121st ASEE Annual Conference & Exposition
Indianapolis, IN
June 15-18, 2014

Paper ID #8496

Student Perceptions of Connections between Statics Class and Co-op Work Experience

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Abstract

In this paper, a collection of essays written by students at Kettering University in a sophomore-level engineering class, Statics, is analyzed to determine what connections the students see between their classroom experience in Statics and their co-op work experience. These students were given a class assignment to write an essay in which they reflected on the links between their co-op work assignment and their Statics course. The pedagogical purpose of this assignment was to prompt students to think in depth about the links between their authentic engineering experiences and the theoretical knowledge they gained from the classroom, and articulate their thoughts, in order to enhance their understanding and retention of the course material. Since students at Kettering alternate between a term in the classroom and a term of co-op employment, and complete at least six co-op work terms in the course of their education, the majority of students had completed several co-op terms prior to this course. Those who had not typically had experienced some other form of experiential education, which provided them with opportunities to reflect on applications of the course material. After completion of the assignment, students were asked for consent to include their essay in this research project.

The research purpose of this project is to (1) show how students can be prompted to make such links between academics and work, through this classroom assignment; (2) determine what links students see between the course and their work assignments; and (3) provide data to allow instructors to better show students how the material they learn is relevant to a variety of work environments. The collection of assignment essays for which the students gave consent was analyzed to determine the students' opinions regarding the strength of the relationships between their co-op assignments and the work they were doing in the Statics course. The result of this essay analysis is discussed in the context of relevant literature and presents recommendations to instructors so they are better able to provide an authentic experience for the students.

I. Introduction

One of the potential benefits of co-operative work experiences for engineering students is to provide authentic learning experiences. By seeing the relevance of their coursework in the workplace, students are more motivated to learn the material and better able to apply it in the future. Researchers have found that students often have difficulty making this connection. Instructors who are not familiar with industrial practice may have difficulty seeing and sharing these associations.

This paper will focus on the associations seen by students at Kettering University in a sophomore engineering class, Statics, who were given an assignment to write an essay in which they reflected on the links between their co-op work assignment and their Statics course. At this university, all students are required to spend a significant amount of time on co-op work assignments (six terms/quarters), and by sophomore year almost all students have completed at least one co-op assignment. The co-op assignments vary tremendously from one student to the next, with students working in a diverse range of companies, industries, and types of engineering positions. Typically, students remain with a single co-op employer throughout their education, although a small number of students do work for more than one employer over the course of their degree program.

The specific essay prompt was developed by a mechanical engineering professor, with input from a communication professor in the Department of Liberal Studies with experience in designing reflective writing assignments. Students were instructed to describe their co-op employer and work assignment, discuss class content from the Statics course, and then reflect on the relationship between the two. The essay prompt, included in the Appendix, stated that they could discuss both connections through the class content and the general problem-solving skills that they learned in the course. The small number of students who had not yet experienced a co-op term were instructed to select some other type of authentic engineering experience to use as the focus of their essay.

II. Background

Statics is considered by many to be a foundational class, full of threshold concepts that are difficult for students to grasp (perhaps partly because students often have to unlearn their old concepts). It has been stated that "Statics is a "threshold concept" in engineering in that mastery of this area can serve as a "conceptual gateway" that opens up "previously inaccessible way(s) of thinking about something"[1]. Some educators, such as Steif and Dollar, are concerned that even among those who successfully pass the class there are those with poor conceptual understanding[2]. According to an important recent study by Venters, McNair and Paretti, written reflection improves conceptual understanding in statics[1]. Their study asked students to describe in concrete language the process they took to solve (mathematical) problems. Though this written reflection did not improve procedural knowledge, "[b]y having student explain their mathematical solutions, students can make links between problem-solving procedures and course concepts. Writing may also be used to promote reflection, which can result in metacognitive thinking and adaptive problem solving"[3]. These written process descriptions process showed "significant gains in conceptual understanding"[1]. Rittle-Johnson and Alibali state that conceptual knowledge stems from understanding the principles that govern a domain as well as how pieces of knowledge connect to one another in a domain[4]. Because the ability to make thoughtful connections may be an indicator of strong conceptual understanding and developing expertise, the focus on making and fostering connections proves important for the present study. These connections can be facilitated by experiential learning, as demonstrated by Holzer and Andruet, who designed a computer-based experiential learning environment for engineering mechanics[5]. This was well received by their students, whose feedback indicated that they were able to "think intelligently and learn"[5], suggesting that other types of experiential learning may be effective in making and fostering connections as well.

An equally important line of inquiry for the present study is the role of reflection in experiential learning. The research context, Kettering University, a technically-focused university with a substantial co-op requirement for graduation (six terms), offers an important experiential learning component that can then be integrated with academics. But it is not enough for students to simply have experiences. Dewey, an important early proponent of experiential education, claimed, "We do not learn from experience… we learn from reflecting on experience"[6] and Gibbs, in an oft-quoted passage, echoes:

> It is not sufficient simply to have an experience in order to learn. Without reflecting upon this experience it may quickly be forgotten, its learning potential lost. It is from the feelings and thoughts emerging from this reflection that generalisations or concepts can be generated. And it is generalisations that allow new situations to be tackled effectively.[7]

Here, Gibbs begins to explain how being reflective about an experience facilitates experiential learning. Kolb's experiential learning cycle, as explained by Gibbs, has four stages and is endlessly iterative: concrete experience; reflective observation; abstract conceptualization, and active experimentation[7]. If reflection is not fostered among students having experiences, the experiential learning will suffer. One important vehicle for reflection is writing. Reflective writing on one's experience has been used extensively in practice-oriented professions such as nursing, teaching, and social work: "There is widespread practitioner acceptance, particular in education, nursing, medicine, law and other disciplines requiring professional practice. The literature reports extensive and positive anecdotal evidence and perceptions around the efficacy of reflective practice for learning"[8]. In addition, some educators have integrated writing assignments into technical classes where students would typically expect to see only tests, projects, and problem sets, e.g., electrical engineering, software engineering, design, and courses such as statics [9, 10, 11, 12].

Reflection is consistently linked to praxis, a term attributed to Jurgen Habermas and Paulo Freire that means the interdependence of theory and practice, research and development, thought and action. Reflective writing can even help students name hitherto tacit knowledge about their practice[8]. In fact, often the purpose of reflective writing is to help the student test out the theories of a discipline against practice at an organization and further inform the theories with the practice, as in the case of service-learning. Making connections across the different domains of theory and practice, classroom and office is vital in a context where students engage in a great deal of co-op education and have the capacity for testing theory and practice against one another.

This study focuses on a reflective writing assignments designed to connect academics, in this case, the conceptual gateway course of statics, to co-op experiences. By seeing the relevance of their coursework in the workplace, students may be more motivated to learn the material and better able to apply it in the future. This writing assignment focused on connections between the statics class and the workplace promotes higher-order thinking, specifically application and analysis (in contrast to recognition and comprehension, which are often the goals of multiple choice testing), according to Bloom's Taxonomy. The writing assignment also fosters students' engagement in praxis, judging theories against practice and informing theories with practice. Yet, we cannot assess the amount of learning the writing assignment promoted based on the connections made in students' writing because of the variability of co-op assignments, a point reiterated by the students themselves. Still, the authors find connections significant because they are a marker of expertise; "Conceptually, novices demonstrate fragmented knowledge with relatively few connections while experts have highly structured knowledge rich in meaningful connections"[1]. While the number and depth of connections cannot correlate meaningfully with the amount of learning because of the variability of co-op workplaces, we nonetheless find connections significant in a number of ways.

III. Methods

A. Development of essay assignment

The essay assignment was developed byDr. Peters, who is the instructor of the Statics course and is in the mechanical engineering department of the university, with guidance from Dr. Arbor, a communication professor in the university's Liberal Studies department. The assignment was designed to take advantage of the students' practical work experience in their co-op assignments and to prompt them to think about how the course was relevant to their work experience. Due to the diversity of co-op work assignments, the assignment was intentionally designed to be open-ended to accommodate the variety of different student experiences. The assignment description is given in Appendix A.

While the majority of students had completed at least one co-op term, and most had completed two co-op terms, a few students who were taking courses out of the normal sequence or who had transferred into the university had not yet had a co-op assignment. These students were instructed to either write about their upcoming co-op assignment or to discuss an alternative essay with the instructor. In the one such case included in this paper, the student in question had completed a personal project which provided him with experiential learning similar to many students' co-op assignments, and therefore he was able to write his essay based on that particular project. While some students wrote about their upcoming co-op assignment, no such essays are included in the sample analyzed here, since those students did not give permission for their essays to be used in the study.

B. Participants

This assignment was given in two consecutive sections of sophomore level Statics, with each section of the course spanning an academic quarter. (Because the university has alternating student populations, there were no students who took the course twice.) In the first section, 32 students completed the assignment; in the second section, 28 students completed the assignment. In accordance with the IRB approval received for the project, students were asked for permission to use their essays in this research project, and out of the 60 students in these two sections, 11 consented (18%). These students included 10 males and 1 female, with 4 students from the first section and 7 from the second section. The majority of the students work for automotive suppliers, as indicated in Table 1. One of the students had not yet completed a co-op assignment and chose to write about a technical project he had undertaken independently.

Table 1: Study Participants

Pseudonym	**Gender**	**Type of Employer**
Aaron	Male	Automotive supplier
Benjamin	Male	Automotive supplier
Cody	Male	Supplier to multiple industries, including automotive
Dean	Male	Automotive supplier
Edward	Male	Automotive supplier
Faith	Female	Defense
Gerald	Male	Outdoor power equipment
Harris	Male	Automotive supplier
Ivan	Male	Personal project
James	Male	Automotive supplier
Kyle	Male	Product development

C. Analysis of Data

The data was analyzed independently by the two authors of this paper. In this analysis, the essays were evaluated to determine the number of connections and the types of reflections present. Also, the analysis looked at whether the students saw connections through the course content, problem solving skills and techniques, or both. The results of the analysis were compared, showing that the number and type of connections seen was consistent between the two authors. Details are summarized in Section IV. The authors chose to analyze the data inductively, rather than choosing a specific theoretical framework or formulating hypotheses in advance.

IV. Findings

While most students discussed both problem-solving techniques and course content, the emphasis they placed on these two areas was not equally weighted. Out of the 11 participants, three focused primarily on problem-solving skills as the connection between their Statics course and their co-op work experience, six focused primarily on the course content, and two people discussed both content and problem-solving skills in approximately equal amounts. The focus of each student, and sample quotes, are given in Table 2, as is the number of connections the students mentioned.

Table 2: Types of Connections Seen

Pseudonym	Number of Connections	Primary Type of Connection	Sample Quotes
Aaron	1	Problem-solving skills	I learned a lot of the different ways of approaching problems, as well as different methods for solving a problem as well. For instance, drawing the free body out, labeling what you know and don’t know, and solving for what you don’t know.
Benjamin	3	Course content and problem-solving skills	The most important skill that will help with my work tasks is; the creation of free body diagrams. At work I create many drawings and diagrams to explain what my tests are going to accomplish... The other skill that I learned from MECH 210 that is transferable to my job is the knowledge of moments.
Cody	1	Course content	What I can relate between my co-op and the class is some of the smaller fixture and organization projects I’ve done. I’ve had to design quite a few tool organizers and shelf units for specific places. These obviously needed to be static and hold up to daily use.
Dean	2	Course content	A great thing about the co-op program at [university] is that what we learned in classes one term can directly be applied in our work studies the next term. One of the classes that this certainly applies to is our Statics class. In Statics we learn an incredible amount about our field of study, and I know that I can use it directly in my co-op.
Edward	3	Problem-solving skills	I would argue that there is a deep connection between my coop job and statics class on a more conceptual and indirect way. There are skills such as becoming proficient at algebra, or problem solving through a multistep solution, or even handling groups dynamics well...
Faith	2	Course content and problem-solving skills	Statics and the work place have a direct correlation for my place of employment in both new education in topics and problem solving skills in general.
Gerald	3	Course content	Statics take their most important role in tool design in the construction of the tool mounting, or “shoe”. Loaded into a press that can output millions of pounds of force… a die shoe has to be incredibly strong, and are therefore often cast as solid pieces of steel weighing anywhere from a few hundred to tens of thousands of pounds.
Harris	2	Course content	Now that I have finished my Statics course it is easy for me to see how these ideas I learned in Statics are applied at my work place. For starters, the differentials that we make at work need to be able to withstand the forces that are going to be applied to them while they are being used, like the force from the different axles and the force coming from the engine.
Ivan	1	Course content and problem-solving skills	[A] large component of a personal project that I worked on last winter was a direct application of statics… The main thing that I have learned in MECH 210 is how to mathematically approach different types of problems.
James	1	Course content	Seeing as how my job mainly involves parts that move and are constantly having new forces enacted upon them such as varying road surfaces there are few areas where statics principles directly apply. I can use it when designing the initial brackets.
Kyle	3	Problem-solving skills	In my opinion, MECH 210 helped me gain knowledge in problem solving which is a must have knowledge when it comes to engineering. You need to have a wide variety of tools in which can help you solve problems in the real world.

A. Problem-Solving Techniques

Several problem-solving techniques were specifically mentioned by multiple students. One of these was the use of free-body diagrams, which were mentioned by Aaron, Benjamin, and Kyle. Aaron stated about free-body diagrams that

> This helped me visualize all of the forces that were acting on the object at rest. It also helped me visualize what is actually going on and what is acting on the body instead of just looking at the original picture.

Benjamin also found free-body diagrams useful and drew connections between them and the diagrams that he produced at work for various purposes.

> The most important skill that will help with my work tasks is; the creation of free body diagrams. At work I create many drawings and diagrams to explain what my tests are going to accomplish. I also create diagrams in my reports to help explain the data that I have recorded.

Kyle also generalized what he learned from free-body diagrams; while he did not expect to use them often in his work, he saw them as being useful for what they taught him.

> Another topic which I felt was very instrumental in my maturing as an engineering (sic) was free body diagrams. Although, I will probably never actually create one in my particular instance, it showed me how to look at a problem in a different way. It created a mind set to which I had to observe a problem, identify what is influencing or acting on that problem, and then use what I know or tools I have to fix the problem.

Harris also specifically mentioned free-body diagrams, and felt that they were an important step in problem solving, stating,

> To really figure out what you need to sum up it is a good idea to draw a free body diagram. This will tell you all the different forces in a system so you make sure to account for everything.

In addition to free-body diagrams, several students mentioned mathematical techniques and the logic that they had learned in the class as being useful beyond this particular class. Aaron specifically mentioned that he had never before learned to use matrices to solve equations, and Kyle mentioned several aspects of the mathematics as being important in addition to mentioning free-body diagrams again.

> Here I reinforced vector addition, division, multiplication, and subtraction. Also, I gained knowledge in concurrent force systems which largely dealt with drawing free body diagrams which assisted in identifying all force interacting on a point, object, or structure.

Cody felt that one of the useful skills he gained was using a logical problem-solving approach.

> Another skill I have gained from statics is using multiple equations and logically solving problems. We got practice at using these different types of problems and skills together to solve more complex problems. I have a bad habit of just trying to remember witch (sic) directions things go in and some other things like that and statics has given me practice in writing down all steps and signs of more complicated problems.

Ivan also discussed the problem-solving approach in contrast to what he had previously done, saying,

> The main thing that I have learned in MECH 210 is how to mathematically approach different types of problems. I was not previously in the habit of breaking forces down into their components—I envisioned vectors in space and tried to make sense of them. Knowing how to simplify problems by breaking them down will allow me to solve more complex problems. Additionally, the likelihood of error is reduced when a problem is broken down.

While Ivan also wrote at length of a project in which he used Statics and its principles, he felt that the problem-solving skills were a key feature of his knowledge from the course. Kyle also heavily emphasized the problem-solving skills, saying

> In my opinion, MECH 210 helped me gain knowledge in problem solving which is a must have knowledge when it comes to engineering. You need to have a wide variety of tools in which can help you solve problems in the real world.

Students also felt that the teamwork skills they learned in class would be useful beyond the classroom. Edward mentioned the group dynamics that had to be navigated in team projects, and Faith mentioned the value of working together with other students to understand and solve problems.

B. Course Content

The ways in which the course content was linked to their co-op employment varied tremendously from one student to another, due to the differences in their employers and responsibilities. Benjamin saw moments, frames, and trusses as being the most important things he had learned, in regard to his work.

> The other skill that I learned from MECH 210 that is transferable to my job is the knowledge of moments. With the mirrors that are created at [company] they experience a moment on the three studs that affix them to the door of the car. I now know how to calculate the moment exerted on these studs from the weight of the mirror. I also believe that the knowledge learned from the chapter about frames and trusses will come into play while I am at work because the base frame of each mirror assembly has internal structure designed in it to improve strength while using as little material as possible.

Cody stated that some of the principles from the class could be used to describe his employer's product, but focused his attention on the relationship between the class and some of the specific projects he had completed.

> What I can relate between my co-op and the class is some of the smaller fixture and organization projects I've done. I've had to design quite a few tool organizers and shelf units for specific places. These obviously needed to be static and hold up to daily use. Luckily all of the projects I worked on were not too limited and could be slightly overbuilt to make sure they would last but after this class I have a much better understanding of how to approach things that are limited in space or weight.

Dean felt that Statics was a key class, because he was able to see how his education could be used, and he was able to link Statics directly to a product he had worked on.

> Also, I believe statics is pretty much the first class that we as mechanical engineering majors take that actually show us how we will be able to use all the stuff we learned in other, core classes, for things in our major. This in turn, caused me to appreciate those classes more and attempt to understand them better… In Statics we learn an incredible amount about our field of study, and I know that I can use it directly in my co-op. One instance where I know it applies is a part in the inside of a seatbelt retractor called the lock dog. The lock dog is a set of spring loaded teeth and is on the spindle that turns the actual belt and can be set off by many different things including: vehicle speed, vehicle tilt, and speed at which the webbing is being extracted. When the lock dog is engaged its job is to stop webbing, the belt part, pay-out, it gets spun out and its teeth mesh with the teeth on the frame of the retractor. While most of this is a dynamic system, as soon as the teeth make contact with each other the system is static.

Faith felt that the knowledge she gained from the Statics course shed a new light on work she had done during her previous co-op term.

> [T]he new knowledge that I have gained in Statics has given me a new sense of understanding for the test I ran at [company]. I ran many stress test for different components of vehicles by applying forces to beams ect. (sic) An example of this would be a test I ran on a yoke shaft. In this test, there was a force applied at different point on the shaft to locate its max loads and decide if it was a suitable replacement for the current shaft.

Gerald saw links between Statics class and his co-op work through tool and die design, although he also saw the limitations of the techniques that he was learning in class.

> Statics take their most important role in tool design in the construction of the tool mounting, or “shoe”. Loaded into a press that can output millions of pounds of force… a die shoe has to be incredibly strong, and are therefore often cast as solid pieces of steel weighing anywhere from a few hundred to tens of thousands of pounds… Trade-offs have to be made between stability, ease of use, and quality of procedure… So, static principles must be used to determine where strength is needed least, and weight loss needed the most… Statics could be used to quantitatively analyze the capabilities of your tool over time, but here we come upon some limits of the science and the industry. While very accurate statics models exist, they become increasingly difficult, time consuming, and expensive to construct… Much information that would be needed for a very accurate statics model is simply not available, due to physical or financial limitations.

Harris also saw connections between the course content and his work experience and discussed the relationship between Statics and differentials at some length.

> Now that I have finished my Statics course it is easy for me to see how these ideas I learned in Statics are applied at my work place. For starters, the differentials that we make at work need to be able to withstand the forces that are going to be applied to them while they are being used, like the force from the different axles and the force coming from the engine. Using Statics, I could assume that all the forces in the system of

> differentials are going to add up to equal zero, since nothing is moving because it is Statics. Then I could figure out the different forces that are going to be applied to the different internal parts in the differentials, using this knowledge you can gather what the different load conditions that your parts are going to be able withstand are. Now you have these different expected load conditions that you can design for based on the different axle forces and engine forces being applied, but these axle and engine forces should always be constant. This is one way that I could see how statics could be applied to my workplace.

Ivan had not yet worked at a co-op assignment; however, he had worked on a personal project about which he was passionate and which clearly was linked to his coursework.

> [A] large component of a personal project that I worked on last winter was a direct application of statics. In short, the project was to install a 5.7L V8 from a 2004 Pontiac GTO in my tiny 1994 Mazda Miata, which came equipped with a far more modest 1.8L four cylinder engine… I drew free body diagrams to help understand what kinds of forces will act on the car under different conditions. I drew separate diagrams for braking, acceleration, turning in steady state, turning while accelerating, and turning while braking. Through having a rough idea of the cars center of gravity, mass, weight distribution, and the g-force attainable during the different behaviors, I was able to estimate the magnitudes of the forces acting on the chassis. The next step was to look at the chassis and predict the load paths and make as good of guesses as I could as to which parts of the chassis were sufficiently robust and which ones would deflect… This vehicle has since been finished, and with a number of competitions and a few hours of open track time under my belt, I can say with great confidence that the changes have made a sizable impact on performance… there is still plenty of room for improvement. I designed the bracing to be expandable, including mounting points for bolt-in underbody bracing that I expect will greatly increase the torsional rigidity of the chassis for the minimal amount of weight that it will add. Completing the aforementioned brace is on my off season to-do list, and knowing what I know now from MECH 210, I should be in a better position to gauge it's (sic) effectiveness and make changes to the design.

James also saw connections between the course content and his co-op experience, although the connections were not as strong or as obvious to him as some other students' experiences; however, he was able to see where other courses in his engineering curriculum would be applicable, and commented on that.

> Seeing as how my job mainly involves parts that move and are constantly having new forces enacted upon them such as varying road surfaces there are few areas where statics principles directly apply. I can use it when designing the initial brackets. I will be able to better determine the forces within the component when doing stress fracture testing on individual components. I will be able to better predict what point the part will fail at… From what I know about the future courses, the Dynamic systems and Materials courses will be the most applicable to my current field of work… Overall this course has furthers my knowledge of the aspects of engineering as related to forces and torques in nonmoving components.

Kyle saw few connections between his work and the course content, choosing to focus exclusively on the ways in which the problem-solving skills would be useful to him, as noted in Section IV-A.

C. Reflections

Several students reflected on their past experiences, and how their knowledge from Statics would have affected their approach to problems they had worked on in their co-op experiences. In particular, Aaron and Faith wrote about how they would have approached problems differently as a result of what they had learned in the class. Aaron commented that the problem-solving approaches he had learned would have made it much easier to solve a problem he had faced.

> The problem I was noticing was one of the lathes kept breaking the roughing tools for that part it was machining. So instead of inspecting the carbide insert first, I went off and changed tool seats and tool bars, and then had my boss look at it and slow down feed rates and speeds. About 3 hours later I thought to myself, "It could it be just the carbide?" It was the carbide. The batch of carbide had weird coloring to the coating than normal coating. A problem like this would have taken a lot less time if I had analyzed everything first, instead of going off and changing a bunch of variables that could actually make the problem worse. Had I done that it would have saved a lot of time and money.

Faith also discussed how the problem-solving approaches she had learned affected her understanding of a problem she had worked with, and went on to comment on the connections that could be made beyond just the single course of Statics and her work.

> This course has given me a new insight to my work place and has encouraged me to recognize the connections between other classes as well. As a student who choose [university] for this program, it is really encouraging to see the link between the work done at school and the work done at, well, work. This program is a success in my eyes because students, such as myself, can see these connections and take the valuable knowledge from our education and directly apply it in the place of employment.

Cody also went beyond the parameters of the assignment given and reflected on the overall link between his co-op experience and his coursework as a whole, saying,

> All in all I believe that the mix of work experience and classes has many benefits. Although I may not need all the concepts we learn in classes, statics in particular, at my co-op right now, I can see that they may be useful down the road. The more knowledge I have, the more productive I can be to my company. On the flip side, the hands-on experience from working has helped me to better visualize in class concepts. Although I can see that relationship for all of my classes in the past, statics is the first class that I've analyzed its relevance to work term. Overall the combination of working and classes make for a very full education. There are very different things to be learned at each part and connecting them together makes you a well-rounded person.

Edward also reflected on the need to make connections in general, beyond the bounds of simply one class and his current work assignment.

> No matter how direct the connection is, it is important that I make the connections, any connections. I need to be able to transcend my theoretical experience in class with the practical experience at work. To me, life is about making connections, learning and thinking, and applying the knowledge to help other people live better lives.

While most of the students focused primarily on answering the questions asked in the assignment, these four students had gone beyond the parameters of the assignment and were able to achieve a deeper understanding of why the connections between coursework and co-op work were important.

V. Discussion

As discussed in Section II, it has been shown that reflection on experiences helps students to learn, and that writing can be a useful tool for reflection. Our results concurred with this, as students' essays indicated that they had consciously reflected on the material in the course. When describing what they had learned, instead of simply summarizing the syllabus, they focused on key ideas, as when Harris summarized what he had learned:

> There isn't really that many big ideas in Statics not (sic) that I'm looking back. Most everything comes from the Newton equations and the idea that the sum of the forces are equal to zero in the x and y direction. Of course you need to know how to add and subtract vectors in i j k form and how to find the moment of something, but from those ideas you can apply them to different beams, trusses, frames, machines, etc.

In the work required to write the essay, he clearly was able to integrate the course material and summarize it in just a few words. Other students also indicated that they had gained an understanding of the material through their reflections, although some of them focused more on how the simple concepts could lead to complex problems, as when Edward reflected on the complexity he saw in seemingly simple problems:

> What may seem intuitive, say the angle between two cylinders when you vary the weights, actually becomes quite difficult when you get to the nuts and bolts of it all. To each project there are the superficial concepts that anyone can understand, and then there are the deeper layers to it. The equations and mathematics that were used, the visualization and collaboration that had to take place, etc.

While some students were able to reflect more deeply than others and see different levels and types of connections, all of these students were able, when prompted, to see connections of some type between the material they were learning in their Statics class and their engineering co-op or other practical experience. The number of connections varied, as shown in Table 2, although this is in large part a function of the students' varying co-op assignments and cannot be assumed to reflect their higher-order thinking skills. The fact that they were all able to connect their coursework with authentic engineering experiences, when prompted, indicates that reflection on the material learned is beneficial in showing that the material learned in class is relevant. The students were able to realize, also, that while they may not see the immediate relevance of the course material they learned, problem-solving skills were relevant in the short term, and in the long term they could imagine some ways in which the course content might have future relevance. As the research cited in Section II has shown, this improves learning and retention, and therefore it should be encouraged in all engineering classes.

Instructors can promote this kind of reflection, and thereby provide their students an authentic engineering experience, in several ways. Here, we present three recommendations that can assist instructors in this.

1. Provide real-world examples relevant to the course from the instructor's knowledge.

   Textbook problems are, of necessity, simplified to enable students to solve them with the tools they have learned. While this provides useful practice in the techniques being learned, it does not necessarily show the full utility of the material. By integrating real-world examples into the course, students can be encouraged to think of the material as useful beyond the classroom. The first author of this paper began each lecture with examples of "good statics" and "bad statics," i.e., static structures that were successful and structures that had failed. This was something that students found useful; as one student, Kyle, said, "Every class we had examples of good statics and bad statics which made me realize my work can have a life or death consequence for people who use my product." These examples can come from recent, well-known events such as a bridge collapse that was in the news, articles in the magazines of technical societies such as ASME, or the instructor's own experience. In the case where an instructor has significant industry experience or has performed research with industrial applications, including one's own real-world examples can be a powerful example of the ways in which classroom material is relevant.

2. Encourage students to reflect on their work experiences.

   While many instructors have a wide range of engineering knowledge, no one has worked in every field of engineering, every company, and every type of engineering position. In a program where many if not all students work as co-ops or hold internships, an instructor can take advantage of this to provide students with authentic experiences. Either through a writing assignment like this one or through some type of classroom discussion, students can be encouraged to consciously consider the links between their coursework and their work experience. This further provides the instructor with additional examples that he or she can use in subsequent classes to continuously enrich the learning environment for later students.

3. Emphasize the general applicability of problem-solving techniques.

   While different parts of the mechanical engineering curriculum are more or less relevant to different types of jobs, the problem-solving techniques that are learned in one context can be generalized and applied to other contexts. Instructors can draw parallels between different types of problems and show how the problem-solving techniques can be applicable beyond a single class. This can be useful for those students who have less work experience as well as those who see their engineering degree as part of a career pathway into management, law, or other fields.

VI. Conclusion

The students in this study were able to successfully connect the class with their co-op work assignments and other authentic experiences, although the connections varied tremendously in their form and scope. Some students were able to see ways in which the course content would be useful to them in the workplace, while others focused on the problem-solving techniques that they had learned in the class. These connections, in whatever form they take, can be used to increase student motivation and retention of the material. By consciously drawing on these authentic experiences, instructors can assist their students in integrating the various portions of their engineering education and increase their understanding of the material.

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Appendix: Essay Assignment

Format/length requirements:

- 3 pages minimum, double spaced
- 12 point Times New Roman font
- Electronic submission preferred (PDF or MS Word)
- If submitting electronically, name your document "MECH210_essay_LASTNAME", where you replace the text "LASTNAME" with your own last name.
- On the first page of the essay, include your name and a title.

Purpose:

The purpose of this assignment is for students to reflect on how the facts, techniques, and skills learned in MECH 210 can be useful in their co-op job, and/or how their co-op job impacts their view of the material learned in class.

Structure:

The essay should contain the following elements. These are not separate questions; there should be a logical flow and transitions between the paragraphs.

- A description of your co-op assignment, with sufficient detail so that a reader could understand what industry the company is in, what they do in general, and what your specific role is. You may also include information on what you plan or hope to do in future co-op terms, if this is different than what you've done to date.
- A description of what you feel you're learning in MECH 210. This must include a description of the course content, but may also include skills such as general problem-solving skills. Be as specific as possible about this; it should be at least a full paragraph.
- Your thoughts on what the links are between your co-op assignment on the content and skills you learn in MECH 210. Spend some time, and write as extensively as possible, on this part of the essay. If you feel there are very few links between the course content and your co-op assignment, discuss why this is the case, then focus on more general problem-solving skills.
- A brief conclusion, in which you summarize and tie together the most important things (in your opinion) that you've said in the essay
- Acknowledgements, if applicable; if you feel that it would be helpful, you can ask for assistance from various university resources such as the Academic Success Center or from a classmate. Acceptable assistance includes feedback on whether your writing is clear, discussions to help you clarify your thoughts on content, and help with grammar and spelling. Your acknowledgement should take the form of "I would like to thank (NAME) for assistance with (PROOFREADING, ENGLISH GRAMMAR, SPELLING, OR WHATEVER HELP YOU RECEIVED)." You will NOT get a lower grade if you seek out and receive this type of assistance.