> **Olof**: That is my definite impression. Yeah, those that feel that they, well, knows more are hugely engaged and stay on in the room and feel that they, that they really want it to function, yes it is clear that there are such persons. There are also those that feel like this is just a course they happened to take.

This also leads to some clustering of ambitious students around more important parts of the project. Olof has a hard time defining what parts are seen as important, but returns to parts that are crucial for the development of the physical deliverable as important.

**Discussion**

This story is based on the column belonging to the key feature *mechanisms for work allocation* and the general aspect motivation is highlighted. Olof's descriptions and impressions on how work was allocated and the consequences provides insights from a student point of view into most of the practices identified as important in section 10.3. The story blends them together and I will try to unravel the effect on the practices one by one to assist in interpreting this story.

One of the main practices mentioned, cooperation among students in order to make them learn how to work with colleagues, and learn how to combine different tasks into a main project, are in focus in Olof's story. The desired practice *working efficiently and constructively in a large project team of developers* is in parts well implemented. Both the project, in terms of the complexity of the task, and the number of developers is large. But, according to the collected experiences, the efficiency and constructiveness could be improved. Olof points out how problematic it is to gain experience of this aspect of working practice in a project.

The practice *getting experiences of applying previous knowledge and learning skills of tools used in the community of IT-workers* is affected by the divide-and-conquer behavior adopted by the students. When students divide such a complex task, and at the same time feel stress about fulfilling the task, it leads to students working within a narrow field. While it might be fair to assume they will be experts, or at least more skilled, in that particular field, it will also restrict them from learning in other areas. Since much time is spent on a specific task it will become difficult to switch to other tasks. This switch is further restricted by the perceived stress. Knowing that the project consumes 20 weeks of study, the experience of applying previous knowledge could extend to more fields. Overall, there is a risk for conflict between deep learning in one specific technical area, and enriching knowledge in a broader sense.

Perceived stress in the projects seems to predispose students to adopt more of a divide-and-conquer appraoch, affecting the practice *integrating smaller tasks into a larger task*. The divide-and-conquer approach to the project tasks not only separate the tasks, but further separates the students, thus making it more difficult for them to share goals, feel that they are doing this together, and therefore share the experience. This problem gets worse and worse the more they divide. The experience described does not mention positive effects of this, it rather illustrates the limiting effect it has on discussions. Valuable discussions are lost, and hence the number of peer learning situations are reduced. It is especially interesting to note that the more tasks were divided up, the harder it became for the students to help each other. Here, the number of people involved in the projects could be problematic, since it makes it harder to get an overview of the project, and hence the opportunities for sharing knowledge become fewer. In terms of legitimate peripheral participation a development towards less interaction is not fruitful since members of the project/community will not be able to share and thus become more central in the projects.

Practicing *integrating smaller tasks into a larger one* is problematic in Olof's experience. Olof identifies the general complexity as being too high, and there being too many people involved for him to get the overview needed to perform both a nice integration and an effective environment for peer learning. Time pressure, leading to stress is a factor that also influenced the manner in which Olof's friends used their peers in discussions. When the students had to divide the work, they also lost some of the valuable discussions that created learning opportunities.

It is clear that Olof felt profoundly influenced by how work was allocated in the project and also that he at times only had a fuzzy understanding of how it was done. Bringing up Olof's thoughts on learning, it is clear that he views it as each student has its own responsibility for learning during the project. This belief is somewhat in contradiction to what one of the course responsible teachers' says, when he states that the reason for the complexity of the task is to function as a catalyst to force the students to collaborate, thus securing the goal of achieving collaboration among the students.

Olof's comment that the responsibility for learning is the student's and not the teacher's is interesting. The intention of student learning with the course, and its design to meet the intention, seems to be ignored by Olof. Blaming fellow students for the negative impact is hence the result of Olof's analysis. The intention with the course, increased learning through the project, seems to be forgotten, which might imply that this intention was not foremost in Olof's mind. The failure of the course design here means that students don't really have access to the practices which will lead them to increased learning. While it is up to the student to engage, and therefore their responsibility, the course should also be designed in a way that accounts for differences in personality, drive, etcetera.

Another very interesting thing that emerges from this story, is when Olof describes the students' own level of responsibility for learning in the project. This has lead to some of the members not taking that responsibility and placing themselves apart from the tasks that matter in the project. This does not help the process of legitimate peripheral participation, nor gives the students enhanced learning. It is also possible that the highly motivated students dominate the important tasks and basically prevent less dominant students from being fully involved.

It is interesting to note that the way Olof experienced this had both negative and positive implications on how it affected the set of important practices, i.e. how it influenced his role as legitimate peripheral participant or central participant. It is for instance doubtful that he got enough training with regard to working constructively in a large project team, but had ample practice in *integrating smaller tasks into a larger task*. This should not be seen as a critiquing the teacher, but rather as an indication of the high complexity of the goal, i.e. to aid the students in becoming members of the community of practice of IT-workers.

The practice *training in working with an external stakeholder, usually an external company involved in the project* is not a current issue in this story since no company or other external stakeholder was involved. But the lack of such external stakeholder is an issue, and will be discussed in next story. Likewise will also the practice *planning and following-up of a complex project task, and taking care of unexpected things that might occur* be present there.

## Denoting focus on result or process

Hjalmar is participating in the same project HUGE, described above in Olof's story. Hjalmar has, due to involvement in extra activities in the project at a late stage in development, got a fairly good overview of the entire project. During our interview, Hjalmar refers to different parts of the project in order to illustrate mechanisms or thoughts he raises. Starting from the discussion on work allocation we came to talk about how the group makes sure they work on what they need. Hjalmar believes that it is very much up to their own choice for the students in terms of trying to meet the requirements of the project task:

> **Interviewer**: How do you make sure that [...] the group do the things you need?
> **Hjalmar**: It is a bit up to each one to do so I think. Well, some are able, some have chosen to do things they know they can do in that they sort of won't be looking stupid or incapable, and some have been sitting here, sort of to learn things. Maybe to complement with things they miss. Well, it's up to each one what to do.

Hjalmar gives us the impression that students can chose to do things the feel sure about, but also take on more challenging tasks in areas they think they need more knowledge in. So both strategies are present, and Hjalmar's experience is that they make these choices themselves. In the early stage of Hjalmar's experience, he relates this to a matter of work allocation. Hjalmar has a mature observations on the same question:

> **Hjalmar**: And we have tried to, at the same time, jump around a bit between areas within the project [...]. Then I feel that, no I want to, no I actually want to perhaps start coding a bit and, well I chose to do it because I felt that it was a weak spot for me.

What Hjalmar talks about here is that a fair amount of flexibility is allowed during the project, when it comes to choice of task. That means, if someone would like to try to do something else, that would be ok. This is an important thing to remember as we continue our story. But, the flexibility in terms of choosing tasks is mostly present at the beginning of the projects. During the interview, it is clear that the amount of reallocation of tasks that happens becomes more and more rare as the project moves along (clues for this development are given later on in the story).

The question of how to make sure people do what is needed, led to initiated and engaged answers, where Hjalmar said that this was an issue during the project. In the final part of Hjalmar's answer, an important discussion is raised about the aim with the project and the connection between that aim and peoples' choice of task and behavior. Hjalmar mentions that he felt the conflict of interest between maximal contribution to the project and its expected physical result and the learning outcome. In Hjalmar's experience, this dualism is an ongoing question. He concludes, or argues, that the project is a course where the opportunity and responsibility to learn is in focus. The learning focus is for him more important than the production of the robots:

> **Hjalmar**: So I saw it more like a sort of course where I learned instead of that I, well should contribute as much as possible. There is this issue, should I really do the things I'm best at, and thus contribute as much as possible, or should I get something out of this and, well, learn something. Because otherwise, well, I felt, I took things I wanted to learn as well. It is actually a course.

Overall, Hjalmar's different answers and discussions during the interview are influenced by the topic of dualism between producing and learning. In an interview with Claes, from the same project group, the same experience is evident:

> **Claes**: We have discussed it, we've said it, but this is a course and the purpose is actually that we should learn a lot, sort of.

Claes and Hjalmar's shared experience illustrates the dualism between contributing to the desired product or putting the learning outcome first. This is a real issue for the students. The choice that Hjalmar has identified here is also used by students in different ways. Since the choice between seeing the project as a learning opportunity or a production of a desired task, is shared by many students I let Claes take the story forward. When I ask Claes about how he thinks that other students approach this, he tells us that the perceived choice between focus or process was a worry for the project members:

> **Interviewer**: How did the others view it, this actual issue. Have you reasoned about this?
> **Claes**: Yes, actually we have [...] It is a lot in the beginning; it felt like we should sort of produce a lot, to deliver. And people were scared of sort of making mistakes and it was really like this.

Here we have a clear experience of, with regard to Hjalmar's initial choice, the other point of view, where the interpreted pressure to make results heavenly influences the students' choice of actions and practices during the project. Hjalmar and his fellow students feel an implicit pressure to produce, while at the same time wanting to take advantage of the opportunity to learn, and have also had a discussion about how to interpret the fact that they were participating in a course. Hjalmar has experienced discussions about which mistakes are allowed for the sake of learning. The project groups' discussions dealt with people's worries about making mistakes. Hjalmar explains:

> **Hjalmar**: [...] but this is still a course. We are allowed to make mistakes; we learn from making mistakes. Well we are a sort of afraid of making mistakes and it was brought up in order for us to become more daring [...]

Another interesting experience that Hjalmar shares during our discussion is about different status in different tasks. Hjalmar has been working on testing and functionality. He describes a feeling that testing, although critical to ultimate success, is more of a supporting activity. Let us listen to how Hjalmar reasons about this:

> **Interviewer**: What were you doing?
> **Hjalmar**: Well, testing stuff sort of. And... it didn't feel like a high status thing to do, really. It was rather like this, well, I don't know, it was also sort of the reason I chose something else because I felt I wanted to deliver, well, to get acknowledgement also on it sort of, that I've done something. Not just like

> this, ah well I know myself that I've worked. It has also been important to get recognition for it.

It is clear that Hjalmar has been experiencing how less progress oriented tasks can be seen as contributing less to the project. Hjalmar's reaction to this was to choose another task. The main arguments given in the excerpt above, and also given in other parts of the interview, was desire for acknowledgment from fellow participants and a desire to contribute in a visible manner. Claes gives an example from the project where the need for, or desire to reach, results is superior. On the question:

> **Interviewer**: Was there some situation where someone [said], I'm good at this, you know I am, but I don't want to do it.

Claes answers that in similar situations, people reasoned in favor of achieving of the desired outcome. But, it is also a testimony to how the students' reasoned about the dualism between learning and producing. Claes especially notes the slight difference on changing tasks later in the project:

> **Claes**: And then I said that, the best would probably be, if we took the guy that is very good at programming and had him doing the coding and that we take some hardware guys and let them work on the hardware and let them work on it all the time, it will be for the best. But it is not for that reason we take this course, and it has been so that one has changed groups and so to learn about everything. And then when one has changed group then one had to start from scratch sort of, and it takes a lot of time, when one learns from the start.

It is especially interesting how Claes notes that a change of groups, and hence task, also means starting at a lower position in terms of knowledge on the new task.

### Discussion

This story is based on the column belonging to the key feature *denoting focus on result or process*. Using the result or process feature as probing tool, reveals some very interesting experiences of the students' how the they regard engaging with either the process of learning or the production of the desired artifact. The dichotomy between producing a physical artifact and the process of learning is present. The mediating zone is where each student, or the team itself, negotiates and renegotiates how to handle the dilemma between contradictory demands, and where doing one often means failing in the other.

The story shows that what seems to be a matter of work allocation is connected to what is recognized as important to do in the project. And what is important in the project is decided based on a focus on either result or process. In the collected experiences, the focus has shifted from learning, and hence the process, to the product. Things that might not seem to drive the work towards the desired product could be less acknowledged in the group. This is independent of if the tasks are seen as less important in the scope of the desired identified practices or not. Tasks not acknowledged, but identified as important practices in relation to the community of IT-workers, should not be avoided since that will affect the desired learning.

It seems like it is very much up to the students what to work on in the project. At least this is true in the initial phase of the project. But we also have experiences of fellow students considering placing people in different positions based on their initial skills. In either case there is a discussion on these issues among the experiences caught. Due to real or imagined time pressure and a focus on results, fewer and fewer shifts in tasks are made in the later stages of the project. At this time the cost is recognized as too high in terms of obtaining new knowledge connected to the new areas of work. This also affects the dynamics of *planning and follow-up of a complex project task, and taking care of unexpected things that might occur.* More stress tends to lead to higher degrees of specialization. Hence the unexpected things people have to take care of most often relate to their own piece of work. What also happens when the degree of dynamics lowers, is that crucial parts in the development of community of practice, the development of shared practices, are missed. The transition to become more central members of the community thus becomes harder.

Hjalmar's experience about letting students choose positions more freely may lead to people doing what they already know, is interesting and perhaps not completely positive. The process of developing the shared repertoire will be less rapid, since members continue to focus on the things they already know. The learning part of the community, or project, then tends to be smaller.

The clustering of ambitious students around more important parts of the project might also work against the desired practice of *getting experiences of applying previous knowledge, and learning skillful use of tools used in the IT-community*. Those students not taking part in activities recognized as important might have a harder time to both apply their previous knowledge, and learn skills of tools used in the community of IT-workers. The latter is true because it is likely in the projects that things that seemed to be of importance are also connected to core skills in the larger community of IT-workers.

Ending up with a less important task does not seem to contribute to the practice of *working efficiently and constructively in a large project team of developers.* This causes Olof to bring up an experience with different motivation and ownership detractingfrom cooperation on the important part of the tasks. Students' beliefs about individual responsibility, the complexity of the task, and the lack of mechanisms to ensure that all students can take part in important practices results in neither learning nor engagement in practices leading towards becoming members of the community of IT-workers.

One of the identified practices, *getting experiences of applying previous knowledge, and learning skillful use of tools used in the community of IT-*

*workers*, might also be less productive under the experiences collected. For instance, if the use of previously obtained knowledge is one goal and the participants feel time pressure to produce, the experiences collected indicate that students' tend to work with things they already have good knowledge in. They do this despite the fact that they thus are missing out on learning things in less well known areas, and this behavior also leads to some participants ending up with tasks with lower acknowledgement. Although important, these might not lead to increased learning or involvement in the more central tasks of the project. These results are also supported by Barker (2005) who report from a study where believed pressure to finish projects for clients, led to students choosing project role based on comfort. Barker argues further that 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. Overall, when the discussion centers on issues such as being able to learn, or produce, the focus is pointing in the wrong direction, it should instead be about choices made and remade in relation to the general learning aim and identified practices.

To summarize, the project is seen and discussed as being a course. There are several moments during the development of the project when students' think of the dichotomy between getting as many different experiences as possible, versus producing the physical artifact. One interpretation is that the reality of the project, and the desired result, has the advantage that students realize the complexity and amount of work needed in the project.

## Level of freedom in task

Ingvar is an engineering student in information technology who would like to work in the IT business. Ingvar participated in project HUGE, described above. Ingvar has been a reasonably motivated participant in the student project. Ingvar knows most of his teammates in the project from earlier courses. At the beginning of the project Ingvar has spent quite a lot of time thinking about the course. According to Ingvar it is more of a learning experience, where being able to experience the desired practices is the goal, rather than just producing a rescue robot. Ingvar relates that his teammates discussed this:

> **Interviewer**: Which was the task in the project?
> **Ingvar**: It rather felt as if.. for me it felt like it was that we should develop ourself as persons. It is not as if we should develop something that should be able to do certain things.. sure, it was the assignment in one way, but it was not the mail goal.

Ingvar elaborates on the fact that the team of teachers acts both as mock clients in the projects, and as examiners of the students. Ingvar thinks that this combination sometimes led to odd situations in the way they would interrupt in the decisions made with regards to the task itself. The team of teachers are acknowledged for their experiences and expertise in technical matters. At the same time, they are seen as interfering too much in design decisions. This is expressed by Ingvar when he says:

> **Interviewer**: Can you describe a situation where the group and the teachers discussed?
> **Ingvar**: I know that several things we discussed, for example many of the parts related to image processing were things we had worked quite a bit on. We then had design meetings where the students had suggestions about what to do and had investigated the particular technology or area. We presented this for the teachers and they had the opportunity to ask questions which we answered as good as we could and motivated why we wanted to do it. If they didn't think it was a good idea then they told us so and motivated why they thought so.
> **Interviewer**: It was thus the case that the teachers had the final word about this?
> **Ingvar**: It felt like so... ok... it felt like they were the ones with more experience of this. They had been involved in more projects with robots. Although it felt like one [the students] had really good ideas but they wanted something else and then it felt like they had a different agenda... as if they didn't see the things from the same perspective.

What Ingvar tells us here is that the level of uncertainty makes the work more stressful, since the team has to work in different directions. According to Ingvar, they don't interpret this uncertainty as being planned.

The teachers interference in how the team solved different things on their way towards the goal, also had other consequences. Ingvar talks about the degree of ownership, how much the team feel that the project is their baby:

> **Interviewer**: How was the learning objectives effected by the product goals?
> **Ingvar**: These affected each other, absolutely. If we had had the chance to continue with our own solutions it would've lead to very different results, but it would perhaps not been as good a result. We had some ideas that we thought were great, but which we were unsure about if they would work. It would've been cool if they had worked. If the group had been allowed to continue with them. sure it would've lead to quite a few wasted work hours, but it would've been something that had been fun to do. When they [the teachers] dismissed our ideas we got a strange feeling, like a pity that we weren't allowed to do it, but...
> **Interviewer**: What would have happened if you had been allowed to continue to work on it?
> **Ingvar**: would've felt like it was more of our project. That it would have felt more like our baby than the school's... sort of a feeling of ownership.
> **Interviewer**: What happens when you feel ownership?
> **Ingvar**: Well, one gets more engaged when one feels it is our thing.

What is interesting here is how much the software and hardware means to the team, despite the reduced degree of ownership resulting from the teachers interaction. A major impact on the feeling of both ownership and engagement in the current project is due to being forced to use software and hardware from previous course instances. Let us listen to Ingvar again:

> **Interviewer**: What happened then, at the beginning?
> **Ingvar**: In the beginning it was thus that... that it was somebody else's code that one had to get ones head around. Then, when we did more ourselves, one became more involved.

Ingvar's experience is that the inherited code, which is an essential part of the robot and the task, creates problems in the project. These problems, Ingvar says, are not of a kind that helps the project in any way. However, working with legacy code and hardware is certainly central to professional practice. Perhaps, this reflects weaknesses in the manner in which the course is presented. On this subject, one of Ingvar's teammates Tage is even more critical about the impact of inherited parts:

> **Interviewer**: Could you tell me more about the project experience?
> **Tage**: The robot has been a cause for problems in the project due to many small issues to sort out... well, I think mainly of technology issues. Since it was developing something existing it felt like it was... how should I express it... the project didn't start from scratch in this matter. It felt like we had to pick up a project and continue to develop it. We've had to adopt quite a lot to how they did things. The robots caused more pain than being something good. The only things we did for six months was to "put out fires" and mend things.

Tage points out that this problem makes the team feel less in control. Their own ideas and thoughts concerning solutions are hindered by the given environment they have to work with. This reduces, according to Tage, the level of engagement in the project. Tage has also thoughts about the teachers influence during the course and especially in the process of design decisions. Tage is elaborating on what happens in the group when the team of teachers uses their veto in design decisions:

> **Interviewer**: How did the teachers intervene?
> **Tage**: Well. For example, at meetings and presentations of solutions. Then the teachers said "this was tried two years ago. You can't do that." They didn't have to say things like that, but rather had let us try things ourselves. If we said something at the presentation, then they could say things like that.

It is clear that the teachers' good intentions can be experienced as reducing opportunity to demonstrate initiative and reducing engagement in the team.

The need to curb initiatives can be questioned, since the history and documentation of the project should provide students' with information of what had been tried before. They would already know these things and can avoid trying them, leading to a situation where teachers can avoid interfering. In any case, students' that are allowed to try out their ideas and see them fail will certainly have a learning experience.

### Discussion

This story is based on the column associated with the key feature *level of freedom in task*. This key feature has the potential to make the experience positive or negative. The level of freedom in how to fulfill the task can vary, e.g. who take design decisions to follow. Limiting students' freedom might create a sense of dissatisfaction. Both their experienced ownership and engagement are connected to this.

The question of ownership in the projects also affects the training of the *working efficiently and constructively in a large project team of developers*-practice. There are members in the project who feel they belong more, and those also typically take on greater responsibility in the project. Some students feel they belong more, and some other students notice this (since they don't feel the same). This illustrates a potential problem: students can be made insignificant in the project-community. If this happens, it works against the desired outcome of training practices: to become a member in the larger community of IT-workers. In order to be beneficial, the process of legitimate peripheral participation needs involvement of members in the practices central to the community. It is also interesting to reason about how the freedom in the project can create a feeling of belonging for some but not all students. Do the teachers help the students in trying to motivate the project importance or the importance of the experience as a next step in the students' careers? Do the teachers design the project in a way that requires that all students fully participate? Even though all communities are dynamic and that centrality shifts, it seems important that everyone is central and important in some phase.

How well the practice of *planning and follow-up of a complex project task, and taking care of unexpected things that might occur* is implemented is hard to judge from the story. Reading the underlying data set in section 12.1, traces from experiences of unexpected things can be found. Among the interviewed students' there are quotes about how they handle unexpected things. The transcripts relate that there were great shifts in the planning of the project. Unexpected things happened (and the students' shared experiences confirm this) but this most often led to stress. It is hard to tell whether this practice led to the process of becoming more central in the project community or not.

Listening to the informants it seems that the teachers role as both client and support in the project is problematic, since it restricts the freedom to choose design and approaches to problems, The degree of freedom in what to achieve seems not to be a burning issue. Instead it is how to fulfill the goals that students experience as an issue. The desired practices, listed in section 10.3, that are to be achieved in the projects are not directly affected by this problem, but indirectly they are. What happens is that focus shifts from training in the desired area of professional practice, to frustration over other things. The opportunity to train the desired practices is consequently reduced. The practice *getting experiences of applying previous knowledge, and learning skillful use of tools used in the community of IT-workers* is harder to reach when this happens.

In a similar way, the use of previous student project results as input in the project, and especially when using the old hardware and software are compulsory, affects the team and the project work to a great extent. Again the focus seems to shift away from training in the desired practices, and that seems to affect the opportunity to benefit from engagement in desirable practices.

### Connection to external stakeholders

In this project, no clear external stakeholder was present. The project group had the team of teachers acting as clients. The RoboCup[4] tournament was also an external activity the project team participated in. Neither of those external parts gave a sufficient grounds for reasoning about external stakeholders' connections to the projects, or effects thereof. Analyzing the interviews results in only three occasions when a perspective of external stakeholder is raised.

The practice *training in working with an external stakeholder, usually an external company involved in the project* is then not elaborated on in this analysis. The presence of such connection helps for legitimate peripheral participators to move towards more central positions in the projects, and hence also moving towards the larger community of IT-workers.

## 12.3 Summary

The three stories presented show how complex students' experiences connected to learning in the project is. The approach of combining key features with identified practices reveals experiences by the participating students that are valuable in understanding the learning situation in project courses.

[4] http://www.robocup.org/

# Part IV:

# Conclusion

This part draws conclusions from the results in the final study. I also states some implications for teaching.

# 13. Conclusion and future work

Designing computer science project learning environments has been shown to be a complex educational task. The literature in computer science education research, and this thesis, illustrates this and identifies the need for improved approaches to this task. I conclude this thesis by summarizing the work at a fairly abstract level in order to convey, some general lessons. Details, motivations and more thorough reasoning is found in the reported studies and in the resulting stories presented earlier. I will also include a section with hands-on implications for teaching follows and some suggestions for future work in the research community.

## 13.1 Comments on the initial phase of the thesis

The research presented in this thesis contributes to the field of knowledge of computer science project courses by investigating processes that are of importance in relation to the desired practices that students' should experience. It is built upon eight data collections informing 6 empirical investigations, the first four of these constitute the initial phase of the thesis work. The first investigation, reported in paper I, 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 are identified. The second investigation, reported in paper II, investigates experiences relating to the process of decision-making in a full semester computer science project course. Six categories describing the experience of decision-making are 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 investigation, reported in paper III, investigates Swedish engineering students' conceptions of engineering, where dealing with problems and their solutions and creativity are identified as core concepts. Subject concepts, as mathematics, and physics do not appear in any top position. *Math*, for instance, accounts for only five percent of the total mentioned engineering terms. *Physics*, the second highest ranked subject term, only accounts for approximately one percent. The fourth investigation, reported in paperIV, proposes a model based on four key features for reflecting on how to set up and analyze computer science student projects. The overall aim of the model is to address issues related to the learning outcomes of project courses, and thus be useful for both education researchers and teachers.

## 13.2 Comments on the final phase of the thesis

The fifth and sixth investigation, reported in part III of this thesis and in paper V, are presented more thoroughly.

The starting point in a learning situation must be that the time the students spend in a project course should be more rewarding in terms of learning than time spent in an ordinary industry project. But how do we achieve that? Simulating reality in a university level course is supposed to be motivating for the students but this is not enough as pedagogical model. The project course is not about mimic working life; it is about helping students becoming members of the community of IT-workers and it is important to realize that the students are starting from another perspective, from another community.

Let us start from where it all began, with the research questions. In section 2.2 I considered two research questions related to investigating how different processes in computer science student projects contribute to the learning outcomes. One of them was formulated as: *what processes contribute to learning in computer science student projects?*, which has been addressed by several studies, and from different perspectives. Communities of practice theory has been used to provide a functioning foundation for an analytical method for analyzing learning in the projects, which is a central aspect in addressing this research question. The general idea of participation through shared practices, and hence increased opportunities for learning should be emphasized when designing project courses as learning environments. This builds on the generally agreed pedagogical desire to activate learners, and on supporting activities identified as supporting movement towards becoming a member of the community of IT-workers. It should also be noted that this leads to a situation where the students learn from each other in a peer learning manner.

One major result of this thesis is the method for investigating learning in the projects. The method uses the key features of student project courses identified in the earlier investigations in order to analyze projects in the final phase. The analysis provides insights into the complex issue of how students experience the learning environment in project courses. It is important to keep in mind that both the features and the method do not constitute a full explanation or provide a complete view. They are one, research based, way to address the issue.

Rewarding learning environments are not automatically created by the project model. Different factors and personal choices may hinder learning.

Unclear goals and priorities, for example the choice between focusing on the result of the project or the learning process, can confound the learning outcome. There are also tasks in the projects where people end up not being actively involved in the community. Both these mechanisms work against learning.

A general observation from the results is the balance between using the project course as a means to become more specialized in a particular area, and developing skills that broaden knowledge. This is not only a personal choice since it also seems to affect the existence of peer-learning. The need for a more focused discussion on the prerequisites for peer-learning and collaboration in the projects is considerable. Given the importance of the role of practice as a means of becoming a more central member in the community, it is even more important to consider such things.

## 13.3 Implications for teaching

How should the results, and mainly the results from part III in this thesis, be interpreted in relation to teaching? Let us begin answering that question by looking at the second research question:

> *how can we design and set up computer science projects in order to make them contribute maximally to students' development and educational quality, based on a firm research foundation?*

Answering this question using the knowledge from this thesis leads to implications for teaching. Projects are complex learning environments. A better measurement than a successful product, physical artifact, needs to be developed for project courses. As seen in this thesis, the completion of the physical artifact can in some cases lead to both less collaboration, increased stress and in the end fewer learning opportunities. Therefore it is valuable to use some planning time to reason about how to enhance learning. Brainstorm ideas that might work in your specific setting. Perhaps you should make sure to design a project where students spend time both to learn something new, and to deepen their knowledge in something they already have skills in.

Another outcome is to make both students and teachers aware of the conditions of the learning environment. This could be addressed by discussing how learning can be identified during the project and what is beneficial for increased learning. Bringing up the pedagogical model underlying the project course and presenting it to the students adds new insights to such a discussion.

It is striking that the experiences of some students indicate that the set up and design of the project courses makes it possible for students to choose whether they will take active part in the learning or not. This is a very problematic scenario, and should be prevented. The choice whether to learn or not should be made earlier, when the students enroll in the course, since students not engaging in learning are more detrimental to the other students than in an ordinary course. It is important for the teachers to make sure that this choice is not an option.

The perceived stress experienced is holding back the students from learning opportunities. This is an unfortunate situation, even though some stress probably is a necessary component in such courses. The challenge in designing learning environments is to find mechanisms to benefit from the stressful components in the projects.

The method developed to unravel students' experiences of the project courses studied in this thesis, can be used to investigate experiences in project courses in any subject. In the method, a suggestion for how to reveal information and experiences is given. An idea for improvement is to develop ways of revealing experiences based information, that are less time consuming. In that way it would be easier to develop and use feedback tools for similar project courses.

Based on many rewarding discussions and interviews with students, I would recommend developing a method where students are interviewed in pairs before the project starts. Themes for the interviews could be desired learning, individual learning goals and how to make those happen. To keep the focus on the learning goal, the pair of students can function as mentors for each other during the project, with shared responsibility for raising learning issues during the project. That would lead not only to an increased awareness from start, but also provide a mechanism to maintain awareness during the course.

## 13.4 Future work

Based on this thesis, what possible projects could be suggested as future work? I would answer that question by dividing it in two paths: one being about to enhance the project experiences; and one about developing methods to learn more in the area of project courses and learning outcomes.

The first path, enhancing project experiences, has a couple of low hanging fruit. The results emphasise the challenge of mastering complex project courses and still making sure that all participants have a rich learning experience. The experiences shown indicate that this is complex to master in the project itself. It could therefore be valuable to perform a research study on mechanisms that support students mastery of complex project environments and how they can be used. Another idea could be to develop a project model for capstone courses where the learning experience is brought to the fore. Such project models could supplement existing project models and thus increase the chances of getting rich learning experiences from capstone course.

The second path, developing methods to learn more in the area of project courses and learning outcomes, could be followed by using the method proposed in this thesis as a starting point. Expanding the set of key features and identified practices would be one way to get an even richer insight into the mechanisms in the projects.

Finally, a research project building on part III of this thesis could use the proposed method but in a larger empirical setting. Exploring more insights from more project courses could provide a rich set of experiences that could, in the tradition of Fincher et al. (2001) and (Jonassen, 1991b) be used to develop a set of empirically based guidelines. These could then provide a valuable base for practitioners and thereby enrich the learning experience of students.

# References

Abbasi, Z. A., Backvall, P., Bergman, J., Blommé, C., Brohäll, J., Edlund, J., et al. (2009). *Project huge - final report* (Tech. Rep.). Department of Information Technology.

Ackermann, E. (2001). Piaget's constructivism, papert's constructionism: What's the difference? *Future of learning group publication*.

Acuna, S. T., & Juristo, N. (2004). Assigning people to roles in software projects. *Softw. Pract. Exper.*, *34*(7), 675–696.

Adams, R., Fincher, S., Pears, A., Börstler, J., Boustedt, J., Dalenius, P., et al. (2007, June). *What is the Word for Engineering. in Swedish: Swedish Students Conceptions of their Discipline* (Tech. Rep. No. 2007-018). Box 337, SE-751 05 Uppsala, Sweden: Department of Information Technology, Uppsala University.

Adawi, T., Berglund, A., Booth, S., & Ingerman Åke. (2002). *On context in phenomenographic research on understanding heat and temperature.* Available from `http://www.it.uu.se/research/publications/lic/2002-002/paperB-2002-002.pdf` (Paper presented at the In EARLI, Bi-annual Symposium, Fribourg, Switzerland.Also published in Berglund, A. On the Understanding of Computer Network Protocols. Licentiate theses from the Deptartment of Information Technology, Uppsala University, 2002.)

Back, H., Engberg, R., Herdegard, J., Laaksonen, M., Lejon, R., Nibon, D., et al. (2007). *Developing a location based service for mobile phones* (Tech. Rep.). Uppsala University: Department of Information Technology.

Barab, S. A., & Duffy, T. (2000). From practice fields to communities of practice. In D. H. Jonassen & S. M. Land (Eds.), *Theoretical foundations of learning environments* (pp. 25–55). Mahwah, New Jersey: Lawrence Erlbaum Associates, Inc.

Barker, L. J. (2005). When do group projects widen the student experience gap? In *Iticse '05: Proceedings of the 10th annual sigcse conference on innovation and technology in computer science education* (pp. 276–280). New York, NY, USA: ACM Press.

Barker, L. J. (2009). Student and faculty perceptions of undergraduate research experiences in computing. *Trans. Comput. Educ.*, *9*(1), 1–28.

Barker, L. J., & Garvin-Doxas, K. (2004, June). Making Visible the Behaviors that Influence Learning Environment: A Qualitative Exploration of

Computer Science Classrooms. *Computer Science Education*, *14*, 119-145.

Ben-Ari, M. (1998). Constructivism in computer science education. *SIGCSE Bull.*, *30*(1), 257–261.

Benne, K. D., & Sheats, P. (1948). Functional Roles of Group Members. *The Journal of Social Issues*.

Beranek, G., Zuser, W., & Grechenig, T. (2005). Functional group roles in software engineering teams. In *Hsse '05: Proceedings of the 2005 workshop on human and social factors of software engineering* (pp. 1–7). New York, NY, USA: ACM Press.

Berglund, A. (2005). *Learning computer systems in a distributed project course: The what, why, how and where*. Uppsala, Sweden: Acta Universitatis Upsaliensis.

Berglund, A., & Wiggberg, M. (2006). Students learn CS in different ways: insights from an empirical study. In *Iticse '06: Proceedings of the 11th annual sigcse conference on innovation and technology in computer science education* (pp. 265–269). New York, NY, USA: ACM Press.

Boyer, E. L. (1990). *Scholarship reconsidered: Priorities of the professoriate.* 3175 Princeton Pike, Lawrenceville, NJ 08648.: Princeton University Press. Available from `http://www.eric.ed.gov/ERICWebPortal/contentdelivery/servlet/ERICServlet?accno=ED326149`

Brooks, M. G., & Brooks, J. G. (1999). The courage to be constructivist. *Educational Leadership*, *57*, 18–24.

Brown, J., & Dobbie, G. (1998). Software engineers aren't born in teams: Supporting team processes in software engineering project courses. In *Seep '98: Proceedings of the 1998 international conference on software engineering: Education & practice* (p. 42). Washington, DC, USA: IEEE Computer Society.

Brown, J., & Dobbie, G. (1999). Supporting and evaluating team dynamics in group projects. In *Sigcse '99: The proceedings of the thirtieth sigcse technical symposium on computer science education* (pp. 281–285). New York, NY, USA: ACM Press.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated Cognition and the Culture of Learning. *Educational Researcher*, *18*(1), 32-42. Available from `http://edr.sagepub.com/cgi/content/abstract/18/1/32`

Bruner, J. (1996). *The Culture of Education*. London, England: Harvard University Press.

Clear, T. (2009, September). *Course material, master of computer and information sciences, 408206, collaborative computing and workflow.*

Collins, A. (1990). Cognitive apprenticeship and instructional technology. In L. Idol & B. F. Jones (Eds.), *Educational values and cognitive instruction: Implications for reform.* Hillsdale, NJ: Lawrence Erlbaum.

Collins, A., Brown, J. S., & Newman, S. E. (1989). Cognitive apprenticeship: Teaching the craft of reading, writing and mathematics. In L. B. Resnick (Ed.), *Knowing, learning and instruction: Essays in honor of robert glaser* (pp. 453–494). Hillsdale: Erlbaum.

Computing Curricula, T. J. T. F. for. (2005, September). *Computing curricula 2005.* Available from `http://www.acm.org/education/curric_vols/CC2005-March06Final.pdf`

Cope, C. (2002). Educationally critical aspects of the concept of an information system. *Informing Science*, *5*(2), 67-79.

Coppit, D., & Haddox-Schatz, J. M. (2005). Large team projects in software engineering courses. In *Sigcse '05: Proceedings of the 36th sigcse technical symposium on computer science education* (pp. 137–141). New York, NY, USA: ACM Press.

Cox, A. (2005). What are communities of practice? A comparative review of four seminal works. *Journal of Information Science*, *31*(6), 527-540. Available from `http://jis.sagepub.com/cgi/content/abstract/31/6/527`

Craig, C. J. (2009). The Contested Classroom Space: A Decade of Lived Educational Policy in Texas Schools. *American Educational Research Journal*, *46*(4), 1034-1059. Available from `http://aer.sagepub.com/cgi/content/abstract/46/4/1034`

Crotty, M. (1998). *The foundations of social research.* SAGE Publications.

Daniels, M., & Asplund, L. (1999, November). Full scale industrial project work, a one semester course. In *Frontiers in education conference, 1999 fie '99. 29th annual* (Vol. 1, pp. 11B2/7 – 11B2/9 vol.1).

Daniels, M., & Asplund, L. (2000). Multi-Level Project Work; A Study In Collaboration. In *30th asee/iee frontiers in education conferences* (p. F4C-11 - F4C-13). Kansas City, MO, USA.

Danielsson, A. T. (2009). *Doing physics - doing gender : An exploration of physics students' identity constitution in the context of laboratory work.* Unpublished doctoral dissertation, Uppsala University, Department of Physics and Materials Science.

Danielsson, T., Olsson, M., Ohlsson, D., Wärrmegård, D., Wiggberg, M., & Carlström, J. (2006, July). A climbing robot for autonomous inspection of live power lines. In *Proceedings of aser06, 3rd international workshop on advances in service robotics.* Vienna, Austria.

David, T. (Ed.). (1998). *Researching early childhood education: European perspectives.*

Davidson, J. E., & Sternberg, R. J. (2003). *The psychology of problem solving,.* Cambridge University Press.

Deetz, S. (1996, March). Describing differences in approaches to organization science: Rethinking burrell and morgan and their legacy. *Organization Science*, *7*(2), 191–207. Available from `http://links.jstor.org/sici?sici=1047-7039%28199603%`

2F04%297%3A2%3C191%3ADDIATO%3E2.0.CO%3B2-U

Duffy, T. M., & Cunningham, D. J. (1996). Constructivism: Implications for the design and delivery of instruction. In D. H. Jonassen (Ed.), *Handbook of research for educational communications and technology* (pp. 170–198). New York: Simon & Schuster Macmillan. Available from http://www.aect.org/intranet/publications/edtech/07/index.html

Eckerdal, A. (2009). *Novice programming students' learning of concepts and practise*. Unpublished doctoral dissertation, Uppsala UniversityUppsala University, Division of Scientific Computing, Numerical Analysis.

Ehn, B., & Löfgren, O. (2001). *Kulturanalyser*. Gleerups.

Ekberg, P., Folkesson, C., Bijarbooneh, F. H., Haglund, R., Jin, X., Liljenberg, L., et al. (2009). *Project green fox - course report.* Available from http://www.it.uu.se/edu/course/homepage/projektDV/ht08/GF_course_report.pdf

Entwistle, N. (1977, October). Strategies of learning and studying: Recent research findings. *British Journal of Educational Studies*, *25*(3), 225–238.

Ernest, P. (2009). The one and the many. In L. P. Steffe & J. E. Gale (Eds.), *Constructivism in education* (chap. 26). Lawrence Erlbaum Associates.

Faculty of Science and Technology, Uppsala University. (2007a, January). *Project course description.* Available from http://www.selma.uu.se/publik/main?AF=0200&funktion=kplan&fakultet=TM0&amne=DVA&kurs=1DT160&lang=spraken (Retrieved 30th Jan 2007)

Faculty of Science and Technology, Uppsala University. (2007b). *Study plan graduate study programme in computer science with specialization in computer science education research.* Available from http://www.teknat.uu.se/internt/forskarutbildning/amne/datavet_didaktik.pdf (Retrieved 2nd December 2007)

Faulkner, X., Daniels, M., & Newman, I. (2006). Open ended group projects (OEGP): A way of including diversity in the IT curriculum. In G. Trajkovski (Ed.), *Diversity in information technology education: Issues and controversities* (p. 166-195). London: Information Science Publishing.

Fincher, S., & Petre, M. (2004). *Computer science education.* Routledge Falmer,.

Fincher, S., Petre, M., & Clark, M. (2001). *Computer science project work: principles and pragmatics*. Springer.

Flanagan, J. (1954, July). The critical incident technique. *Psychological Bulletin*, *51*(4), 327-358.

Gadamer, H.-G. (1976). Critical Sociology, Selected Readings. In P. Connerton (Ed.), (p. 117-133). Harmondsworth UK: Penguin Books Ltd.

Gillström, P. (2010). *Övergång till forskarutbildning utifrån föräldrarnas utbildning (2010-01-26:2010/1)* (Tech. Rep.). Swedish National Agency for Higher Education.

Hauer, A., & Daniels, M. (2008, January). A Learning Theory Perspective on Running Open Ended Group Projects (OEGPs). In Simon & M. Hamilton (Eds.), *To appear in the proceedings of tenth australasian computing education conference (ace2008)* (Vol. 78). Wollongong, Australia.

Hause, M. L. (2003). *Software Development Performance in Remote Student Teams in International Computer Science Collaboration.* Unpublished doctoral dissertation, The Open University, UK.

Hause, M. L., Almstrum, V. L., Last, M. Z., & Woodroffe, M. R. (2001). Interaction factors in software development performance in distributed student teams in computer science. *SIGCSE Bull.*, *33*(3), 69–72.

Heidegger. (1962). *Being and time*. Oxford: Basil Blackwell.

Henderson, M., & Bradey, S. (2008). Shaping online teaching practices - the influence of professional and academic identities. *Campus-Wide Information Systems*, *25*(2), 85–92.

Holland, D., & Reeves, J. (1996). Activity theory and the view from somewhere: Team perspectives on the intellectual work of programming. In B. A. Nardi (Ed.), *Context and consciousness: activity theory and human-computer interaction* (p. 257-281). Cambridge, MA, USA: MIT Press.

Holmes, J., & Meyerhoff, M. (1999). The community of practice: Theories and methodologies in language and gender research. *Language in Society*, *28*(02), 173-183. Available from `http://journals.cambridge.org/action/displayAbstract?fromPage=online&aid=28553&fulltextType=RA&fileId=S004740459900202X`

Husserl, E. (1970). *Logical investigations*. London: Routledge and Kegan Paul.

Husserl, E. (1982). *Ideas Pertaining to a Pure Phenomenology and to a Phenomenological Philosophy*. Boston: Kluwer.

Jaques, D. (1995). *Learning in groups* (2nd ed.). London: Kogan Page Limited.

Jonassen, D. H. (1991a). Evaluating constructivistic learning. *Educational Technology*(Sep), 28–33.

Jonassen, D. H. (1991b). Objectivism versus constructivism: Do we need a new philosophical paradigm? *Educational Technology Research and Development*.

Jonassen, D. H. (1997). Instructional design models for well-structured and ill-structured problem-solving learning outcomes. *Educational Technology Research and Development*, *45*, 65–94.

Kahn, J. S. (1989). Culture: Demise or Resurrection? *Critique of Anthropology*, *9*(2), 5-25.

Kinnunen, P., & Malmi, L. (2004). Do students work efficiently in a group? - problem-based learning groups in basic programming course. In *Kolin kolistelut - koli calling 2004. proceedings of the fourth finnish/baltic sea conference of computer science education* (p. 57-66). Helsinki, Finland: Helsinki University of Technology.

Klein, G. (1999). *Sources of Power - How People Make Decisions*. MIT Press.

Klein, G., Calderwood, R., & MacGregor, D. (1989, May-June). Critical decision method for eliciting knowledge. *IEEE Transactions on Systems, Man and Cybernetics*, *19*(3), 462-472.

Klein, H. K., & Myers, M. D. (1999, March). A set of principles for conducting and evaluating interpretive field studies in information systems. *MIS Quarterly*, *23*(1), 67–93. Available from `http://links.jstor.org/sici?sici=0276-7783%28199903%2923%3A1%3C67%3AASOPFC%3E2.0.CO%3B2-Q`

Kolikant, Y. B.-D. (2005). Students' alternative standards for correctness. In *Icer '05: Proceedings of the 2005 international workshop on computing education research* (pp. 37–43). New York, NY, USA: ACM Press.

Kolikant, Y. B.-D., McKenna, A., & Yalvac, B. (2006). The emergency of a community of practice in engineering education. *New Directions for Teaching and Learning*.

Kolmos, A. (2002). Facilitating change to a problem-based model. *International Journal for Academic Development*, *7*. Available from `http://www.informaworld.com/10.1080/13601440210156484`

Kolmos, A., & Algreen-Ussing, H. (2001). Implementing a problem-based and project organized curriculum - a cultural change, das hochschulwesen. In *200): An international student/faculty collaboration: The runestone project, acm conference on innovation and technology into computer science education* (pp. 15–20). Luchterhand Verlag.

Kroksmark, T. (1987). *Fenomenografisk didaktik*. Acta Universitatis Gothoburgensis.

Kvale, S. (1997). *Den kvalitativa forskningsintervjun*. Lund: Studentlitteratur.

Last, M. (2003). *Investigating the Group Development Processin Virtual Student Software Project Teams*. Unpublished doctoral dissertation, Kingston University, UK.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation (learning in doing: Social, cognitive and computational perspectives)* (1st ed.). Cambridge University Press. Paperback. Available from `http://www.worldcat.org/isbn/0521423740`

Leeper, R. (1989). Progressive project assignments in computer courses. In *Sigcse '89: Proceedings of the twentieth sigcse technical symposium on computer science education* (pp. 88–92). New York, NY, USA: ACM Press.

Lincoln, Y., & Guba, E. (1985). *Naturalistic inquiry*. SAGE.

Lister, R. (2008, January). After the Gold Rush: Toward Sustainable Scholarship in Computing. In Simon & M. Hamilton (Eds.), *To appear in the proceedings of tenth australasian computing education conference (ace2008)* (Vol. 78). Wollongong, Australia.

Machanick, P. (2007, March). A social construction approach to computer science education. *Computer Science Education*, *17*, 1-20(20). Available from http://www.ingentaconnect.com/content/routledg/ncse/2007/00000017/00000001/art00001

Marton, F., & Booth, S. (1997). *Learning and awareness*. Mahwah, NJ, USA: Lawrence Erlbaum Associate.

Marton, F., & Fai, P. M. (1999, August). *Two Faces of Variation.* (Paper presented at 8th European Conference for Learning and Instruction August 24 - 28, 1999, Göteborg University, Göteborg, Sweden)

Monshi, A., Axelsson, C., Aksu, E., Yao, J., Vikman, J., Blomdahl, K. S., et al. (2009). *Project cs 2008 course report.* Available from http://www.it.uu.se/edu/course/homepage/projektDV/ht08/IMO_course_report.pdf

Newman, I., Daniels, M., & Faulkner, X. (2003). Open ended group projects a 'tool' for more effective teaching. In *Ace '03: Proceedings of the fifth australasian conference on computing education* (pp. 95–103). Darlinghurst, Australia: Australian Computer Society, Inc.

Nibon, D. (2006, November). *Project Plan, Point of Interest - Revision A* (Tech. Rep.). Uppsala University: Department of Information Technology.

Nilsson, C. (2006, November). *Teazle Goes Mobile - Project Plan v1.5* (Tech. Rep.). Uppsala University: Department of Information Technology.

Nilsson, C., Dong, H., Chen, N., Söderlund, A., Pettersson, S., Lundmark, S., et al. (2007). *Teazle Goes Mobile* (Tech. Rep.). Uppsala University: Department of Information Technology.

O'Loughlin, M. (1992). Rethinking science education: Beyond piagetian constructivism toward a sociocultural model of teaching and learning. *Journal of Research in Science Teaching*, *29*, 791-820. Available from http://dx.doi.org/10.1002/tea.3660290805

Olson, K., & Clark, C. M. (2009). A Signature Pedagogy in Doctoral Education: The Leader-Scholar Community. *Educational Researcher*, *38*(3), 216-221. Available from http://edr.sagepub.com/cgi/content/abstract/38/3/216

Organisation for Economic Co-operation and Development (OECD). (2009, September). Highlights from education at a glance 2009.

Papert, S., & Harel, I. (1991). Situating constructionism. In S. Papert & I. Harel (Eds.), (chap. 1). Ablex Publishin Company. (http://www.papert.org/articles/SituatingConstructionism.html)

Pears, A., & Daniels, M. (2010, May). Developing global teamwork skills: The runestone project. In *Educon 2010* (p. To appear). IEEE Education Society.

Pettersson, P. (2006). *Project course presentation.* Available from http://www.it.uu.se/edu/course/homepage/projektDV/ht06/02-gruppindelning.pdf (Retrieved 30th January 2007)

Pettersson, P., Gällmo, O., Hessel, A., & Mokrushin, L. (2006). *Project course webpage.* Available from http://www.it.uu.se/edu/course/homepage/projektDV/ht06/ (Retrieved 30th January 2007)

Resnick, L. B. (1987). Learning in school and out. *Educational Researcher*, 13–20.

Richard Coulson, R. S. znd, Feltovich, P., & Anderson, D. (1988). Cognitive flexibility theory: Advanced knowledge acquisition in ill-structured domains. In *Proceedings of the 10th annual conference of the cognitive science society.* Hillsdale, NJ: Erlbaum.

Ricoeur, P. (1981). *Hermeneutics and the Human Sciences: Essays on Language, Action and Interpretation* (J. B. Thompson, Ed.). UK: Cambridge University Press.

Rising, L., & Janoff, N. S. (2000). The scrum software development process for small teams. *IEEE Softw.*, *17*(4), 26–32.

Roth, W.-M. (1998). *Designing communities* (Vol. 3). Dordrecht, Boston: Kluwer Academic Publishers.

Schulte, C., & Knobelsdorf, M. (2007). Attitudes towards computer science-computing experiences as a starting point and barrier to computer science. In *Icer '07: Proceedings of the third international workshop on computing education research* (pp. 27–38). New York, NY, USA: ACM.

Scriven, M. (1983). *Evaluation models: Viewpoints on educational and human services evaluation.* Martinus Nijhoff Publishers, Brill Academic.

Seat, E., & Lord, S. M. (1998). Enabling effective engineering teams: a program for teaching interaction skills. In *Frontiers in education conference 1998. fie '98. 28th annual* (Vol. 1, p. 246 - 251). Tempe, AZ.

Säljö, R. (2000). *Lärande i praktiken - ett sociokulturellt perspektiv.* Stockholm: Bokförlaget Prisma.

Staver, J. R. (1986). The constructivist epistemology of jean piaget: Its philosophical roots and relevance to science teaching and learning. , 28.

Strauss, A. L., & Glaser, B. G. (1967). *The discovery of grounded theory; strategies for qualitative research.*

Strazdins, P. (2008). Applying the community of practice approach to individual it projects. In *Ace '08: Proceedings of the tenth conference on australasian computing education* (pp. 137–146). Darlinghurst, Australia, Australia: Australian Computer Society, Inc.

Vartiainen, T. (2006). Moral conflicts perceived by students of a project course. In *Baltic sea '06: Proceedings of the 6th baltic sea conference on computing education research* (pp. 77–84). New York, NY, USA: ACM.

Vetenskapsrådet. (1990). *Forskningsetiska principer inom humanistisk-samhällsvetenskaplig forskning* (Tech. Rep.). Author. Available from `http://www.vr.se/download/18.6b2f98a910b3e260ae28000360/HS_15.pdf`

Waite, W. M., Jackson, M. H., Diwan, A., & Leonardi, P. M. (2004). Student culture vs group work in computer science. In *Sigcse '04: Proceedings of the 35th sigcse technical symposium on computer science education* (pp. 12–16). New York, NY, USA: ACM Press.

Walsham, G. (1995). Interpretive case studies in IS research: nature and method. *European Journal of Inforamtion Systems*, *4*(2), 74-81.

Wenger, E. (1998). *Communities of Practice: Learning, Meaning, and Identity* (1st ed.). Cambridge, United Kingdom: Cambridge University Press.

Wenger, E., McDermott, R., & Snyder, W. M. (2002). *Cultivating communities of practice: A guide to managing knowledge*. Harvard Business School Press.

Wiggberg, M. (2007). "I Think It´s Better if Those Who Knows the Area Decides About It" - A Pilot Study Concerning Power in Student Project Groups in CS. In A. Berglund & M. Wiggberg (Eds.), *Proceedings of the 6th Baltic Sea Conference on Computing Education Research, Koli Calling* (p. 132-135). Uppsala University, Uppsala, Sweden.

Wiggberg, M. (2008a). Computer Science Students' Experiences of Decision Making in Project Groups. In R. Lister & Simon (Eds.), *Seventh Baltic Sea Conference on ComputingEducation Research (Koli Calling 2007).* Koli National Park, Finland: Australian Computer Society, Inc.

Wiggberg, M. (2008b). *Unwinding processes in computer science student projects* (No. 2008-001).

Wiggberg, M., & Dalenius, P. (2009). Bridges and problem solving : Swedish engineering students' conceptions of engineering in 2007. In *Proc. 1st international conference on computer supported education : Volume 2* (pp. 5–12). Institute for Systems and Technologies of Information, Control and Communication.

Wiggberg, M., & Daniels, M. (2008). Reflecting on running large scale student collaboration projects. In *Proc. 38th asee/ieee frontiers in education conference* (pp. S3C-8–12). IEEE.

# Appendices

# Letter of informed consent

UPPSALA
UNIVERSITET

# Letter of Informed Consent

*I, (print name in full) ___________________ am a student registered at ________________________ In signing this consent form, I agree to volunteer in the research project being conducted by Mattias Wiggberg between October 2006 and January 2007. I understand that the research being conducted relates to social components in project work in Computer Science.*

*I understand that data from the design task and associated design criteria elicitation will be used in aggregate, and that excerpts from tape-recorded verbal communications with the researcher will be studied and may be quoted in papers, journal articles and books that may be written by the researchers.*

*I grant authorization for the use of the above information with the full understanding that confidentiality will be preserved at all times. I understand that my name or other identifying information will never be disclosed or referenced in any way in any written or verbal context.*

*I understand that my participation is entirely voluntary and that I may withdraw my permission to participate in this study without explanation at any point up to and including, the last day of January 2007.*

*Date*

*Name*

*Personal nr.*

*Signature*

**Mattias Wiggberg, Ph.D. Student, Department of Information Technology, Uppsala University**
Box 337, SE-751 05 Uppsala,SWEDEN, Telephone +46 70 – 999 88 44, +46 18 - 471 3176 Telefax +46 18 – 51 19 25
Internet: user.it.uu.se /~mattiasw E-mail: mattias.wiggberg@it.uu.se

UPPSALA
UNIVERSITET

# Informerat deltagande för medverkan i studie

Jag (fyll i namn) ____________________ är student registrerad på _______________. I och med undertecknandet av detta dokument så anmäler jag min avsikt att som frivillig deltaga i ett forskningsprojekt som utförs av Mattias Wiggberg mellan oktober 2006 och januari 2007. Jag förstår att forskningen handlar om sociala faktorer i projektarbete inom datavetenskap.

Jag är medveten om att informationen som samlas in vid försökstillfället kommer att användas tillsammans med information insamlad från andra försöksdeltagare. Den information som smalas in inkluderar bland annat skriven text och ljudinspelningar. Informationen kommer att studeras av forskaren och kan komma att citeras i olika artiklar och böcker som forskaren författar.

Jag ger härmed tillstånd till forskaren att använda ovanstående information i vetskap om att konfidentialitet garanteras vid alla tillfällen. Jag är också medveten om att mitt namn eller information som kan identifiera mig aldrig kommer att avslöjas eller refereras i skriftlig eller verbal form. Jag är medveten om att mitt deltagande är helt frivilligt och att jag kan dra tillbaka mitt tillstånd att delta, utan någon som helt förklaring, när som helst fram till och med den sista januari 2007.

*Datum*

*Namn*

*Person nr.*

*Namnteckning*

**Mattias Wiggberg, Ph.D. Student, Department of Information Technology, Uppsala University**
Box 337, SE-751 05 Uppsala,SWEDEN, Telephone +46 70 – 999 88 44, +46 18 - 471 3176 Telefax +46 18 – 51 19 25
Internet: user.it.uu.se /~mattiasw E-mail: mattias.wiggberg@it.uu.se

# Questions data set A

# Introduction script

Present consent form, and maybe explain it.
Familiarizes the interviewees with what I'm trying to accomplish
Let them know that they are making a contribution to computer science education
Tell people they can withdraw or refuse to answer a question.
I tell them that I won't even ask them why they don't want to answer and so on.

**Mattias Wiggberg, Ph.D. Student, Department of Information Technology, Uppsala University**
Box 337, SE-751 05 Uppsala,SWEDEN, Telephone +46 70 – 999 88 44, +46 18 - 471 3176 Telefax +46 18 – 51 19 25
Internet: user.it.uu.se /~mattiasw E-mail: mattias.wiggberg@it.uu.se

UPPSALA
UNIVERSITET

# Interview questions, English

**Power**
How does your team make decisions?
- Give me an example of an important decision the team made.
- Who said what to whom?

How much influence do you think you had in that decision?
- Is this typical?

Who do you think has the most influence in making decisions in the team?
- What is it that makes them decide?
- What is it that they decide about?
- How does influence affect the learning?

Is it always the same people that decide?
- Does it vary, depending on the type of decision being made?

**Responsibility**
What kinds of responsibilities are shared among team members?
- How are these distributed?
- How does the distribution of responsibilities effect learning?

Who do you consider responsible in the team?

What does it mean to have responsibility in the project?
- How is the responsibility distributed in the team?
- Why do you think it is distributed in that way?
- What do you think you are responsible for in the team?

**Roles**
Who chose to work with what?
- Why did they choose that particular area?
- Can you see any pattern in their choice of area?
- Did they choose to work in the area based on earlier skills?

Can you se any typical project roles in the team?
- What is the importance of them?
- How did people get assigned to those roles?

Is there any connection between the assigned or taken role and the learning?

(Just one women is present in the team, so maybe skip this question?)
Do you feel that you are assigned important or trivial tasks?
- Who makes these decisions?
- Do you think you are assigned tasks based on beliefs about what kinds of things women are good at versus what kinds of things men are good at?

**Mattias Wiggberg, Ph.D. Student, Department of Information Technology, Uppsala University**
Box 337, SE-751 05 Uppsala,SWEDEN, Telephone +46 70 – 999 88 44, +46 18 - 471 3176 Telefax +46 18 – 51 19 25
Internet: user.it.uu.se /~mattiasw E-mail: mattias.wiggberg@it.uu.se

**Competence**
(This is a mechanism for reveling information)
Start with a scenario of how they make decisions about what to do
Then ask "what made you decide that was the appropriate course of action?"
Elaborate on the answer given, “how do you know that another person is competent”, “what makes you believe in this competence”
What did X say or do to make you think they were competent?

What does it mean to be competent in this situation?
- Who is thought to be competent?
- Is responsibility connected to competence?
- How is competence connected to influence/power?

**Result**
How do you track progress?
- Did you decide this formally as a group?
- How well is knowledge about the progress understood within the project?

**Generic follow up questions (can be used in conjunction to any of the above questions)**
Listen to "what could have happened, but didn't?", maybe ask about it.
Why do you think it is so?
Can you elaborate more on that?
Is that always the case?
Can you remember such a situation?

# Completion script

Is there anything else you would like to add before we end this interview?

Again, your anonymity and confidentiality will be preserved at all times.

In order not to bias subsequent interviews, please do not discuss details of the tasks with other students.

Thanks four your cooperation.

**Mattias Wiggberg, Ph.D. Student, Department of Information Technology, Uppsala University**
Box 337, SE-751 05 Uppsala,SWEDEN, Telephone +46 70 – 999 88 44, +46 18 - 471 3176 Telefax +46 18 – 51 19 25
Internet: user.it.uu.se /~mattiasw E-mail: mattias.wiggberg@it.uu.se

UPPSALA
UNIVERSITET

# Interview questions, Swedish

**Makt**
Hur fattas beslut i gruppen?
- Kan du ge mig ett exempel på ett viktigt beslut som fattats av gruppen?
- Vem sa vad till vem?

Hur mycket inflytande hade du over det beslutet?
- Är detta ett belysande/typiskt exempel?

Vem tror du har mest inflytande i gruppens beslutfattande?
- Vad är det som gör att de bestämmer?
- Vad är det som de bestämmer över?
- Hur påverkar möjligheten att bestämma hur mycket folk lär sig?

Är det alltid samma människor som bestämmer eller varierar det?
- Varför varierar det?

**Responsibility**
Vad för typ av ansvar är fördelade mellan gruppmedlemmarna?
- Hur är dessa fördelade?
- Hur påverkar fördelningen av ansvar lärandet?

Vem tycker du är ansvarig I gruppen?

Vad betyder det att ha ansvar I projektet?
- Hur är ansvaret fördelat i gruppen?
- Varför tror du att de är fördelat på detta sätt?
- Vad är du ansvarig för i gruppen?

**Roller**
Vem väljer att arbeta med vad?
- Varför valde de just detta område?
- Kan du se något mönster i valet av områden att arbeta med?
- Valde de att arbeta i områden baserat på tidigare kunskap eller något annat?

Kan du se några typiska projektroller I gruppen?
- Hur betydelsefulla är de?
- Hur hamnade folk i dessa roller?

Finns det någon koppling mellan den tilldelade, eller tagna rollen, och lärande?

(Endast en kvinna I gruppen, kanske skippa denna)
Känner du att du har en betydelsefull roll?
- Vem bestämde vilken roll du skulle ha?
- Tror du att du fick rollen baserat på föreställningar om saker som kvinnor respektive män är bra på?

**Mattias Wiggberg, Ph.D. Student, Department of Information Technology, Uppsala University**
Box 337, SE-751 05 Uppsala,SWEDEN, Telephone +46 70 – 999 88 44, +46 18 - 471 3176 Telefax +46 18 – 51 19 25
Internet: user.it.uu.se /~mattiasw E-mail: mattias.wiggberg@it.uu.se

**Kompetens**
(Detta är en metod för att få fram information)
Börja med ett scenario om hur de fattar beslut om vad de ska göra.
Fråga ”vad fick dig att bestämma vad som var rätt att göra i denna situation?”.
Utveckla svaret
- Hur vet du att den personen är kompetent?
- Vad var det som X sa som fick dig att tro att X var kompetent?

Vad betyder det att vara kompetent I denna situation?
- Vem anses som kompetent?
- Hur är ansvar kopplat till kompetens?
- Hur är kompetens kopplat till inflytande?

**Resultat**
Hur mäter ni framsteg?
- Bestämde ni detta gemensamt?
- Hur stor är den löpande kunskapen om framsteg i gruppen?

**Allmänna följdfrågor (kan användas I samband med frågorna ovan)**
Lyssna efter ”vad kunde ha hänt som inte gjorde det?” kanske fråga om det?
Varför tror du att det är så?
Kan du utveckla detta?
Är det alltid så?
Kan du komma ihåg en sådan situation?

# Avslutande skript

Är det något mer du vill tillägga innan vi avslutar intervjun?

Din identitet kommer att behandlas konfidentiellt.

För att inte påverka de kommande intervjuerna ber jag dig att inte diskutera detaljer eller frågor med de andra studenterna förrän efter den sista januari 2007.

Tack för ditt deltagande, det har varit mycket värdefullt.

**Mattias Wiggberg, Ph.D. Student, Department of Information Technology, Uppsala University**
Box 337, SE-751 05 Uppsala,SWEDEN, Telephone +46 70 – 999 88 44, +46 18 - 471 3176 Telefax +46 18 – 51 19 25
Internet: user.it.uu.se /~mattiasw E-mail: mattias.wiggberg@it.uu.se

# Questions data set B

# Interview questions, English

**[Phenomenon in focus]**
Decision making and learning

**[Decision making]**

What is your experience of communication activities that are performed in your meetings?
*(DeSantics et al., 1985, p. 591). To confirm what kind of activates that happens when the group make decisions. The result can be compared with the theory stated in the article.*
I would like to get them to talk about their experiences in order to bring the subject to the surface. Also a way for me to get clues about what kind of experiences that I can continue to ask for.

What do you think about your meetings? Do you like your meetings?
- Why, why not?
- Any special part that is good/bad?
- Do you reckon your meetings as effective ones?
- How is the word (ordet) assigned?
- What is the role of the meeting?
- Do you learn anything from the meetings?

*(DeSantics et al., 1985, p. 591) To get an insight in the effectiveness of the meetings.*
Is the meeting a central part of the decision process? What happens during the meetings?

What kind of tools are you using for the collaborative parts of the work?
*(DeSantics et al., 1985, p. 594) Do they use any GDSS for collaboration? At what level?*

Is any technology used for supporting the meetings (or decisions)?
- How does it affect the process of decision making?
- Who is using the technology?

*(DeSantics et al., 1985, p. 591) Is any GDSS in use in their process?*
This is just to learn about where the decisions are made. The literature carefully tries to track the decision making process' different loci. Therefore I need to find where decisions are made. The hypothesis is that they don't use any GDSS and by asking this question I can exclude a lot of reasoning around GDSS.

How do you experience the discussions in the group?
-Are there some people who have more influence?
-Is someone more dominant in the discussions?
-What happens when some person has an opinion that is not the common one?
*(DeSantics et al., 1985, p. 596) Common problems experienced by decision making groups (what is such a group?).*
Is the initiative in decision at some particular place?

Is there any connection between the assigned or taken role and the learning?
*This is an important question that I need to extend. How?*

Who do you think has the most influence in making decisions in the team?
- What is it that makes them decide?
- What does it mean to decide in terms of possibility to learn from the project work?
- How does influence affect the learning?
- Is it always the same people that decide?
- Does it vary, depending on the type of decision being made?

*Who has the imitative in making decisions? Does any?*
Connection between decisions and learning?

What is your experience of planning in the group? In setting up meeting strategies? In problem formulation?

**Mattias Wiggberg, Ph.D. Student, Department of Information Technology, Uppsala University**
Box 337, SE-751 05 Uppsala,SWEDEN, Telephone +46 70 – 999 88 44, +46 18 - 471 3176 Telefax +46 18 – 51 19 25
Internet: user.it.uu.se /~mattiasw E-mail: mattias.wiggberg@it.uu.se

*(DeSantics et al., 1985, p. 592) Successful groups spend more time in these things.*
Here I would like to get information about where in time (and how) decisions are made. Is the decision making process organized and planned? Do people know where to break in if they like to be a part of the decision making?

Do deciding also means that you are first in line when choosing tasks?
Connections between decision making and task (and possibility to do new things, might lead to learning?).

What is learning in your project?
- Who learns something?
To put focus on learning. In the middle.

What is your experience of responsibility in the project?
- Does any kind of responsibility come with deciding?
- What kind?
- Does responsibility mean something extra in terms of learning?
- How is the responsibility distributed in the team?
- Why do you think it is distributed in that way?
- What do you think you are responsible for in the team?
*Is responsibility formal or informal? By putting this question after the one of decision I will be able to find lateral linkage between them.*
Responsibility and learning

Describe a decision made in the project.
- Give me an example of an important decision the team made.
- Who said what to whom?
- How did people come up with their input to the process?
- How does your team make decisions?
- How much influence do you think you had in that decision?
- Is this typical?
*(Langley et al., 1995, p. 262) Is decision making according to Cohen or is it rational?*
Trying to catch one decision making experience in order to make the subject speak freely.

Think of a decision made during the project. Can you point out when it happened?
*(Langley et al., 1995, p. 266) Is there always a clear point when decisions are made?*
Is it clear when a decision is made?

Can you see any difference between members in the group regarding decision making?
- Why do you think it is so?

**[Cultural]**
Do you think everyone see it that way?

Is there any difference between Swedish and Chinese students?
- For instance, what do you think they think about the process of decision making?

Have your changed your mind about decision making during your time in Uppsala?

**Mattias Wiggberg, Ph.D. Student, Department of Information Technology, Uppsala University**
Box 337, SE-751 05 Uppsala,SWEDEN, Telephone +46 70 – 999 88 44, +46 18 - 471 3176 Telefax +46 18 – 51 19 25
Internet: user.it.uu.se /~mattiasw E-mail: mattias.wiggberg@it.uu.se

UPPSALA
UNIVERSITET



**[Generic follow up questions / question process (can be used in conjunction to any of the above questions)]**
Listen to "what could have happened, but didn't?", maybe ask about it.
Why do you think it is so?
Can you elaborate more on that?
Is that always the case?
Can you remember such a situation?

**Mattias Wiggberg, Ph.D. Student, Department of Information Technology, Uppsala University**
Box 337, SE-751 05 Uppsala,SWEDEN, Telephone +46 70 – 999 88 44, +46 18 - 471 3176 Telefax +46 18 – 51 19 25
Internet: user.it.uu.se /~mattiasw E-mail: mattias.wiggberg@it.uu.se

# Interview questions, Swedish

**[Eftersökt fenomen]**
Beslutsfattande och lärande

**[Beslutsfattande]**

Vilken är din erfarenhet av kommunikation på gruppen möten?

Vad tycker du om era möten? Tycker du om era möten?
- Varför/Varför inte?
- Någon speciell del som är bra/dålig?
- Anser du att era möten är effektiva?
- Hur bestäms vem som får ordet?
- Vilken roll har mötena?
- Lär du dig något under mötena?

Vad för verktyg använder ni för att samarbeta?

Används några tekniska hjälpmedel under mötena (eller besluten)?
- Hur påverkar dessa beslutsfattandet?
- Vem använder de tekniska hjälpmedlen?

Hur uppfattar du diskussionerna i gruppen?
- Finns det personer som har mer inflytande?
- Dominerar någon diskussionerna?
- Vad händer om ni inte kommer överrens?

Finns det en koppling mellan den tilldelade eller påtaga rollen och lärande?

Vem tror du har mest inflytande i gruppens beslutsfattande?
- Vad är det som gör att det får bestämma?
- Vad betyder inflytande i termer av möjligt lärande från projektarbetet?
- Är det alltid samma folk som bestämmer?
- Varierar det med vilken typ av beslut det rör sig om?

Vilken är din erfarenhet av planering i gruppen? Av att bestämma mötesstrategier? Av problemformulerande?

Betyder bestämmande också att du får välja uppgift?

Vad är lärande iert projekt?
- Vem lär sig något?

Vad är din erfarenhet av ansvar i projektet?
- Vad är du ansvarig för i gruppen?
- Följer något ansvar med inflytande?
- Betyder ansvar något extra för lärande?
- Hur fördelas ansvar i gruppen?
- Varför tror du att det fördelas så?

**Mattias Wiggberg, Ph.D. Student, Department of Information Technology, Uppsala University**
Box 337, SE-751 05 Uppsala,SWEDEN, Telephone +46 70 – 999 88 44, +46 18 - 471 3176 Telefax +46 18 – 51 19 25
Internet: user.it.uu.se /~mattiasw E-mail: mattias.wiggberg@it.uu.se

Beskriv ett beslut som fattats I projektet
- Vem sa vad till vem?
- Hur kom folk upp med information till beslutet?
- Hur fattar din grupp beslut?
- Hur mycket inflytande hade du?
- Är detta typiskt?

Tänk på ett beslut i projektet. Kan du berätta när i tid det hände?

Är det någon skillnad mellan gruppmedlemmar avseende beslutfattande?
- Varför tror du att det är så?

**[Kulturella]**
Uppfattar alla det på det viset?
Ser du någon skillnad mellan svenskarna och kineserna?
- Jag menar till exempel vad du tror att de tycker om [beslutsdiskussioner]

Har din inställning till [beslutsdiskussioner] förändrats under din tid i Uppsala?

**[följdfrågor]**
Lyssna efter vad som kunde hänt men som inte gjorde det…
Varför tror du att det är så?
Kan du berätta mer om det?
Är det alltid så?
Kan du påminna dig en sådan situation?

- Fråga vad de hade förväntat sig om X?

- Hur blev X?

- Hade alla förväntat sig detta omX?

- Om inte, hur tror du att det kom sig att nu gjorde X på just det sättet?

- Sätt **förväntningar** i relation till **utfall**.

- Alla frågor bör ha en släng av "Vad tror du att ..", Hur skulle du säga att ...."

- Ser du någon skillnad i vad svenskarna och kineserna förväntat sig om X? G e exempel?

- Ser du någon skillnad i vad svenskarna och kineserna tycker om X/gör med X? Ge exempel?

Dessutom det finns ju beslut. Om vem som gör vad, till exempel.

Bara vara tyst. Och inte bli besvärad av tystnaden.

**Mattias Wiggberg, Ph.D. Student, Department of Information Technology, Uppsala University**
Box 337, SE-751 05 Uppsala,SWEDEN, Telephone +46 70 – 999 88 44, +46 18 - 471 3176 Telefax +46 18 – 51 19 25
Internet: user.it.uu.se /~mattiasw E-mail: mattias.wiggberg@it.uu.se

# Questions data set C

# Appendix D

## Critical incident: Background

A central design issue for using the critical incident technique is creating the initial "framing" questions (Flanagan, 1954). A preliminary interview protocol was designed and piloted with 3 academic and postgraduate staff, in two institutions. The initial framing questions were drawn directly from Flanagan (Flanagan, 1954) and were found to be very difficult for participants to interpret. The questions were adapted, firstly to include the word "real" and secondly to prompt the participant to think of concrete examples of engineering activity. These were piloted with 3 further postgraduates and 2 graduate students, and found to be easier for participants to understand.

## Critical incident: Interview Protocol

We are making a study of students' attitudes to, and understanding of, "engineering". We believe you are well-qualified to talk to us about <insert subject studied>. The purpose is to get your perceptions and your experiences. There are no right or wrong or desirable or undesirable answers. I would like you to feel comfortable with saying what you really think and how you really feel. The entire interview should take approximately 30 minutes to complete.

#### REQUEST FOR GENERAL AIM

Q1 In a few words, what would you say real engineering is?

Q2 Can you give me some examples of engineering in the world? (If the participant asks "what is in the world" encourage them to interpret it as they see fit.)

#### ELICITING CRITICAL INCIDENT

Q3 Can you think of an engineering experience you have had that you particularly enjoyed? Or an experience that you felt represented your ideas of engineering? We are interested in something that actually happened to you.

*a. Can you give a brief overview of the experience?*

*b. What did that experience involve?* (Questions i-v are optional prompts)

- i) Scale: was it a big thing? Or a more private, "aha" moment?
- ii) Setting: where did this happen? Was it at home, or in school, or somewhere else?
- iii) Circumstances: was this one in a sequence of things, or a one-off? Were they doing something normal, or unusual?
- iv) Client: was it when you were involved in an engineering experience yourself? If so, whom were you working for?
- v) Groups involved: were you working with others at the time? Were you in a team? Were you working with other teams?

*c. What is it about that experience that summarises "engineering"?*

*d. Why do you think this particular experience came to mind? Why was it important?*

# Survey data set D

# Runestone 2008 Project Survey

Exit this survey >>

This survey investigates student focus and aims in the Runestone course. The purpose of the research, of which this survey is a part, is to increase the pedagogical efficacy of computer science student projects. In order to form strong conclusions it is important to get as many responses as possible. Your participation is crucial and I ask for your kind help.

Completion of the survey will not take longer than 10 minutes. It is completely voluntarily to answer the survey, there are no sensitive questions, and you do not have to respond to all questions in order to complete the survey. The survey web tool keeps a log of responders to connect them with some background data and to support sending out reminders. All data will be treated confidentially.

No data for individuals or groups will be shared with your instructors, nor will your instructors ever know whether you completed this survey or not. Teachers involved in the course management will not take any part in the research process based on the data collected.

I sincerely appreciate your help!

Next >>

# Runestone 2008 Project Survey

Exit this survey >>

## Result

### 1. How much time did you spend on average on the project?

Hours per week

### 2. How much do you think you have learned from the project?

| | Very little | Some | Neither a little nor a lot | Quite a lot | Very much |
|---|---|---|---|---|---|
| Gained skills | | | | | |

### 3. How important has your contribution been to the final result in terms of

| | Not at all | A little | Neither important nor unimportant | Quite | Very |
|---|---|---|---|---|---|
| The LEGO robot itself | | | | | |
| The grade of the group | | | | | |
| Achieving what is needed to pass the course | | | | | |

### 4. How important have the following been to you during the Runestone project?

| | Not at all | A little | Neither important nor unimportant | Quite | Very |
|---|---|---|---|---|---|
| Deliver on time | | | | | |
| Meeting the requirement specification | | | | | |
| Extra functions not seen by the teachers | | | | | |
| Extra functions that are visible to teachers | | | | | |
| Achieving what is needed to pass | | | | | |
| Neat technical solutions | | | | | |

Next >>

# Runestone 2008 Project Survey

Exit this survey >>

## Team processes

### 5. How important have the following been to you during the Runestone project?

| | Not at all | A little | Neither important nor unimportant | Quite | Very |
|---|---|---|---|---|---|
| That team members don't waste time in social chatter, but are always focused on tasks | | | | | |
| That all team members do their share of the team's work | | | | | |
| That all team members are involved in decision making, even when it takes up time that for instance could've been spent on designing the LEGO robot | | | | | |
| That team members spend time getting to know each other | | | | | |
| That all team members feel that they are part of the team | | | | | |

Next >>

# Runestone 2008 Project Survey

Exit this survey >>

## Task allocation

### 6. Please state the two tasks that you have spent most time working on.

Task 1

Task 2

### 7. To which extent did your group give you responsibility

| | Not at all | A little | Neither a little nor a lot | Quite a lot | Very much |
|---|---|---|---|---|---|
| of task 1 | | | | | |
| of task 2 | | | | | |

### 8. To which extent did you in fact work on

| | Not at all | A little | Neither a little nor a lot | Quite a lot | Very much |
|---|---|---|---|---|---|
| task 1 | | | | | |
| task 2 | | | | | |

### 9. Thank you very much for your time! Your participation is extremely valuable.

### If you have any comments or questions, please write them in the space below.

<< Prev Done >>

Survey data set E

Capabilities

**Exit this survey >>**

**Introduction and Purposes of the Survey**

This survey investigates capabilities considered critical in software development. You will be asked to complete the same survey at the end of the project course. The aim with this particular investigation is to learn about individual development in relation to the project course.

The purpose of the overall research, of which this survey is a part, is to increase the pedagogical efficacy of computer science student projects. In order to form strong conclusions it is important to get as many responses as possible. Your participation is crucial and I ask for your kind help.

Completion of the survey will not take longer than 15 minutes. It is completely voluntarily to answer the survey, there are no sensitive questions.

All data will be treated confidentially. No data for individuals or groups will be shared with your instructors, nor will your instructors ever know whether you completed this survey or not. Teachers involved in the course management will not take any part in the research process based on the data collected.

I sincerely appreciate your help!

Next >>

# Capabilities

Exit this survey >>

## Assesement of Capabilites

**1. Assess your own skill level in each of these capabilities, by ticking the applicable radio button.**

| | High | Medium | Low |
|---|---|---|---|
| Analysis | ○ | ○ | ○ |
| Decision Making | ○ | ○ | ○ |
| Independence | ○ | ○ | ○ |
| Innovation/Creativity | ○ | ○ | ○ |
| Judgement | ○ | ○ | ○ |
| Tenacity | ○ | ○ | ○ |
| Stress Tolerance | ○ | ○ | ○ |
| Self-organization | ○ | ○ | ○ |
| Risk Management | ○ | ○ | ○ |
| Environmental Knowledge | ○ | ○ | ○ |
| Discipline | ○ | ○ | ○ |
| Environmental Orientation | ○ | ○ | ○ |
| Customer Service | ○ | ○ | ○ |
| Negotiating Skills | ○ | ○ | ○ |
| Empathy | ○ | ○ | ○ |
| Sociability | ○ | ○ | ○ |
| Teamwork/co-operation | ○ | ○ | ○ |
| Co-worker evaluation | ○ | ○ | ○ |
| Group Leadership | ○ | ○ | ○ |
| Planning and Organization | ○ | ○ | ○ |

Done >>

Questions data set F

**Instruktion**

**Följande frågor vill jag att du skriver en berättande text om. Texten är så lång som du önskar att den blir. Det är dock bra om texten hänger ihop.**

**Det är dina tankar och funderingar som är viktiga, inte vad du tror förväntas av dig. Det du berättar om här kommer inte att förmedlas till någon lärare på kursen annat än i sammanställd form för hela gruppen och då långt efter kursens avslut.**

1/4

Berätta hur din syn på ditt mål med deltagandet i projektkursen har ändrats ut med kursens gång. Hur såg du på målet med deltagandet före kursen, i början av kursen och hur ser du på det nu?

2/4

Berätta hur du uppfattar att graden av frihet i att planera arbetet och i utformningen av projektuppgiften har påverkat hur mycket och vad du lär dig?

3/4

Berätta hur fördelningen av uppgifter påverkat vad och hur mycket du tror att du kommer att lära dig under projektets gång?

4/4

Berätta vilken syn du har på projektets fokus. Är ditt fokus på processen att arbeta med projektet, eller är det själva den färdiga produkten som är viktigts? Hur har dina tankar kring valet av uppgift i projektet påverkats av det fokus du har?

## Instructions

**Please write a narrative text, a story, about the following questions.**

**It is your thoughts that I am interested in, not what you think is expected of you. Nothing that you write is good or bad, but every thought you have is warmly welcome.**

**What you write here will not be read by any teachers.**

**Good writing!**

1/4

Tell me about your view on your participation in the project course. I am interested in learning about your motivation and goal with your participation. How was your view on this issue before the course started, *during* the course and how is it *now*?

2/4

Tell me how you feel about the level of freedom in the project planning. Is the degree of freedom high or low? How has the actual degree of freedom influenced what and how much you learn from the project so far?

3/4

Tell me about the work allocation in the project. How has your project's model for allocating work influenced what and how much you will learn?

4/4

Tell me about your view on the focus of the project. Is it the product (software) itself, or is it the process you consider more important? Have you been affected in your choice of project role by the interpreted focus of the project?

# Questions data set G

**Survey/interview questions based on the examples in Wenger (1998, p 125). Answers to those should provide me with enough information to define the particular projects as CoP.**

***Mutual engagement***

- Doing things together
- Relationships
- Social complexity
- Community
- Maintenance

Examples
"Being included in what matters is a requirement for being engaged in a community of practice,"
This is an interesting statement. I wonder if you could say something like

Q: What are the activities that really matter for your project? Who participates in these? Does everyone participate in about the same way?

Q: What kinds of things have you done in the project? Have you done about the same amount of things, had about the same responsibility, or has this increased or decreased over time?

Q: Could you give some examples of ways of working in the project? How is the work laid out on each of you? Do you collaborate? Could you describe the collaboration?

Q: How do you handle information in the project? Is information shared between you and the others? In what way and how? (too vague)

***A joint negotiated enterprise***

- Mutual accountability
- Interpretations
- Local response
- Rhythms

Q: Can you describe a time when your group solved a problem together? How did that come about? Were there times when the group had a problem to solve, but didn't solve it as a group? How did that happen? Do you think this is a typical way of solving a problem or something that has become really specific to how you as a group work together?

Q: Can you explain what areas of expertise your colleagues have? Did you know what your fellow colleagues worked with during the project?

Q: Can you describe how you work together?

Q: Please describe how you talk, communicate and behave to each other in the room? Do you think you've come up with some ways of talking that are really specific to your project?

Q: Are there people who seem more like they belong than others? How connected do you feel to other group members?

***A shared repertoire of negotiable resources accumulated over time***

- Stories
- Artifacts
- Styles
- Actions
- Discourses
- Concepts
- Historical events

Q: Do you have any specific habits, norms or cultural expressions in the group? Are there times when you're not focused on some project related task? What do you do then? What are the expected ways of being involved for a member of your group? If you could describe "the perfect group member" for this project, what would it be?"

**Note**

Also, keep in mind that those who later review your work might want to know how you avoided leading interviewees to give answers that fit into those categories. That is, sometimes people choose a theoretical perspective and then when they collect data, they amazingly can report on it, because people were kind enough to respond to their questions rather than to say "what has this got to do with my involvement with colleagues?"

Questions data set H

**Frågor/teman till lärare på projektkursen**

1. Vilka praktiker, saker som studenterna förväntas göra och lära sig, uppfattar du som centrala i projektet?

   Uppföljning
   - tekniska aspekter, något verktyg eller så,
   - färdigheter på ett mer övergripande plan,
   - centrala praktiker i projektet.
   - skiljer sig din uppfattning från kursplanen (http://www.uu.se/en/node701?kpid=11639&type=1) (speciellt map. det som benämns Learning Outcomes)?

2. Vilket anser du syftet är med IT-projektkursen?

3. Vilka fem praktiker är absolut viktigast att studenterna får öva på, och varför? Rangordna dem gärna på det vis som går.

# Acta Universitatis Upsaliensis

*Digital Comprehensive Summaries of Uppsala Dissertations from the Faculty of Science and Technology* 722

Editor: The Dean of the Faculty of Science and Technology

A doctoral dissertation from the Faculty of Science and Technology, Uppsala University, is usually a summary of a number of papers. A few copies of the complete dissertation are kept at major Swedish research libraries, while the summary alone is distributed internationally through the series Digital Comprehensive Summaries of Uppsala Dissertations from the Faculty of Science and Technology. (Prior to January, 2005, the series was published under the title "Comprehensive Summaries of Uppsala Dissertations from the Faculty of Science and Technology".)

Distribution: publications.uu.se
urn:nbn:se:uu:diva-120081

ACTA
UNIVERSITATIS
UPSALIENSIS
UPPSALA
2010