

Constructive Alignment of Learning Outcomes with Student Perceptions in a first-year Engineering Course

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Abstract—This innovative practice, work in progress paper investigates constructive alignment in a first-year engineering course. Constructive alignment describes a course environment where stated course outcomes are in alignment with what students learn in the course. This study develops a novel method to explore the extent of constructive alignment. Drawing on minute papers which were already incorporated in the course, the study uses student responses to a final minute paper which required students to reflect briefly on what they learned in the course. Qualitative analysis of 189 responses determined four main themes, with two of them featuring prominently in some detail: teamwork and problem-solving. This was important evidence of alignment as these are key outcomes of this project-centered course. A further interesting finding was that students see programming as a focus for their learning but don't explicitly link it to the modeling of an engineering system as stated in the course learning outcomes.

I. INTRODUCTION

This study focuses on the first in a sequence of two first-year engineering courses in an institution with an increasingly diverse student intake. This course uses a project-centered design focused on the following outcomes:

1. Compare and contrast the contributions of different types of engineers in the development of a product, process, or system
2. Articulate holistic and ethical issues that impact engineering solutions
3. Solve problems using systematic engineering approaches and tools
4. Model an engineering system
5. Communicate solutions and arguments
6. Develop teamwork skills

Recently, one of the instructors (third author) teaching this course had employed the use of the minute paper to help track students' perceptions of each class session as well as prompting students to actively reflect on their own learning. In a minute paper, students are asked one or two simple questions at either the beginning or end of class [1]. Minute papers have been shown to be an effective strategy to encourage active learning [2]. Previous studies have shown how the minute-paper technique can be used to evaluate the students' understanding of the concepts and their ability to apply them. This quick and easy process allows the instructor to alter teaching methods at the earliest possible moment [3]. Previous research also shows that the use of minute papers is found to have a significant positive impact on student grades [1]. In a study where minute-papers were used in lower-level classes, students mentioned how

minute-papers presented an opportunity to ask and mention things that were confusing and unclear [4].

Within this study, we sought to understand through the analysis of these minute papers, the different kinds of learning the course had prompted and whether this learning relates back to the course objectives. Whether students' learning matches the intention of courses continues to be a source for important investigation in project-centered courses like these. The research question guiding this study is:

What are the similarities between students' views on what they have learnt from the course and the intended learning outcomes?

II. THEORETICAL FRAMEWORK

The theory guiding this study is that of constructive alignment which was proposed by John Biggs. Constructive alignment dictates that if students are to learn desired outcomes in a reasonably effective manner, then the teacher's task is to get students to engage in learning activities that are likely to result in their achieving of those outcomes [5,6]. This points to how the learning activities students will be taking part in must support or contribute to the learning objectives of the course. Furthermore, students' learning has seen to increase to the extent that they engage with and thus study the material, and the minute-paper encourages both reflecting on the material and asking questions [7,8] which increases student engagement. This theory is embedded in the constructivist theory of learning and it emphasises the alignment between the intended learning outcomes and the assessment tasks [9]. Key aspects of constructive alignment are to clarify learning outcomes and to design a course which directs students towards these outcomes. By aligning the teaching, learning, and assessment activities in this way, the educator is more certain that the intended learning will be achieved [10].

III. METHODS

This project followed first year engineering students in an introductory engineering design course at Virginia Tech. During the semester, students worked on a series of assignments and modules as a part of the course which also included small group projects. As a result of all these experiences, in a final minute paper we asked students to respond to the following question: *What is something specific that you have learned over the course of this semester that you can apply to your prospective career as an Engineer?*

We collected 189 student responses and the data were anonymized and de-identified. From these 189 student responses, we found 143 of the responses to be relevant to the research question. The other 46 student responses had no relation to the question that was asked to them and so these were not included in the coding sequence. Two levels of coding were carried out. The first level identified commonalities from the participants' responses that could be grouped together into themes. The second level of coding identified sub-categories that fit into the larger themes that created in the first pass [11]. These themes and sub-categories were then compared with the learning outcomes stated in the course syllabus to gauge constructive alignment. Table 1 below shows the four main themes analyzed from student responses.

The research design for the study was submitted to the Virginia Tech Institutional Review Board and it was determined not to constitute human subjects research since it uses regular classroom assessment materials with the anonymization of student materials involved (IRB #21-281).

Table 1-Main themes and associated Frequencies

Theme	Sub-Theme	Sub-Frequency	Frequency
Teamwork	Value of	20	47
	Challenges	5	
	No evaluation	22	
Problem-Solving	Stakeholders	11	41
	Ethics	10	
	General	20	
Coding	N/A	N/A	32
Different disciplines	N/A	N/A	23

IV. RESULTS

The first two themes in the table are those which were mentioned most and with more detail and thus form the main focus for this paper.

A. Teamwork

The most common theme that emerged in the students' responses to what they learned in the course was the importance of working in teams, with three sub-themes being 1. positive experiences of group work and recognizing the value of working in teams, 2. challenges faced while working in groups and areas they felt they needed to improve on, and 3. critically neutral mentions of working in groups (i.e. no real mention of the student necessarily liking or disliking anything about it).

As an example of the first sub-theme, here is one full response:

Student #95: "[I learnt] The importance of maintaining a positive and passionate mindset. Engineering is a team sport, so

it's necessary to know how to communicate and treat others. For example, your [the instructor's] humorous personality helped engage and make the material more interesting. Being able to get people excited about engineering is how we will attract the brightest minds and develop the future."

This student goes into detail as to how teams can be effective. The comment is full of positive connotations; diction such as "positive", "passionate", "humorous", "engaged", "interesting" and "excited" are all used describing how they felt positively about this experience with working in teams.

Some students had also spoken about the value that group work will have after they graduate and when they enter the working world. Student #97 mentions:

Student #97: "Working as a team, even virtually, on a subject related to engineering was very useful and will help me down the line. Every project in my future career will require me to have team-working skills so they are very important."

This student clearly recognizes the value practicing working together in groups. This idea of recognizing the importance of working together in groups is also reiterated in the comments made by student #23:

Student #23: "I feel as if the group work contributes a lot to my prospective career as an Engineer. Although I've done a lot of it throughout Highschool I will definitely be doing a lot of it throughout my life so there is never enough group work in my opinion."

This student, like Student #97 mentions how working together in groups will contribute towards their prospective career. The importance of working not only in teams, but with a group of people who aren't necessarily one's friends and whom one doesn't know is also important. This is showcased in the comments made by Student #37:

Student #37: "I'd say working with a group is something that I'm going to do for the rest of my career and this was really the first time I worked with a group for something important that didn't just consist of my close friends."

The student mentions how it was their first time working with a group who weren't their friends and just like the other students, recognizes how working in teams will be something that will be done later in the future. Along with all of the ideas already mentioned, Student #26 had also mentioned the advantages of communicating and discussing ideas with other team members:

Student #26: "I learned that working with a group is super important. Not only do you have to be able to work with a group, but you need to be able to work well with them. It is so nice to bounce ideas off of one another. I need to apply this to the rest of my career because I will always be working with other people."

In the second sub-theme, students mentioned challenges they faced while working together in groups. Unlike the previous theme, this theme had more negative connotations included in the students' comments. One such circumstance was brought up by one of the students who had implied how they experienced frustration with group work as they felt that not all group members contributed equally:

Student #107: "Not everyone is going to pull their own weight, and some of the time you have to suck it up and carry the extra weight."

It is clear this student was frustrated with their experience of working in teams as the student uses the phrase *"you have to suck it up and carry the extra weight."* They felt that other team members may have been slack, and this led to certain students having to do more work than others which is unfair. While this was an unfortunate experience that this student had gone through, it raised an important point; it is not always going to be the case that you will have the perfect team or that all of the other team members will show as much interest or contribute as much to the project as you do.

Part of this experience is being able to work with people who you may not necessarily get along with too well. This was what Student #114 had experienced:

Student #114: "I learned about teamwork and being able to work with people I may not connect with too well."

While the overall outcome mentioned in this comment was more positive, it should still be noted that it is possible that you are in a group with people you may just not "click" with. Getting past this boundary and realizing that you just have to work with people like this, is what we consider a good piece of reflection.

A significant aspect of working together in teams is being able to negotiate differences of opinions and disagreements. This can happen whether a group is composed of people who have never met, or whether they are close friends. Student #102 details this effectively:

Student #102: "I learned how to talk to others while working on a project. I learned how to get through disagreements and produce the best work."

This produced a positive outcome but again, touches on the importance of getting through disagreements with your group. All group members agreeing with each other will never happen as everybody has differences of opinions and has different viewpoints. To be able to practice coming together at a compromised solution is a skill which is needed, and which is what this student has mentioned. A final aspect of this theme is expressed here:

Student #33: "I still need to work on being better about communicating with teammates."

While this isn't necessarily a negative comment, it has been included in this section as it was an observation the student had noted which they need to improve, which we consider a significant aspect of the intended learning in this course.

The third sub-theme concerned comments that did not really offer much commentary on teamwork but did mention that it was part of the learning on this course. Overall, this theme was most prominent in student responses. Many students mentioned having positive experiences with their teams and how they enjoyed group work. There were also some students that had reported experiencing a slightly more negative experience in relation to teamwork. It was important however that these were captured in this theme as it helped us see the difficulties in working with teams and what are some ways in which working in groups can go sour.

B. Problem-Solving

The second-most prominent theme had to do with problem-solving. Students' comments about the problem-solving process fell into three main sub-themes:

- learning about stakeholders and how it relates to the problem-solving process.
- learning about ethics and how that relates to the problem-solving process.
- the problem-solving process in general.

Some students reported learning about the importance of stakeholders when considering a problem. This can be seen from Student #46 below:

"I learned how important it is to consider stakeholders when engineering a solution to a problem."

Similar responses are shown below:

Student #115: "How to identify stakeholders in any given problem."

Student #143: "I learned about stakeholders and how they impact solutions to problems."

Student #141: "Stakeholders are a key component when figuring out a solution."

The second sub-theme included students who talked about the ethical aspects of problem solving. Certain students had mentioned how they primarily just understood the importance of ethics and why it is necessary but did not necessarily relate it to the problem-solving process. This was still included as part of this code however as the ethics component in this course was talked about in relation with problem-solving. Student #21 below mentions how choosing ethical solutions need to be a high priority:

Student #21: "Every solution has pros and cons. You need to choose a solution that is most beneficial for the people as long as it is ethical."

This student clearly recognizes how solutions can be complex and every solution will not suit everyone. However, one of the utmost priorities when considering what solution to choose, is considering the ethical implications it poses. This idea is further represented in the comments made by Student #153. When asked what was learnt in the class, the student responds by saying:

Student #153: "the different ways to look at solutions (ethical issues and such), and how to decide what criteria to meet when doing a project."

It is interesting to note how these students consider ethics to be of a high priority when talking about the problem-solving process. This was the case with another student again who had mentioned the importance of considering ethics when coming up with solutions:

Student #179: "Coming up with solutions, think about who this will effect and what will change --> stakeholders and ethics."

There were some students who had reported never learning about ethics before this course. These students mentioned how

they have just never had to think about ethics and how the whole experience was foreign to them. Student #'s 90 and 180 both reported this and this is shown below:

Student #90: "The ethics part. I have never really had a project where I had to think through the ethics of it."

Student #180: "I guess ethics because even though I was taught engineering throughout high school they never really talked about ethics."

Student #134 had mentioned how the ethical components of the problem-solving process was something that they would make a conscious effort to include as a priority.

Student #134: "Making ethical aspects of the job more prominent in my thinking and problem-solving process. I think the thought was usually there, I just never really spent time thinking and researching about it."

The student mentions that *"the thought was usually there, I just never really spent time thinking and researching about it."* This shows that the student is now aware about the importance of actually considering ethical issues and this reflects on how the class was effective helping this student become more aware of the different ethical aspects in problems. Overall, for this theme students had learnt one of the main learning objectives of the course, understanding the problem-solving process. Many of the students had also gone into more detail highlighting the specific components of the problem-solving process they had learnt (the stakeholders and ethics parts of the process).

V. DISCUSSION/CONCLUSION

Overall, it was clear that the themes related to group work and working in teams and the problem-solving process were talked about in a lot of detail by the students. Table 2 shows us clearly how the student responses categorized into the themes,

Table 2 - Comparison between student responses and learning outcomes.

Themes	Relation to learning outcomes
Teamwork	<i>"Communicate solutions and arguments clearly"</i> <i>"Develop teamwork skills"</i>
Problem-Solving	<i>"Articulate holistic and ethical issues that impact engineering solutions."</i> <i>"Solve problems using systematic engineering approaches and tools."</i>
Coding	N/A
Different Disciplines	<i>"Compare and contrast the contributions of different types of engineers in the development of a product, process, or system"</i>
-	<i>Model an engineering system</i>

relate to the course learning outcomes. With regards to the student comments about group work and teams, a majority of them had mentioned how they had positive experiences in their group activities and learnt aspects of it which would help them after they graduate. When looking at the problem-solving process category, if we disregard quotes where students purely mentioned the problem-solving process without any further elaboration, there was an even split in the number of students who talked about ethics and stakeholders and their relationship to the process of solving problems.

With regards to the research question guiding the study, Table 2 compares the analysis of student responses with the learning outcomes of the course. It should be mentioned that it was interesting to see how 32 students had talked about learning MATLAB or some form of coding even though this was not mentioned in the learning outcomes. This might mean that coding and MATLAB was emphasized heavily during this particular class. One of the outcomes which isn't included was the fourth learning outcome which was to *"model an engineering system."* This is interesting because it is related to the previous point mentioned about coding. Students mentioned how they learned about coding and this is related to modelling an engineering system, they just do not explicitly use the language that is mentioned in this fourth learning outcome. Overall, however, all of the themes found in the codebook covered almost all of the course learning objectives listed for the class and as a result we definitely do see an alignment between what students have mentioned they have learnt, to the learning objectives of the course.

VI. REFERENCES

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