A method for analyzing learning outcomes in project courses

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Abstract
Including projects in courses is widely recognized as important in preparing students for their profession. Typical examples are capstone courses, where the students are supposed to use their previous knowledge and skills to show mastery of their craft. What this actually amounts to in terms of learning objectives is however often quite fuzzy, resulting in contradictory ideas about how to actually run them in order to reach these learning objectives. This paper presents a method for analyzing learning in project courses, based on the combination of the theory of communities of practice and an identification of key features in project work. The method can be used to gain an understanding of project courses in order to set up a learning environment suitable for its learning objectives. The focus is on the students’ experiences and how they are mapped on desirable learning outcomes. The results are stories related to key features of project work expressed in the theory of communities of practice that capture the strengths and weaknesses of the studied project course.

Keywords: Communities of practice, computing education research, learning outcomes, and project courses.

1 Introduction
Group, or project, work is today seen as an integral and important aspect of computer science education, e.g. as expressed in the ACM/IEEE Computing Curricula (2005). The folk pedagogy (Bruner 1996, Lister 2008) of computer science teachers support this by pointing out that project work give the students added challenges and increases their preparation for work life, especially if known development methods from industry is used to emphasize the reality aspect. It is not uncommon to involve industry partners as mock clients in order to increase the feeling of reality in student projects.

There is no shortage of interesting and innovative ideas on how to run project courses, but the educational value is seldom demonstrated. The complexity of evaluating the learning outcome of student projects is daunting (Wait et al. 2004 and Barker 2005) and thus mostly not covered in the literature. Examples of efforts to investigate the effect of student projects in terms of learning outcomes are given by Baker and Garvin-Doxas (2004), Berglund (2005), Daniels et al. (2010), Kinnunen and Malmi (2004), and Wiggberg (2010). Much remains however to be done before the body of knowledge among the computer science teachers related to learning outcomes of various implementations of student projects has reached an acceptable level in comparison to the number of study hours the students spend in such projects. With this in mind it is vital to make sure that the learning experiences are of high quality. The guiding question in this paper is thus:

How can we design and set up computer science student projects in order to make them contribute to students’ development and be of a high educational quality, based on a firm research ground?

A method for analyzing learning outcomes from student projects is presented in order to address this question. The method is built on four key features for learning in student projects, identified by Wiggberg (2008), and is used in combination with the theory of communities of practice (Wenger 1998). One common and important assumption with regard to learning in project courses is that they will prepare the students for their profession, in this case as IT-workers. Investigating this assumption can be approached by using the theory of communities of practice (Wenger 1998) as base, since it provides a platform for discussing work related experiences as well as learning outcomes in terms of how the students enter the community of practice of IT-workers.

The paper first present the theory of communities of practice with special consideration to computer science student project courses, followed by a fuller description of the method. The paper concludes by presenting an illustrative story based on one of key features: the way work is allocated, as illustration of the result and a reflection on how this result can be used in designing computer science project courses.

2 Communities of Practice
In the theory communities of practice, learning is thought of as a result of social participation (Wenger 1998, p. 4). Wenger suggest 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 one- or bi-directional communication between the learner and the teacher is seen as an effective way of transferring knowledge. 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 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, multi-dimensional 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 members increase their expertise in the topic by interacting with each other through certain practices in an ongoing process (Wenger et al. 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 work.

Communities of practice exist in places where we share our everyday lives, and often we do not recognize 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 thus.

Wenger put crucial requirements on the community in order to call it a community of practice. These requirements are captured by these three characteristics:

1. **Domain** A shared domain of interest exists among the members. Competence in the domain subject distinguishes a member from a non-member. This implies a commitment to the domain by the members.

2. **Community** Relationships that enables learning from each other. Members of the community share information and help each other. They are also actively engaged in joint activities and discussions.

3. **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 these three characteristics in a combination. The cultivation of the community of practice is based on development of the three characteristics. Important aspects of communities of practice thus involve shared repertoire, domain, mutual engagement and joint enterprise practice, see figure 1.

A very central mechanism in communities of practice is the concept legitimate peripheral participation and the transition to central participation and the reverse process. Lave and Wenger (1991) formulates legitimate peripheral participation as a theoretical description of how newcomers, people 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 than members with more access (Lave and Wenger 1991). Legitimate peripheral participation hence can be used to reflect how members of the community through practices can become more experienced members of the community. Doing that, they will also be more engaged in different practices in the community.

### 2.1 The Project Group as a Community of Practice

Courses based on computer science student projects are the focus of this paper and the student group in such a course is seen as a community of practice. That community consists of the project group itself and their closest collaborators such as teachers and industry contacts. The idea is that this is a part of the IT-worker community of practice in a constellation of practices as defined in (Wenger 1998).

The group formed by the project participants is not a blank slate. It contains people who have knowledge in different areas in what is 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 take 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 varied level of knowledge among the members in the initial phase of the community.

2.2 Communities of Practice as Yardstick

Communities of practice and especially the central concept of legitimate peripheral participation provide the stage for analyzing computer science student projects as learning environments.

The assumption here is that a communities of practice is created in computer science student projects and that there are enough ties to the community of practice of IT-workers refer to these as constellations of practices. By using empirical data to analyze how participants contribute - or not - to constitute a community in the project course, it is possible to unwind actions and behaviors that facilitate - or prevent - the possibility to become a central member of that community, and hence also belong to the community of IT-workers.

The learning outcomes of computer science project courses are defined by the formal course descriptions and interpreted by the teachers giving the course. The learning outcomes are in this work “translated” to practices under the assumption that the courses works as communities of practices. In the study presented in this paper, the following set of practices was used, derived as described in Wiggberg (2010):

1. Working efficiently and constructively in a large project team of developers;
2. Planning and follow-up of a complex project task, and taking care of unexpected things that might occur.
3. Getting experiences of applying previous knowledge; and learning skillful use of tools used in the IT-community.
4. Integrating smaller tasks into a larger task.

3 Method

The general idea is to explore which effects variations of these features can have on the learning outcomes in the student cohort. The method to analyze learning outcomes is based on a matrix with the key features on one axis and a set of practices deemed important in the community of practice in question on the other axis. The steps in using the matrix are:

1) semi structured interviews give information about the features in the current project;
2) identifying intersections where experiences of key features influenced important practices or vice versa;
3) stories are woven to illustrate the selected intersections with the aid of the interviews.

The stories are the result of the method and reveal the students’ experiences in relation to the learning outcomes in projects.

The starting point of the method can be seen as the identification of key features in the setting under study and to identify important practices in the intended community. Previous work (Wiggberg 2008) has identified four such features that will be used in this paper. The next step is to get information about these features from the student group in question, including selecting students to conduct semi-structured interviews with. The conceptual framework of key features is used to categorize interview data and to identify experiences connected to the key features, and establishing relations between key features and identified important practices.

A matrix is then created, where key features are columns and identified important practices constitute the rows as depicted in table 1. The excerpts from the semi-structured interviews are then analyzed in order to find experiences of key features influencing important practices or vice versa that can be mapped onto intersections in the matrix. In the final step, for each column in the matrix (representing one key feature) the excerpts from intersections in the column that are marked as interesting are traced back to their original interview. Interviews showing a high presence of findings in a column are selected as candidates for being used as a foundation for the creation of a story2.

<table>
<thead>
<tr>
<th>Practice</th>
<th>Mechanism for Work Allocation</th>
<th>Connection to External Stakeholders</th>
<th>Focus on Result or Process</th>
<th>Level of Freedom in Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>Practice 1</td>
<td>Observed connection</td>
<td>Observed connection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Practice 2</td>
<td></td>
<td></td>
<td>Observed connection</td>
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<td>Practice . . .</td>
<td>Observed connection</td>
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<tr>
<td>Practice n</td>
<td></td>
<td>Observed connection</td>
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</tbody>
</table>

Table 1: Matrix combining key features and identified important practices.3

In the following section an illustration of the outcome of the method is presented.

4 An illustrative story: A Matter of Motivation and Work

4.1 Background

Data was collected from 11 students participating in a computer science project course (Wiggberg 2010). The

2 Excerpts from different interviews with the same student can inform the same story.

3 Real data are not present in this general illustration. Cells are filled by interesting observations from interviews.
aim with the project was to develop rescue robots, and the project involved building upon software and hardware from earlier instances of the same project course. To fulfill the main task of the project the students had to build rescue robots that autonomously could locate victims in hazardous environment. This included using advanced sensor systems as well as managing advanced communication between the robots. The project team consisted of 22 students (Abbasi et al. 2009).

The practices identified were discussed in relation to legitimate peripheral participation in the theory of communities of practice. The key reason for relating to legitimate peripheral participation is that newcomers who gain access to experts and can study their practice, understands their own activities within the community (Lave and Wenger 1991). Legitimate peripheral participation is thus a natural concept for reflecting on how a student becomes a more experienced (central) member of the community. A natural observation is that being engaged in different practices in the community is an important aspect in the transformation from being a peripheral to becoming a central member of the community. The aim is to capture aspects of the project under study that promote – or hinder - the transformation towards becoming a central member and to express these experiences of the students in stories. One such story is given below.

David⁴ was an Information Technology engineering student that wanted to work in the IT business. David participated in the project HUGE (Abbasi et al. 2009)). During the course, David and the other participants were expected to experience practices identified as important for the movement into the larger community of practice of IT-workers. Recalling the practices identified as capturing this experience is described by:

1. Working efficient and constructive in a large project team of developers.
2. Planning and follow-up of a complex project task, and taking care of unexpected things that might occur.
3. Get experiences of using obtained knowledge, and learn how to use certain tools used in the IT-community.
4. 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.

4.2 Story

David had been reasonably motivated to participate in the student project. He had confidence in his skills in relation to the project, and felt confident in making himself and his needs listened to. During the project, David thought a lot about how the process of work allocation was implicitly and explicitly handled in the project group.

Initially David reflected on the amount of people in the project. He said that his possibility to get an overview of different subtasks and work performed was low due to the complexity of the main task. The number of teammates in the project had made that situation even harder. David was worried that this would lead to problems with becoming involved in discussions with and learning from his fellow students. During the project David got his expectations of peer learning partly confirmed in that the team had to split both the task and the work in smaller pieces. He found the discussions on technical challenges in these smaller groups rewarding. David had the feeling that they had to split tasks and work to a larger extent than they initially wished.

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

**David:** [...] well it could be a disadvantage that we are as many as we are. **There is a focus on one's own piece of the pie at the price 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.**

Lack of time, the complexity of the task and the stress those two caused were suggested as reasons for less communication among the teammates. The stress led to more solitary work and less interaction between the teammates.

**Interviewer:** How do you collaborate, like do people work with different things, or do two or more collaborate on the same thing?

**David:** 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.

Continuing on the thread of lack of time David described this situation:

**David:** We needed to divide ourselves a bit in order to manage to do everything. That is a bit unfortunate since one should make 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 were mixed with David’s impression on how the members of the project chose tasks. What students did in the project was based on their personal interests.

**Interviewer:** What lies behind where one ends up? I have understood that you have divided the tasks.

**David:** 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.

David thought that the level of competence was approximately equal since all students had similar backgrounds. Starting from an even level, David felt that participants quickly became specialized in different areas. Discussions became less frequent after some time since fewer people have the needed level of information and

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⁴ Names have been changed to preserve the anonymity of those involved.
knowledge.

In David’s opinion, each student had the responsibility for his own learning during the project. He said clearly that it couldn’t be the teachers’ responsibility. The belief that teachers did not have the responsibility for learning led to shortcomings with respect to the desired learning, since some students didn’t take their responsibility for learning. Those project members had, according to David, an impact on the rest of the students in the project. Their lack of seriousness affected the learning opportunities in the project, especially for David and others who wanted to learn much.

Ownership was something that David found to vary in a similar way as the taking of responsibility for learning. Those who saw the project just as any another course took less ownership. David expressed that it felt like these didn’t belong to the project in the same way.

**Interviewer:** Are there some in the project that belong to it more than others?

**David:** 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 led to clustering of ambitious students around more important parts of the project. David had a hard time defining what parts were seen as important, apart from identifying parts that were crucial for the development of the physical deliverable as important.

### 5 Discussion

This story is based on the column in table 1 captured with the key feature *Mechanisms for work allocation* and the general aspect *motivation* is highlighted. David’s descriptions and impressions on how work was allocated and the consequences provide insights from a student’s point of view into most of the practices identified as important. The story blends these insights together and a dissection of the story with respect to the identified practices one by one is given below as an aid to interpret the story.

One of the 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*, is in focus in David’s story. The desired practice working efficiently and constructively in a large project team of developers was in parts well implemented in the project. Both the project, in terms of the complexity of the task, and the number of developers was large. But, according to the collected experiences, the efficiency and constructiveness could have been improved. David pointed out how problematic this practice is to get experience with in a project.

The practice *getting experiences of applying previous knowledge and learning skills of tools used in the IT-community* was affected by the divide-and-conquer behavior opted for by the students. When students divide such a complex task as the one in the project, and at the same time feel stress about fulfilling the task, it tend to lead to students working within a small 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 for each student indicate that the experience of applying previous knowledge could extend to more fields. Overall, there is a risk for conflict between deep learning in one subject and enriching knowledge in a broader sense.

Perceived stress in a project seem to lead to opting for a divide-and-conquer division of work, affecting the practice *integrating smaller tasks into a larger task*. The divide-and-conquer approach to the project tasks not only separates 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 sharing the experience. This problem gets worse and worse the more they divide. The experience described does not mention positive effects of this, it rather points at the limiting effect it has on discussions. Valuable discussions are lost and hence the number of peer learning situations is reduced. Especially it is interesting to note that the more tasks were divided up, the harder it became for the students to help each other. Here, the amount 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 are becoming 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 community.

Practicing *integrating smaller task into a larger one* was problematic according to David’s experience. David pointed at the general complexity as being too high and there being too many people involved in order to get the overview needed to perform both a nice integration and an effective environment for peer learning. David noted time pressure leading to stress as a factor that influenced the manner in which the students 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.

In summary, it was clear that David 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 David’s thoughts on learning, it is clear that he views it as all students have their own responsibility for learning during the project. This belief was somewhat in contradiction to what one of the course responsible teachers’ said when he stated that the reason for the complexity of the task is to function as a catalyst to forces the students to collaborate and thus securing the goal of collaboration among the students.

David's comment that the responsibility for learning was the individual student and not the teachers’ is interesting. The intention relative student learning with the course, and its design to meet the intention, seemed to have been ignored by David. Blaming fellow students for negative impact on learning was hence the result of David’s analysis. The intention with the course, increased learning through the project, seemed to have been forgotten, which might imply that this intention was not on
top of David’s head. The observation is that the design of the course didn’t lead to the students getting access to the practices leading 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, etc.

Another very interesting part of the story is when David states that it is the student’s own responsibility to learn in the project. The students that didn’t take that responsibility placed themselves apart from the tasks that mattered in the project. Such a behavior does not help the process of legitimate peripheral participation, nor give 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 David 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 criticizing 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.

6 Conclusion

The importance of project courses and the amount of time students, and not least teachers, spend in them warrants careful consideration of how to set up and run them. The described method is a step towards addressing this issue in a scientific manner.

Acknowledgment

We would like to thank the students who participated in the interviews. We also would like to thank the reviewers pointing out improvements to make.

References


