Comparing Collaborative Activities, Discourse and Self-Reported Learning of Students Working on Ill-Structured Capstone Projects

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Abstract

We examine how students' collaborative activities, discourse and self-reported learning differ depending on the structure of the capstone project that they work on. We completed a case study to investigate how two pairs of students in an upper-division undergraduate physics laboratory collaborate to come up with ideas on two capstone projects that differ in content and structure. One pair completed a capstone project which built on an existing experiment that the students did in an earlier course, while the other pair of students completed a capstone project which did not build on an existing experiment. Our analysis of the discussion between pairs of students working on these two capstone projects has indicated a difference in the types of statements made during the discussion. We find that students working on one of the structured capstone projects made more statements that present information or ideas while students working on the less structured capstone asked more questions and made fewer statements that present information or ideas. However, we find that students in both capstone projects made very few statements demonstrating that they evaluated or reflected upon their ideas.

Background and Introduction

The ability to solve problems has long been acknowledged as an important skill for future scientists and engineers. To effectively build problem solving skills in our students, we must recognize that the problems learners encounter in their professional life can differ from those that they are typically trained to solve in the classroom.

Problem structure can be considered to vary from well-structured to ill-structured along a continuum (Jonassen, 2007). Well-structured problems are well constrained with all elements of the problem specified explicitly. Thus, well-structured problems have well defined initial and final states and clearly defined solution paths. In contrast, ill-structured problems are vaguely defined with some elements of the problem unknown. Hence, ill-structured problems may have multiple solutions and multiple solution paths (Jonassen, 1997; Shin et al., 2003). Well-structured problems are more commonly encountered in schools than ill-structured problems, which are mostly encountered in everyday and professional settings (Jonassen, 2000). As a result, most studies on student problem solving have focused on well-structured problems with few studies looking at students' ill-structured problem solving.

In this study we investigate the process by which college students work collaboratively on an ill-structured problem solving task which is encapsulated by an end-semester capstone project. The use of capstone projects is common place in several upper-division science and engineering courses. In this paper we focus specifically on student interaction with each other as well as with the materials during the ill-structured task. We also analyze students' self reflections about their own capstone experiences. We examine how students' collaborative activities, discourse and self-reflection differ depending on the structure and content of the capstone project which they work on.

Several studies have looked at such student collaborations while students are working on group activities. Hogan et al. (1999), for example, have examined the interaction patterns of groups of eighth graders as they constructed mental models of the nature of science while Resnick et al. (1993) looked at conversations among triads of university students discussing the subject of nuclear power policy. These investigations have mostly looked at students' discussions while creating models in class with a few studies looking at students in a laboratory setting (Fisher et al., 1998; Hofstein, 2004).

We have completed a case study of two pairs of students in an upper-division undergraduate physics lab collaborating on two capstone projects that differ in their content and structure. Our research question is: *How does the students' discourse and self-reported learning differ between two groups of students, each working on a different capstone project?*

Methodology

Students in an upper division electronics course for physics majors -- *Physical Measurements and Instrumentation* (PMI) -- at Kansas State University, worked in pairs to complete a capstone project. This course covered analog and digital electronics. The course was designed such that the students spent the first half of the semester learning about analog and digital electronics and building circuits using these components. Then, in the latter half of the semester students spent all their class time working on the capstone projects. The capstone projects required the students to come up with ideas based on their newly learned knowledge of electronics to do a physical measurement or to come up with ideas to improve a measurement done in an experiment that they had done in a previous laboratory course. It was required that these ideas involve a considerable application of the electronics knowledge that they had learned in the first half of this electronics course. After consulting with the instructor of the course, the students then went on to implement their ideas or a slight modification of their ideas by actually building circuitry to automate or control the experiment or the physical measurement being done.

Each pair of students worked on a different capstone project and the students spent about eight hours a week for four weeks working on these capstone projects. We have conducted in-class observations involving video and audio recordings of the students working on these capstone projects. In addition, we have interviewed the students before and after working on the capstone projects and also collected the students' written responses to conceptual questions that related to the content of the capstone projects. The video recordings of these in-class observations were qualitatively analyzed to understand the patterns of the students' discussions and how the pairs of students made initial plans on how to tackle the capstone projects. We have used the students' performance in the pre- and post-interviews and responses to conceptual questions to gain an understanding on how students progressed from the beginning to the completion of their respective capstone projects.

Analysis and Findings

The video recordings of the in-class observations for the initial parts of the capstone projects were transcribed and then open coded to look for emerging themes and common trends of the two different capstone projects. In this initial part of the capstone projects the pairs of students were engaged in discussions to come up with their plan of tackling the capstone projects. The two capstone projects that we have looked at are the superconducting quantum interference device (SQUID) project and the speed of light (SOL) project. Next we describe our general impressions of the kinds of activities that students engaged in during the two capstone projects. Later we examine the nature of the discourse between the students in these two projects.

Analysis of Students' Activities

For the SQUID capstone project, the students were required to apply their knowledge of electronics from the first part of the PMI course to improve the measurements done in the SQUID experiment. The SQUID experiment involves measuring various properties of a superconductor such as critical temperature and critical current. The students had done the SQUID experiment in an earlier advanced lab at least one year ago. Initially, the students reviewed what they had done previously in this experiment, then they brainstormed some ideas that they could implement in order to improve the measurements done in that experiment.

We have found that the students doing the SQUID project spent a majority of their time referring to the lab manual that is available for use with the SQUID experiment. This was mostly because the students had to review what they had done in that experiment before deciding on how to apply their knowledge of electronics to improve the measurements done in the experiment. The other reason for students spending most of their time referring to the lab manual was because they eventually decided to build circuitry for a flux locked loop and this circuit was included in the lab manual and so they referred to the circuit in the lab manual as they were building their own circuit. The flux locked loop circuit was a new concept to them and so they spent a lot of time referring to the lab manual and conversing with the instructor of the course in order to understand how the circuitry worked.

The students doing the SOL capstone project were required to build a circuit that they could use to measure the speed of light through a fiber optic cable given that they had a laser diode, a photodiode and a variety of electronic chips which they had learned about during the first part of the PMI course. These students spent a majority of their time searching the internet for ideas on circuitry they could use in order to measure the speed of light. The students initially opted to search for a ready made circuit rather than come up with their own design using the equipment available to them. However, following intervention from the instructor they were advised to break down the main circuitry design into smaller parts with which they were more familiar from the first part of PMI. This allowed the students to make progress in the circuit design.

Clearly, the two capstone projects differed in content as well as structure. The structure of the SOL project is different from that of the SQUID project in the sense that the SQUID project is developed around the SQUID experiment while the SOL project does not directly apply to an already existing experimental set up. The SQUID capstone offers the students an initial starting point (the SQUID experiment) from which students can begin to formulate a way to approach the project while in the SOL capstone the students only have bits and pieces (the provided components) from which they have to come up with a circuit design.

Analysis of Student Discourse

To analyze the discussions of the student pairs, we followed an approach similar to Hogan et al. (1999) whereby while coding the transcripts, we looked at the types of statements that the students made to one another during their conversations. Three main categories of statements were made. These statements are in the form of presenting information or ideas, asking questions and evaluating or reflecting on an idea.

The following excerpt is a discussion between the pair of students in the SQUID capstone. In this excerpt lines 1, 7, 9, 13 and 14 indicate examples of presenting information or ideas statements and lines 4, 5, 10 and 11 are examples of asking questions statements.

1 Student 1: So this change in voltage is just telling us that it's oscillating. So ... and that has something to do with the screening current.

2 Student 2: Right ... right.

3 Student 1: Ok.

4 Student 1: Hey, what do we do? Like...

5 Student 2: For the project?

6 Student 1: Yeah.

7 Student 2: Read more on whatever flux lock loop is...

8 Student 1: Yeah.

9 Student 2: And then I guess ... temperature control...

10 Student 1: I don't know if there is a better way to read the temperature. I don't know if we can do it as part of the diode?

11 Student 2: To read it?

12 Student 1: Yeah.

13 Student 2: Well there is ... I don't know the difference but ... well since the silicon diode thermostat is something that we usually use ... I don't know if there is something better than just a regular silicon diode.

14 Student 2: Usually they come with like ... tables ... with like calibration.

In another excerpt of a discussion students in the SOL capstone are trying to figure out exactly how to find the time it takes for light to travel through a fiber optic cable. Several questions are asked (lines 1, 2 and 4) and information or ideas are presented (lines 3, 6, 7 and 8). Overall we see that the students are evaluating or reflecting on how to get the time it takes for light to travel through a fiber optic cable.

1 Student 1: So you know the material and you know the distance that the light travels, right?

2 Student 2: What did you say ... material?

3 Student 1: It's supposed to be the speed of light in the material, c is the speed of light in vacuum.

4 Student 2: So how can we get time from here...? This equation…?

5 Student 1: Yeah it's possible. You know the...

6 Student 2: n [the refractive index] is a constant

7 Student 1: And you know c is 3 [actually c = $3x10^8$ m/s]

8 Student 1: You get the speed. And you know the length of the fiber; you take your distance and divide by speed.

The distribution of these statement categories for the student pairs in these two capstone projects is summarized in Table 1.

From the results in Table 1, we see that the students in the SQUID capstone spent a majority of their discussion time presenting information and ideas about the project. This is mostly because the students had a familiarity with the SQUID experiment from their previous advanced lab and so it was much easier for them to come up with ideas related to that capstone. In contrast, the students in the SOL capstone spent a majority of their time asking questions, most probably because they had little understanding of what their task was since it was a completely new situation for them. Evidently both the students in the SQUID and SOL capstones spent a rather small fraction of their time evaluating their statements or reflecting on their ideas.

The differences in the types of statements that the students made during the discussion can be attributed to be due to a variety of reasons. One possibility could be due to the difference in the structure of these two capstone projects. The other possibility might be that these differences in statement types were due to the differences in the actual content of these two experiments, since the two experiments dealt with rather different concepts even though the goal of both capstone projects was for the students to apply their knowledge of electronics to these contexts. Yet another possibility for this apparent difference in statement types might well be that the groups of students involved in these two projects had different ways of communicating with each other.

Analysis of Students' Self-Reported Learning

We examined the transcripts of the students' interviews and their written responses to conceptual as well as self-reflective questions about their capstone project. We found that students in both projects started with a fair understanding of the concepts involved in these projects and with time the students were able to improve their understanding of these concepts as demonstrated by the increase in the details of the students' explanations in their responses to the conceptual questions. When asked to talk about their experiences while working on the projects, students in both capstones indicated that overall they had a positive experience and a good opportunity to relearn concepts (in the case of the SQUID capstone) and to learn new ideas (in the case of the SOL capstone).

When asked to describe their capstone project experience one student in the SQUID group said, "I think it was a good thing to do. I relearned some things that I did in the Advanced Lab and I kind of understand them better now that I have had other classes." Another student stated the following:

> I already kind of knew how the SQUID worked. I kind of relearned that new information but I feel that I have a stronger grasp of it now. Like when I took advanced lab when I was a sophomore I hadn't done any quantum mechanics besides just the square well and

> … so I actually kind of understand how the SQUID works on a quantum mechanics level, which I had no idea of before, so that was kind of new information.

The students in the SOL capstone project described their experiences in terms of what they had learned. These students expressed that they had mostly learned electronics but had not substantially learned any physics concepts. As an example one student in the SOL capstone said, "(I have learned) how the light propagates through a fiber and something about a comparator and counter to build in the circuit and how to design an experiment. I think that's all." Another student when asked whether they thought they had learned any physics concepts said, "I think I learned only electronics."

Overall, both capstone experiences were received positively by the students even though the SQUID group felt that they had relearned a great amount of physics concepts compared to the SOL group who felt they had mostly learned electronics techniques rather than physics concepts.

Conclusions and Implications

Our preliminary analysis indicates that there is an apparent difference in the kind of discourse between the students. Students working on the SQUID project which is build on an experiment that the students completed in a previous course made more statements that present ideas while students working on the SOL capstone which does not build on an existing experiment, asked more questions and made fewer statements that present ideas. However, in both capstones the students made very few statements demonstrating evaluation or reflection of their ideas. From the student interviews we saw that the students in the SQUID capstone acknowledge relearning more physics concepts while the students in the SOL capstone stated that they had mostly learned techniques in electronics, rather than concepts in physics which was one of the learning goals of the project.

The differences between the two groups of students, can be generally attributed to two broad classes of differences. The first class of differences pertains to the differences between the capstone tasks completed by the two groups i.e. the structure and content of the capstone project, The second class of differences could be due to differences between the students in these two groups. To further understand which of these factors is responsible for the observed differences further research would need to be conducted.

Limitations of Study

This study has several limitations. Firstly, the two capstone projects completed by the two groups of students vary in both their structure and content. Therefore, the observed differences in discourse between the two groups of students could be due to either the difference in the structure of the capstones or due to the difference in the content. Another limitation of the study is due to the fact that we are comparing two different groups of students and it is possible that these two groups of students are not similar. These two groups may potentially have different domain knowledge, communication styles and different prior experiences.

To address these limitations and to further test the alternative hypothesis, a new set of data needs to be collected and analyzed to find out which of these explanations is most probable. One way to understand the underlying cause of the differences in discourse as the students work on the capstone projects is by using the same set of students for these two projects. However, due to time constrains it is not possible to require both groups of students to complete each capstone project. However, there are other ways to address these limitations.

To determine whether the differences between the groups that we observe are due to the inherent differences capstones in the capstone task or whether they are due to differences between the students in these groups and the intrinsic group dynamic, we plan to collect and analyze data on the students' discourse when the students are working on a structured task before they begin their capstone project, in order to observe any changes in the students' discourse that might arise as the students progress from the structured to the ill-structured task. Alternatively, it might be possible to assign two similar groups to work on capstone projects that are similar in content but with varying structure and in order to ensure the similarity of the groups we can make a comparison of the students' backgrounds by comparing the students' domain knowledge, prior experiences and possibly their socio-cultural differences.

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Table 1

Percentage Distribution of Statement Categories in the Capstone Projects

Discourse pertaining to…	***SQUID Capstone***	***SOL Capstone***
Presenting information or ideas	66%	40%
Questions	24%	53%
Evaluating or reflecting	10%	7%