Increasing Lab Participation and Content Retention Through Supportive Laboratory Preparatory Assignments

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I. Abstract

A study is done on an electrical engineering circuit lab course to assess the effect on participation, retention of course content and student satisfaction when prelab assignments were expanded to include a write up of the experiment background and goals. Reading that was created specifically for each lab covered background for the lab that the students should be bringing with them from previous courses but did not tell them how to do the lab. They were asked to summarize the reading on the background by the night before the lab in one or two paragraphs. The inspiration for the addition of this assignment was the observation that students that had trouble with previous quarter's subjects were falling behind even further behind and showed low participation, confidence and success. Retention was assessed using test and report scores as well as observations of students in later classes. Participation was assessed through observation and survey results. Satisfaction was assessed through survey results. Survey results showed that 1/3 of the weaker students increased their participation over other labs in the sections that had prelab statements whereas the section with no statements had zero students saying they participated more. Twice as many of the weaker students felt more prepared for lab than the lab without prelab statements. There was also a general upward trend in report grades and quality of organizational and reasoning sections of reports. Through observation, it appeared as if the weaker students were more confident and participating more also.

II. Introduction

Cal Poly implements its "learn by doing" tenet by pairing most lecture classes with a laboratory. The majority of labs require a prelab to help prepare the students for the lab and a postlab to require the students spend time analyzing what they observed in lab. The three pronged process of preparing for the lab, experiencing the lab and then thinking about what has happened in the lab forces the students to look at the material multiple times and follows well the adage "*Repetitio mater studiorum est" (* Repetition is the mother of all learning). But is this really how a lab course should be structured? Because the course is a lab course, shouldn't the assignments be all about making their time in the lab the most valuable? Ideally, the three pronged flow requires the student to analyze the events they observed in lab in the postlab in order to deepen their understanding of a behavior. But shouldn't the stress be on making them curious enough and well equipped enough to realize that something is going on during lab and have them investigate it there? The first inspiration for this work came from students often not having the tools to realize, in lab, that a curious behavior is occurring and to be able to investigate it right then and there.

The second inspiration for this work was the observation that the students that did not do well in previous classes or that have trouble with circuit courses in general were not participating, not

contributing to their groups, not doing well on exams and reports and falling even farther behind compared to their classmates by the end of the class. As happens in many group projects, the most informed, highest-achieving and/or strongest personality often ends up doing the majority of the work and the other members of the group follow orders or stand mute. Observing groups and the individuals in them that seemed to be non- or low-participants, there seemed to be a common thread of a lack of confidence in their abilities and their knowledge. Observations of low-confidence students making good suggestions to their lab partners and being ignored is not a rare event.

The third inspiration for this work was the fact that information on weaknesses of the students was not clear until during the actual lab itself or after the lab had been finished. Feedback is good but the late timing of identification of problems seemed such that it wasn't giving the student maximum value.

The course where these observations took place is the third in a four-quarter series of electronics classes. The first quarter of the sequence starts out holding hands with relatively cook-book style labs. Each successive course gives the student less and less information on the lab procedure until, in the fourth course, the lab is describe in one or two sentences and the student is required to make almost all design decisions. The course targeted here, being the third course in this series, requires a large amount of student decision making in the lab. This prepares them for the fourth quarter in the series and life as an engineer. Any addition to the course to help the students that are missing material from previous quarters must preserve the goal of the labs to make them problem solve.

With these inspirations in mind and the requirement of preserving the problem solving content of the labs, the addition of a "prelab statement" was added to the prelab work. The prelab statement required the student to read a 6 to 15 page handout and summarize the important points in one or two paragraphs. The majority of the content of the reading is background for the lab but does not give answer to how to do the lab. The readings provide the students that need review the chance to start the lab on equal footing with the students in the lab that have better retention of material from previous quarters. It also is a way to sneak in a reminder of topics discussed in previous classes that they may have forgotten if they have not used them since the course. The statements were due the night before the lab which gave time for the instructor to grade and return the statements, with feedback, before lab. To keep the complete work for the course from overwhelming the student, the postlabs were reduced. Two major reports and one rewrite were due during the quarter and on the weeks where a report is due the prelab reading was reduced. In this way, either an involved prelab or postlab (report) was due each week but never both.

Data used in this paper include report content and thinking level grades, the lab final exams, and a survey given to students to see how they think prelab statements enhanced or detracted from the course. Observational results are also included on retention and participation.

III. Example Prelab reading

The first week's lab for the course being discussed here requires understanding of the two previous quarter's material on how a BJT transistor works. The important equations are given

and a more qualitative rather than quantitative explanation of the behaviors that need to be understood for the lab are given. Higher level explanations for behaviors are given so that the student can recognize behaviors in lab without having to do math. Care is given to connect those qualitative explanations to the equations and/or math before finishing the reading.
The reading is purely background. The first lab gives the student two circuits and asks them to say if they can be used to find particular values such as β or the early voltage. The actual prelab (not prelab statement) is a question on whether they can find those values using two given circuits and, if they can, how they would do the characterization (find the values for β, the early voltage and turn on voltage): How they would connect up the machines, what data they would gather and how they would use the data to find the values. Once in lab, the first assignment is to discuss with their lab partner their techniques using the two circuits and if they want to use one of those circuits or another to characterize the transistors they will use for the rest of the quarter. In this case, the lab reminded them of how BJT transistors operated and what some of the important characteristics were that they would need to investigate.

IV. Additional Changes to Course structure

In addition to the prelab statements, the report format and frequency was changed. Report quantity was reduced but each report was more in depth and must follow a format nearer to that of a technical journal paper. This course targeted in this study was suited to such a report format in that all labs are building towards a enabling the student to build a single large circuit at the end of the quarter so three or four labs can be bunched together to form a story. The final report is on the final complete circuit which means that ten weeks of lab information are included in the report. The survey results include a perception that the format used in this study is more work than the usual format but it can be argued that the final report has left the students with that perception.
Another addition to the lab are “checkoff questions”. Checkoff questions are question that the instructor has the student answer verbally, face to face, during lab. These may also be affecting survey and test score results also.

V. Results: Observational

Observationally, prelab statements were a success. In the most recent quarter, five students were noted as less confident early in the quarter due to grade issues or knowing them from previous quarters as low-participators. These five students completed all prelab statement assignments. They were observed throughout the quarter actively participating in their group in doing calculations, using the equipment and talking with their groupmates. The second most recent quarter four students were noted as less confident. One of the four students turned in all of their prelab statements and did well in the class again participating in the group at the level that was near equal with the rest of the group members. The three other students did not turn in their prelab statements for approximately half of the labs and did not participate at a level equal to their groupmates. They were also not able to discuss the lab as well as their peers and consistently had lower grades on reports and exams.

Another rewarding observation was that students seemed to be able to ask better questions in lab and were doing investigation and analysis of their circuits in lab rather than just for the postlab report.

VI. Survey on Student Perception

A survey was created and sent to 225 students. 74 students responded by the time this initial paper was submitted. The majority of students that answered were in labs where prelab statements were used due to many in the earlier classes already having graduated. 18 students were in labs which didn't have prelab statements. In the first survey sent out, instructions were given to the students that did not have prelab statements to do as follows: "If you didn't have prelab statements when you took EE348, still try to answer the questions but replace prelab statement with just prelab. Make sure to note in the comment section that you didn't have prelab statements." The second survey that was sent out went to students known to not have taken the course when prelab statements were used and the questions had prelab statement removed and prelab put in its place.

Survey:

1. Background: What quarter did you take EE348 and what grade did you get?

2. What I think of circuits classes:

- I do well in circuits courses and they are my favorite.
- I do well in circuits courses but they aren't my favorite.
- I don't do well in circuits courses but they are my favorite.
- I don't do well in circuits courses and they aren't my favorite.

3. With the addition of the prelab statements: The work load seemed less/more/the same as other labs.

- Less work than other labs at Cal Poly.
- Same amount of work as other labs at Cal Poly.
- More work than other labs at Cal Poly.

4. With the addition of the prelab statement and reading, when you came to lab, did you feel:

- Less prepared than other labs at Cal Poly.
- Just as prepared as other labs at Cal Poly.
- More prepared than other labs at Cal Poly.

5. With the addition of the prelab statement and reading, when you came to lab, did you feel:

- As if you participated in the lab less than other labs at Cal Poly.
- As if you participated in the lab the same amount compared to other labs at Cal Poly.
- As if you participated in the lab more than other labs at Cal Poly.

6. With the addition of the prelab statement and reading, when you came to lab, did you feel:

- Like you learned less in lab than in other labs at Cal Poly.
- Like you learned the same amount in lab compared in other labs at Cal Poly.
- Like you learned more in lab than in other labs at Cal Poly.

7. With the addition of the prelab statement and reading, when you came to lab, did you feel:

- As if you retained information from the lab less than other labs at Cal Poly.
- As if you retained information from the lab the same amount compared to other labs at Cal Poly.
- As if you retained information from the lab more than other labs at Cal Poly.

8. With the addition of the prelab statement and reading, when you came to lab, did you:

- Like the lab format less than other labs at Cal Poly.
- Like the lab format the same amount compared to other labs at Cal Poly.
- Like the lab format the lab more than other labs at Cal Poly.

9. General comments: Do you have general comments on the format of the labs in terms of prelab, postlab or during lab work? (Or anything else). I'm especially interested in people that have struggled with previous labs and whether this helped or not. Is there some affect of the format that I am not realizing?

VII. Results: Student Perception Analysis

The first results evaluated were by dividing the data into with prelab statement and without prelab statement. This is shown in Figure 1.

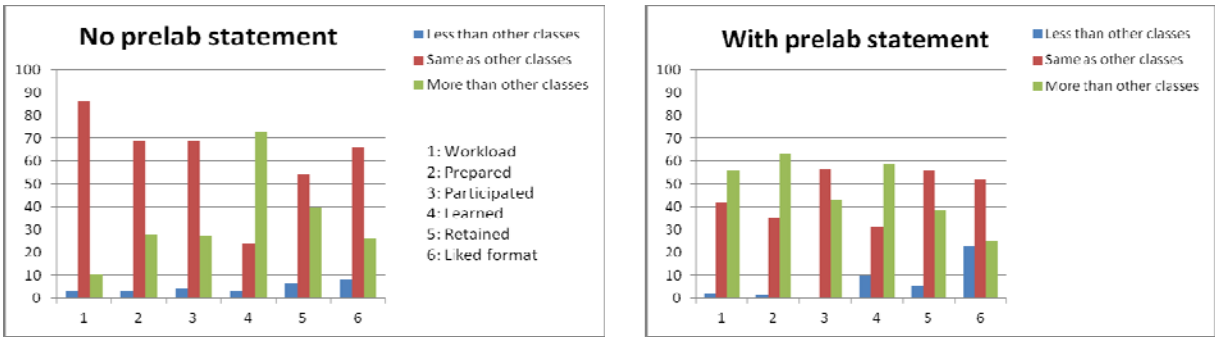

Figure 1: Survey results for students that used prelab statements and those that didn't.

The columns represent questions 3 through 8 on the survey. Column 1 is the perceived workload by the student. As previously mentioned, care was taken to try to keep workload constant from

week to week except on report weeks. It is speculated that the noticably higher perceived workload is due to the final report.

Column 2 shows a clear difference in the perceived preparedness with and without prelab statements. With no prelab statements twice as many students thought that they were just as prepared for lab as the were in previous lab courses whereas, for the students that did prelab statements, the twice the number of students perceived that they were more prepared than in other labs.

Column 3 represents how the students perceived how much they participated in the labs. Almost 50% of the students that did prelab statements said that they thought they participated more in lab than they did in previous labs verses about 25% for the students that didn't do prelab statements. This is a key result for this research.

Column 4 is good news because it says that the majority of students in this course learned more in this lab than they did in previous labs.

Perception of retentionof material, shown in column 5, didn't change between the two teaching styles and showed a little less than 50% of the students in both groups retaining more from this class than previous lab classes.

Column 6 shows that the same number of students disliked the new format as liked it more. This also could be affected by the report writing.

The author admits to getting joy from seeing less successful students succeed and also admits to having that as an ulterior motive for pursuing this research. Having all students succeed is, of course, the goal, but seeing students that may have not realized that they can succeed, succeed is an event that is worth celebrating. Obligatory laboratory preparation has been shown to benefit students who are willing to work but poorly organized or those who may skip preparation due to their course load[1] and, because of the clear advantages, preparatory work done for most labs. To see if the change in the prelab routine of adding a prelab statement helps the students that may have struggled in their previous labs, the survey asked the student to self identify their strengths and likes:

Title on graphs	Meaning
L&G	**L**ikes circuits & gets **G**ood grades in circuits class
D&G	**D**islikes circuits & gets **G**ood grades in circuits class
L&B	**L**ikes circuits & gets **B**ad grades in circuits class
D&B	**D**islikes circuits & gets **B**ad grades in circuits class

Figure 2 shows the results for students that didn't do prelab statements and Figure 3 shows the results for the students that did prelab statements. The X-axis is the same "Less" ("Less than other labs taken at Cal Poly"), "="("Same as other labs taken at Cal Poly") and "More" ("More than other labs taken at Cal Poly"). Values have been normalized to sum to 40.

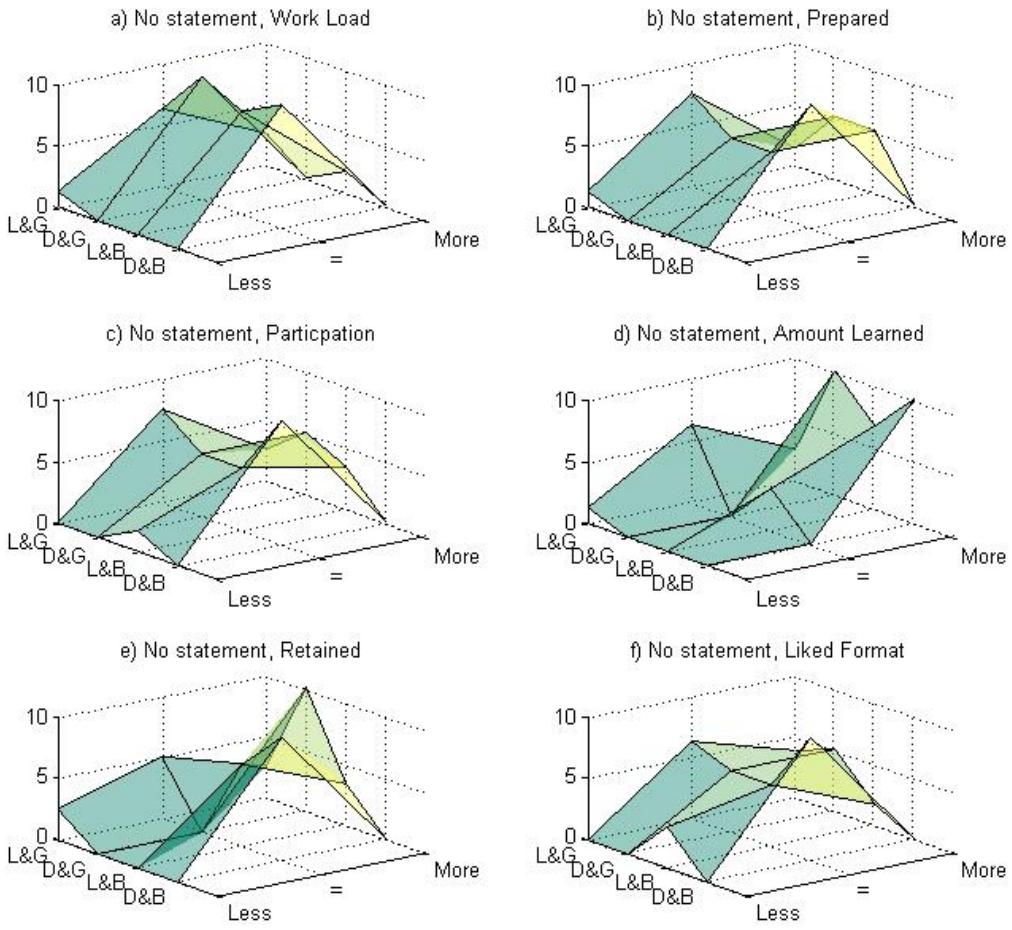

Figure 2: Survey results for students that didn't do prelab statements. Four divisions: L&G (Likes circuits/Good grades), D&G (Dislikes circuits/Good grades), L&B (Likes circuits/Bad grades), D&B (Dislikes circuits/Bad grades).

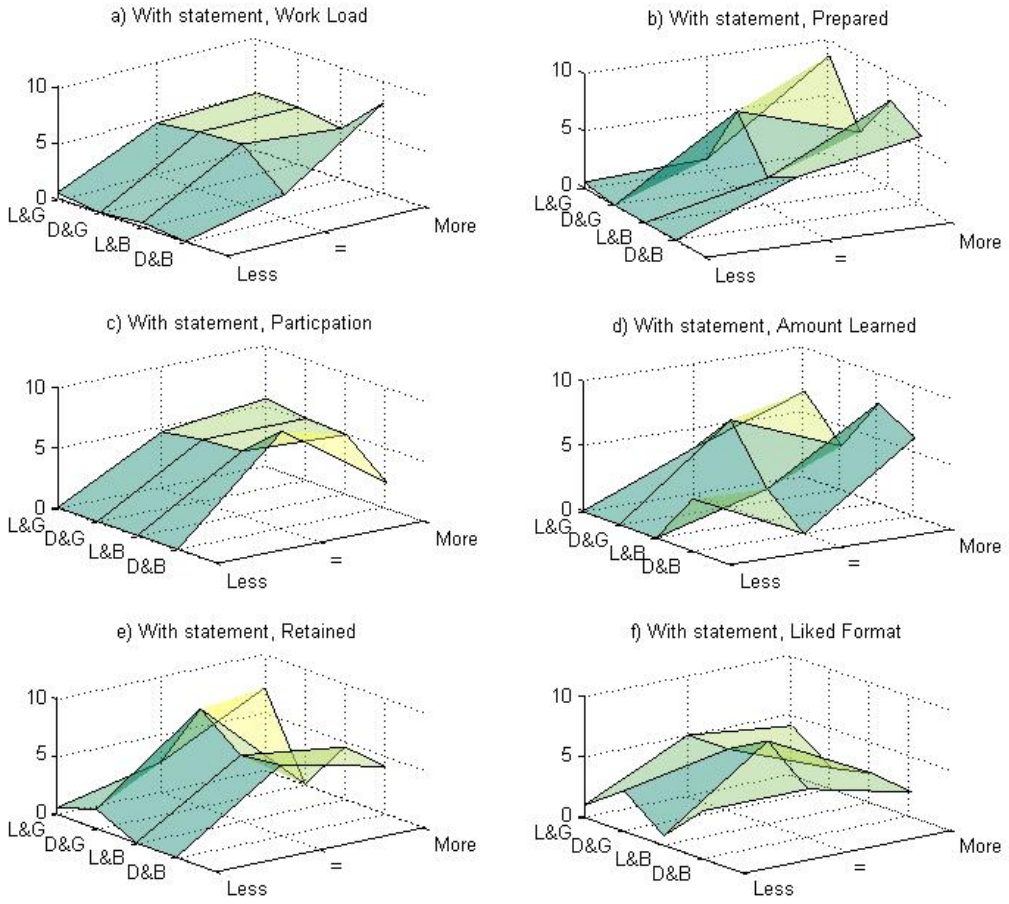

Figure 3: Survey questions for students that did prelab statements. Four divisions: L&G (Likes circuits/Good grades), D&G (Dislikes circuits/Good grades), L&B (Likes circuits/Bad grades), D&B (Dislikes circuits/Bad grades).

In graph a) on Figure 2 shows that for all students, whether they are good at circuits and/or get good grades, the amount of work was perceived to be the same as previous other labs whereas, as shown in graph a) of figure 3, you can see that the weaker students perceived the class as more work than the students that are good at circuits.

Graph b) in Figure 2 shows that the weaker students feel as prepared as previous labs but, with prelab statements, (Graph b) in Figure 3) shows that twice as many of the weaker students felt more prepared than in previous quarters. This is an important result.

Also note that graphs c) in Figures 2 and 3 show that none of the weaker students felt as if they participated more than they did in previous classes in the sections without prelab statements whereas about 1/3 felt like they participated more in the sections with prelab statements.

As in the summary graphs in Figure 1, both groups felt as if they learned a lot in this class as compared to other labs but the data on whether they felt as if they retained information was very

different. None of the weaker students felt as if they retained more than other labs in the section without prelab statements but about 50% of the weaker students said they felt as if they retained more in the sections with statements.

VIII. Results: Comparison of Report and Exam grades

The comparison of report grades is challenging due to the subjective nature of the grading. Also, in quarters where the level of the reports were low, grades may be inflated due to bad reports looking better compared to their competition. Figure 4 shows all report grades from Spring 2010 to F2012 normalized to 1.2. The dotted line shows where prelab statements were introduced. This doesn't prove cause and effect but the main change in how the course was taught was the introduction of prelab statements. Grades have stayed steady above the levels that they sat at before introduction of prelab statements. Reports were not included in a graph if that particular question wasn't used in grading that quarter.

Figure 5 shows the report score that describes whether the student can logically explain their circuit design and results. It too seemed to improve around the time that prelab statements were introduced.

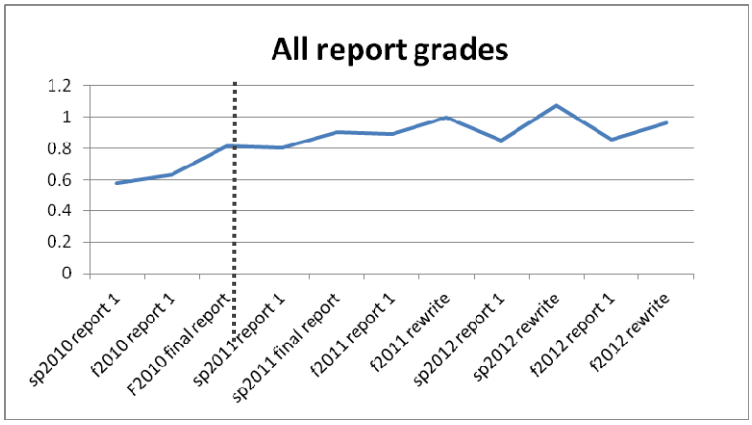

Figure 4: All reports grades compared. Dotted line is where prelab statements were introduced.

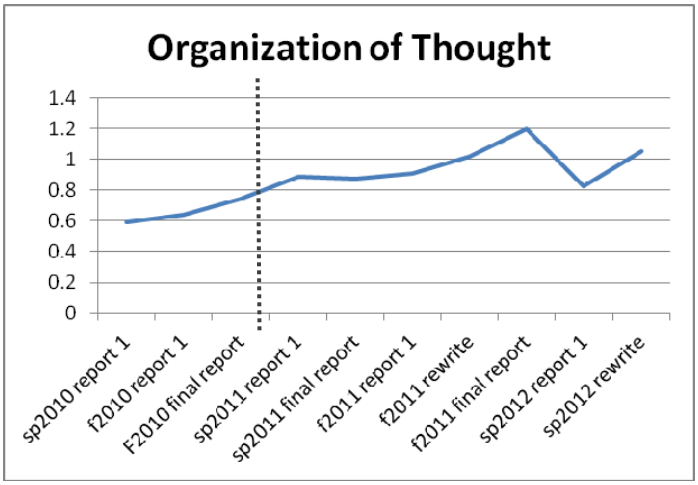

Figure 5: Organization of thought. The ability to tell the "story" of the design of their circuit.

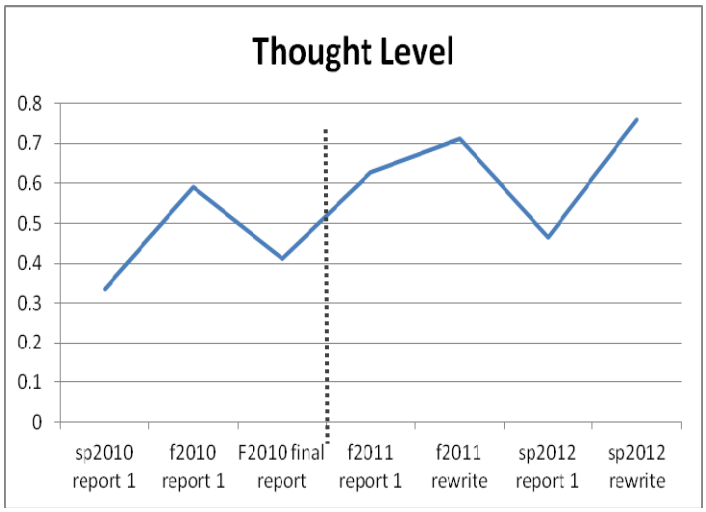

Figure 6: Thought level. This is a measure of the student's attempts to explain unexplained behaviors.

Figure 6 is a measure of the student's explanation of behaviors that didn't fit theory. Scores are high if the student uses their technical knowledge to explain a behavior and low if the student explains a behavior off as human error or machine error. Spring 2012 was a weak quarter for reports.

IX. Student Comments

Both negative and positive comments are included here. The majority of negative comments were in regard to the work load. Positive comments often mentioned being forced to really understand the lab before getting to the lab.

Example positive comments:

- "Prelab questions that explore the theory behind the lab is useful. Also pointing out common mistakes before starting the lab saves alot of time".
- "The prelab statements helped me get a better sense of the overall purpose of the lab. The notes i took in order to make my prelab statement helped me outline the main ideas of lab".
- "It is a really good way to learn more before working on it. The need to submit a prelab statement makes you read the prelab reading carefully and more than once so that you get to understand the content. I felt it helps a lot for grasping the ideas beneath the lab experiment of that week. In addition, in the end of the semester it helped a lot to have this little summaries when writing the final reports and also as an index for knowing which lab reading I had to study again for a given subject. In the labs, one of the things I liked most were the checkoff questions, those helped me understand somethings I didn´t have clear or reassure the learned things. Another thing I liked were the comments at the beginning of the labs, or the ones on the amplifier designs in the last labs, they were clarifying most of the times for some doubts I used to have".
- "I really liked the pre-lab reading because it prepared me to answer the questions during lab. It was really descriptive and interesting because it showed the concepts clearly and how it should be used in applications. I liked how you gave everyone a chance to answer since there is sometimes an imbalance of work during lab. Thus, it gives each lab partner a reflection of how they're doing in lab in general and how much they should be contributing to the lab".

- "Great idea because more people try to keep up with the actual lab work instead of leaving it to lab partners to have the understanding".
- "I really like the pre lab write up. It really helps me come into the lab more prepared. Even though I hate the extra work. They really do pay off because you know exactly what the goal of the lab is".
- "I thought the prelab statements were a WONDERFUL idea along with the final lab reports. Normally, prelab readings are in a manual and they don't make much sense so sometimes I skip reading them.I think you're English-ed versions of the labs made much more sense. Then, making us write a little summary about it made me understand it more. I didn't want to skim the prelab reading, I actually wanted to understand everything so I could put it in my own words. The prelab statements were especially helpful when writing the final reports. They made me realize why I was getting some bugs and what I was doing wrong. …"

Example negative comments:

- "The reading was unclear. Try to make it much more concise and less wordy. Prelab statements don't help students understand the material. Clear explanation of the subject matter is most important".
- "Just felt like there was too much work assigned along with the lecture section which lowered the retention of the information. But it could just be the amount of material the class required".
- "It did help with the individual labs, it is a lot of information and work for a one unit class though".
- "the only thing I really have to say is in regards with the pre-lab statements and the pre-lab. Doing the pre-lab statements helps a lot but in addition to the pre-lab problems, it could sometimes be a lot of work especially when a student has about three labs in one quarter".

X. Conclusions and Further Work

The results of introducing a prelab statement to a Cal Poly circuits lab course were gathered and analyzed. Report grades improved from the quarter that prelab statements were introduced. Two particular sections of reports were analyzed: Organization of thought (ability to logically tell the story of their circuit design and testing) and thought level (ability to explain behaviors that differ from theoretical behaviors using technical arguments). Both showed a general trend upwards after the introduction of prelab statements with the exception of one quarter where report grades were consistently lower.

Student perception of what prelab statements did for them was telling. 1/3 of the weaker students increased their participation over other labs in the sections that had prelab statements whereas the section with no statements had zero students saying they participated more. Twice as many of the weaker students felt more prepared for lab than the lab without prelab statements.

Observational results include increased confidence and participation from the weaker students and more discussion and analysis going on in lab as compared to sections that didn't do prelab statements.

Though [2] concludes that gender equality across a group makes for better decision making by the group, their premise and arguments can be extended to equality in general. The results shown here suggest that the students that perceived themselves as weaker gained confidence and contributed more to their group. This suggests that the group members will now be more equitable, and, as a result, will make better decisions. Better decisions by the group mean that the improvement of the weaker students' skills also benefit the stronger students' decision making skills and experience too. Lab groups are ideally 2-person groups but 3-person groups have been necessary recently due to economic issues. Three person groups, in theory, expose each student to more opinions and therefore a more varied learning experience if all members participate but they also present the danger of having two of the three students take over and leave the weakest student behind. If the weakest student is empowered and is able to discuss their opinions and reach convergence[3], the process becomes more complicated but more successful and valuable.

Because this course is part of a series that requires students to develop their decision making skills quarter by quarter, one of its jobs must be to increase the independence of students where possible. In many labs, data is collected and the student is at home when they have to do analysis. In general that means that they have no way to investigate odd behaviors or delve further into something that interests them. Giving the student the information so that they have the ability to investigate on their own during lab should be an important consideration when teachiing a course like this. The labs used in this class give the students the opportunity to carry out inquiry based learning to solve the central problem[4] but, at the same time, they are given the opportunity to go further. The reports are mentioned early on in the class and the students are told that they often won't know exactly what data they will need until they start to write up the report and try to support their claims. They are also told that it's their responsibility to gather the data for the report. This gets them talking about what data might be important and gets them to further gather data and experiment.

Future work will include understanding why the workload was perceived as so high as compared to traditional sections of the lab and to better measure the advantages and/or costs of prelab statements.

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