Computer Science Students’ Experiences of Decision Making in Project Groups

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Abstract

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

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

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

1 Introduction

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

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\text{[...]} \text{two or more people who are jointly responsible for detecting a problem, elaborating on the nature of the problem, generating possible solutions, evaluating potential solutions, or formulating strategies for implementing solutions. (Desanctis & Gallepe 1987, p. 590)}
\]

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

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

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

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

Learning outcome is defined by Berglund (2005):

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

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

1.1 Research Questions

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

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

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

This question was the driving force in the study. During the investigation, a second question became apparent:
in which ways does the student team work to make decisions?

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

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

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

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

2 Related Work

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

2.1 Decision-Making Structures

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

Barker et al. (1991) suggest five strategies for team decision-making: force, majority vote, compromise, arbitration, and consensus. No single strategy is thought to be best for all teams. Instead, the most appropriate team decision-making strategy is likely to depend on the particular group phase, time constraints, and other such factors (Barker et al. 1991). Wickens & Hollands (2000) extend the discussion on decision-making with domains of decision-making, a model proposed by Shanteau (1992). In this model, the value of practice and experience in a field is questioned in certain domains. Einhorn & Hogarth (1978) have then added understanding of feedback to the model. The model presents the characteristics of good and poor decision-making domains. A good domain is dynamic, involves decisions about things, has decomposable decision problems, and provides feedback. A poor domain is static, involves decisions about people, gives no or poor feedback, and does not provide decomposable decision problems (Shanteau 1992). The conclusion is that in poor domains, decision-making is hard even for experienced people.

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

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

2.2 Projects as an Educational Setting

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

Seat & Lord (1998) emphasize the importance of 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.

Berglund (2005) explores students’ learning within a similar project environment. Among other things, Berglund identifies three different motives for taking the course in focus: academic achievement, project and team working capacity, and social competence. Barker (2005) reports on how perceived pressure to finish a project for clients, together with poor understanding of how to work well in groups, has a negative impact on the learning environment and pedagogic outcome of the project model.

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

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

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

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

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

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

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

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

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

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

3 The Setting

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

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

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

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

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

3.1 The Physical Environment

The physical environment of the project plays an important role in a project (Jacques 1995, p. 129). During the project the students worked in two project rooms. Each team sat in a separate room, but the rooms were located close together. Collaboration between the project teams was encouraged. The work environment was an open-plan office where people located themselves close to the other members of the smaller groups they ended up working in. Each student was given a workspace and a computer. The room was equipped with whiteboard, printer, and some other hardware. The teams were asked to use software for keeping track of bugs, version handler, content management system and personal diary software (Pettersson et al. 2006).

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

3.2 Project Teams and Their Tasks

Twenty-two students participated in the course. Five of them were exchange students from Tongji University, Shanghai, China, who had completed two years of computer science in China and one year at the department prior to the project course. The other 17 students were Swedish and were all enrolled in the Computer Science Masters Program. They had completed approximately two years of compulsory courses and one year based on individual preferences. Both the exchange students and the Swedish students voluntarily applied for the course 1.

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

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

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

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

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

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

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

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

4 Research Design

4.1 Data Collection

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

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

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

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

Decision-making processes might be different in the different project teams, therefore the students’ experience is perceived differently. Since the phenomenon in focus, how the student experiences the process of decision-making, regards the full project.

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

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

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

4Wireless Local Area Network, WLAN, is a standard for linking two or more computers using a wireless network device.
course, this difference is a part of the expected variation in experiences. The interviews were performed in three sets of six interviews each over the duration of the course. The aim with this was to catch experiences from early, middle, and late team phases in the team development, as described thoroughly by Jaques (1995).

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

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

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

### 4.2 Analyzing Data

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

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

### 4.3 Phenomenography and Learning

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

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

Since the categories illustrate different aspects of the same phenomenon, they are logically related to each other. Were they not, they would describe aspects of different phenomena. In general, some categories offer a wider or richer perspective and often come to embrace others in an inclusive structure.

![Diagram of Phenomenography and Learning](image)

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

[... the more embracing categories are generally more desirable. (Berglund & Wiggberg 2006, p. 265)]

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

1. The what aspect of the learning, describing the content of the learning (for example a network protocol) and
2. The how aspect, describing how the students go about learning, or how they tackle their learning.

While the first normally is referred to as the act of learning, the latter is labelled the indirect object of learning. This distinction is, as Marton & Booth (1997) point out, purely analytical: the aspects can only be "thought apart" for research purposes and do not represent different concepts. (Berglund & Wiggberg 2006, p. 265)

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

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

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

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

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

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

See figure 2 for a summary of the analytical framework.

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

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

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

4.3.1 Different Approach on Question B

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

5 Empirical Results

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

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

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

5.1 Question on How Students Experiences Decision-making

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

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

Cat. 1: Decisions by Individuals

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

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

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

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

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

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

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

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

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

Edison: And for example far, I am, I am doing the communication with the client side and if the server goes wrong, and I am
<table>
<thead>
<tr>
<th>Label</th>
<th>(Referential aspect) Decision-making is understood as...</th>
<th>(Structural aspect) The focus is on...</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Decisions by individuals</td>
<td>... too small or involving too few to be handled by any means other than the individual first encountering the decision. The individual perceives the unimportance of the decision and therefore it becomes a private issue.</td>
</tr>
<tr>
<td>2</td>
<td>Decisions by individuals with preferential right of interpretation</td>
<td>...an informal right to interpret and make decisions even though the decision might involve other people.</td>
</tr>
<tr>
<td>3</td>
<td>Decisions by small group discussions</td>
<td>...a mutual agreement in a smaller group. The decision matters for more than just one individual and therefore automatically involves opinions from more people.</td>
</tr>
<tr>
<td>4</td>
<td>Decisions by group discussions supported by a facilitator</td>
<td>...group discussions supported by a facilitator.</td>
</tr>
<tr>
<td>5</td>
<td>Decisions by democracy in full team</td>
<td>...a democratic process in a formalized full team setting.</td>
</tr>
<tr>
<td>6</td>
<td>Decisions by mutual agreement between team and external stakeholder</td>
<td>...democratic involving the full team, but in the same time the ‘reality’ is involved in some way.</td>
</tr>
</tbody>
</table>

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

in charge of every... everything, and I, of course I have the, the right to decide, eh, the architecture and stuff like that.

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

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

Courtney: It is not formal, but it is like, eh, everybody, I do not know, eh, we, it is not written anywhere, but it is like we are working, because everyone, in charge of different things, you, of course, this is your job, and you, you, of course you should have the, eh, [decision/right to decide].

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

Cat. 3: Decisions by Small Group Discussions

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

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

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

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

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

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

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

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

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

Ashley: And she was also sort of part of the discussion, tossed ideas and such, since she’s kind of well situated in everything.

Interviewer: Yes.

Ashley: But she said that, look, we have kind of discussed this for 15 minutes and, it was just a tiny detail. Because this was something that would take like between 5 and 20 minutes to implement. And then she sort of said that enough is enough.

The category involves situations where a group discusses a particular issue. The discussion need not be formalized or planned, but more than one person is involved.

Harold gives another example from this category:

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

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

Cat. 5: Decisions by Democracy in Full Team

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

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

Interviewer: And the first thing I want to ask is how a decision is made in your team.

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

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

Interviewer: And then, did you open up for a general discussion or...

Alfred: Oh, ok, yes, yes, everyone can speak for free, can, give their own opinion about the specific, the scope, and maybe we, eh, how you say, we, kind of vote, voted.

Interviewer: Voted.

Alfred: Yes, voted, kind of.

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

Interviewer: Right... When you say democratic, then you mean that...

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

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

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

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

Leslie starts to illustrate this:

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

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

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

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

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

### Table 2: Categories describing different strategies for decision-making

<table>
<thead>
<tr>
<th>Decision-making strategies</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<tbody>
<tr>
<td>Small group meeting</td>
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<td>Outside meeting</td>
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<td>Full team meeting</td>
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<td>Lottery</td>
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<td>Voting</td>
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</table>

### Cat. 1: Small Group Meeting

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

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

### Cat. 2: Outside Meetings

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

**Roberta:** It is like when everyone is, during lunch-time someone is drinking coke, someone is having their lunch and they just talk freely during this process they gain some decision.

**Interviewer:** So it is in the formal gathering of people?

**Roberta:** Yes. Also, not everyone, are, I mean, not everyone there, (?) talk with each other...

### Cat. 3: Full Team Meeting

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

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

The formal structure is emphasized by Roberta:

**Interviewer:** So tell me a little bit about those Monday meetings, eh, when you are discussing something, like a decision on design or something like that, how, how is the, how is the structure of the discussion. How is the decision made?

**Roberta:** Structure, as to the structure...

**Interviewer:** Is everyone giving his or her opinion and then the leader decides or is it in some other way.

**Roberta:** The leader always stands in front of that whiteboard.

**Interviewer:** Ok.

**Roberta:** And, he writes what we are going to discuss, the, the points, all the points and topics and he lists that on the whiteboard.
and everyone discuss the topics one by one. Eh, some of the members they maybe not, I mean, they talk not, not not that much, but most of the members they give their opinion.

Cat. 4: Lottery

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

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

Cat. 5: Voting

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

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

6 Conclusion and Implications

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

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

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

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

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

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

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

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

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

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

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

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

7 Acknowledgements

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