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A Survey of the Challenges Faced by Students when asked to Transfer Learning

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Introduction

Teaching such that students can transfer their learning between contexts and applications is a key goal of all educators [1]-[3]. In the engineering field specifically, various groups and organizations have recognized the need for graduating engineers to be able to transfer. The idea of a "T-shaped" professional who possesses a deep understanding of their core discipline (the vertical of the tee) as well as the ability to transfer this knowledge across a range of inter-disciplinary applications (the horizontal of the tee) has been widely discussed as a model for graduating students [4]-[8].

At the same time as we recognize the need to train adaptable engineers who can transfer their learning, knowledge and skills between contexts, the challenges students face when asked to transfer learning have been widely reported [1]-[3],[9],[10]. Various reasons have been given for the reasons students fail to successfully transfer their learning; a lack of deeper learning of the knowledge or skills to be transferred [11]; not revisiting important skills, knowledge and/or concepts throughout the curriculum such that students are only exposed to them for singular or brief instances [12]; not teaching material via problems, examples, or by using applications in which students see how the material is used [13]; and, not making explicit the connections between the knowledge, skills and concepts used in various areas of the curriculum [14].

Prior work by the author has investigated the challenges students face when tasked with transferring learning in the context of engineering statics. In this prior work [15],[16], a series of think aloud interviews (n=23) demonstrated student difficulties in solving problems in which integral calculus was needed to determine the location of a centroid and suggested several reasons why these difficulties might arise [17]:

- Lack of, loss of, or possession of inaccurate prior knowledge
- Lack of conceptual understanding
- Lack of applications being taught
- Material not revisited since being taught
- The instructor presenting negative view of material
- Preference for using alternate solution techniques
- Confusion regarding the language of the problem and symbols used
- Variations in approach to problem solving

In this study we build on this prior work [15]-[17] that investigated student ability to transfer knowledge in order to solve an engineering statics problem. Here we attempt to broaden the population of student participants and determine if any larger patterns exist in the challenges faced by a larger group of students tasked with solving the same problem.

Methodology

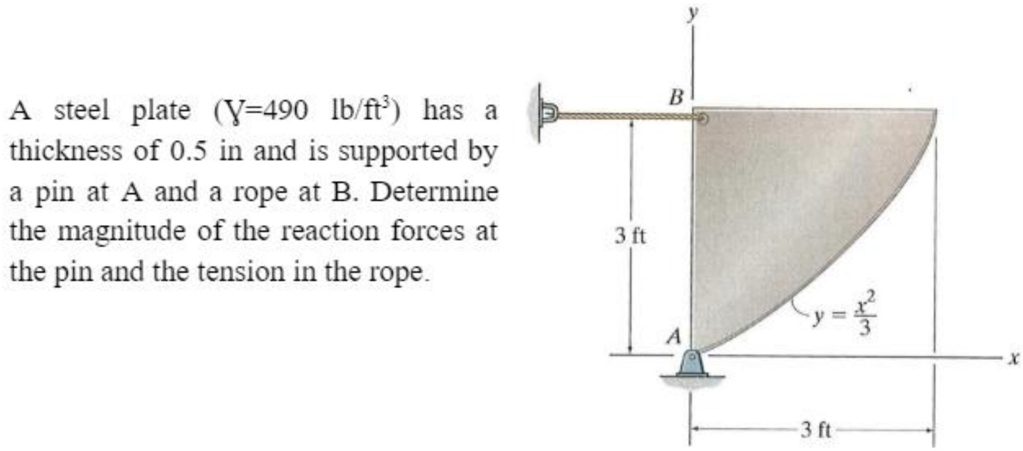

Figure 1: Engineering statics problem students were asked to solve [18].

The investigation detailed in this work took place in a second-year undergraduate mechanical engineering dynamics class held at a large, mid-Atlantic university in the spring of 2025. Students enrolled in the class were asked to solve the problem shown in Figure 1 as part of an active-learning activity included in week ten of a fifteen-week semester. This problem was chosen as it is the same as that used in prior work [15]-[17] and is typical of a rigid body equilibrium problem that students would solve in an engineering statics course. Notably, this problem requires the use of integral calculus to solve for the location of the centroid and to successfully calculate the solution.

Following this in-class assignment, students were asked to complete the post-activity survey included in Appendix A. The survey consisted of both unstructured response questions and Likert-scale statements aimed at developing an understanding of the challenges faced by students when tasked with solving the problem presented in Figure 1. At the start of the survey, students were asked to self-identify whether they correctly answered the problem or not after being given the correct solution. Following these survey items, student self-identified demographic data was collected along with student consent to be part of the research study.

Table 1: Participant Demographics (*n*=111 total participants)

	Of Total *n*			Of Total *n*		No. of Students Identifying in Group			
	Male	**Female**	**Gender Diverse**	**Sophomore**	**Junior**	**URM**	**LGBTQ+**	**Transfer Student**	**ESL**
Count	88	20	3	101	10	16	7	5	6
% of total	79%	18%	3%	91%	9%	14%	6%	5%	5%

All participants in this problem-solving activity and survey were mechanical engineering undergraduate students who had previously taken engineering statics (topic of centroids covered, C- grade required to progress to the dynamics class) as well as various physics and mathematics pre-requisites (at least calculus A & B). A total of n=151 students completed the in-class activity. After accounting for those students that did not consent to be part of the study and the removal of partial responses, a total of n=111 usable responses remained. These n=111 responses serve as the basis for the analysis presented here. A high-level breakdown of participant demographics is presented in Table 1.

Resulting data from the survey responses were analyzed using statistical analysis software (JMP v18.2.1). Results were analyzed using various descriptive statistics for Likert-scale responses - primarily ANOVA and Chi-Square with post-hoc Bonferroni, while thematic analysis [19] was employed for the constructed responses to open-response items.

Findings & Discussion

A total of n=16 (of the total n=111), or 14%, of the participants in the problem-solving activity self-identified as being able to solve the statics problem correctly when shown the solutions. Student solutions were not independently verified and so there is some question as to the validity of this result. It is interesting to note, however, that a significant majority of students stated that they were unable to solve the problem. In terms of the survey data, no statistically significant associations were found between any of the Likert-scale survey responses and problem-solving success, nor was there any statistically significant association between GPA and whether the participant could solve the problem, $X^2(1, n = 111) = 0.91, p = 0.34$.

Those students who could not solve the problem were asked to provide an unstructured response to the question "*Please write a brief reflection on why you believe you could not solve this problem.*" A total of n=95 participants provided a reflection and of these responses, 65/95 (or 68%) mentioned challenges with finding the centroid. A common theme in the responses (39/95 or 41%) was that the participant had in some way forgotten the necessary equation needed to find the centroid of an irregular shape via integration; "*I could not remember how to relate, density, thickness, and area to create a force, I knew centroids and integrals were required but didn't remember which equations to use or how to relate them."* A lack or loss of knowledge was cited as a major challenge in prior work and the broad discussion of this difficulty here is evidence of this particular challenge being a broader, more general concern among study participants.

Other themes in responses related to mathematical errors (15/95 or 16%), running out of time (11/95 or 12%), the length of time between last working with centroids (5/95 or 5%), or being unsure of the correct approach to take (4/95 or 4%). The idea of the length of time between working with various topics in the curriculum has been seen in prior work as well as here; "*I don't think I've had enough practice with this particular problem, and I haven't done it in a* *while*", with this particular participant picking up on both the issue of lack of repeat practice or connections between courses being made as well as the time between this activity and last (knowingly on their part) working with centroids.

Table 2: Themes in responses to the question: "*Please write a brief reflection on why you believe you could not solve this problem.*" (*n*=95 responses)

Theme	Count	%	Core Sentiment	Sample Quote
Pervasive Forgetfulness	39	34%	Direct admissions of forgetting the material or not recalling steps.	*"I did not remember how to calculate the centroid."*
Struggle & Calculation Errors	19	17%	Feelings of confusion, making mistakes, or getting "stuck."	*"I think I messed up solving the x-axis location of the center of mass which was needed to solve the moments."*
Successful Recall	14	13%	Respondents who were "able to" or "knew how" to solve it.	*"I couldn't remember how to get the center of mass to place the weight of the object, but I knew how to do the rest…"*
Time Constraints / Time Gap	17	9%	Running out of time or noting it has been a long time since learning.	*"I did not have time to fully work out the problem."*
Unsure of Approach	6	5%	Brief admissions of having "no clue" or simply "Idk."	*"… it took me at least 5 mins to figure out how to approach the problem"*
Instructor Bias	3	3%	Specific mentions of Statics instructor stating that content was not important.	*"[Instructor] told us that these types of problems weren't going to be on tests, so we never practiced these examples extensively."*

Table 2 lists further themes found in the analysis of the participant reflections. Note that in this table, keywords & themes from each reflection were marked such that the total number of mentions of each theme are described and that each reflection could contribute to more than one theme. These themes are further evidence for the challenges that have previously been described in the literature [10]-[14],[17]. In particular, forgetfulness, or the lack/loss of prior knowledge and issues with recall is a prominent theme in the responses. Interestingly, there were a number of responses around the theme of recall i.e. I knew how to solve this part of the problem but ran into issues with this part, or similar. Clearly some aspects of the problem were more tractable than others. The final theme of instructor bias was also noted in prior work. In the case of this study, all 3 instances of instructor bias relate to the statics course instructor saying that finding centroids via integration was not an important skill to learn. Clearly, statements such as this are problematic and the fact that instructor bias has been described as a challenge in multiple years of this study are even more concerning.

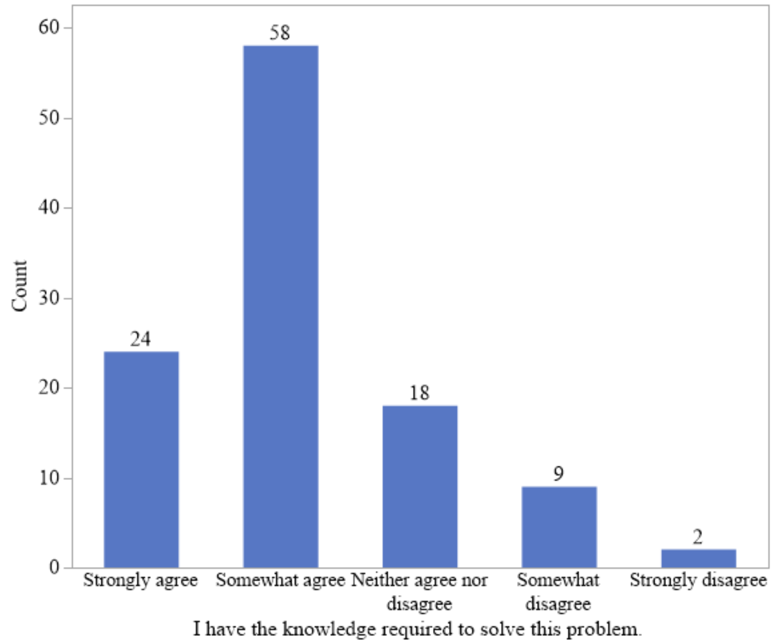

Figure 3: Breakdown of participant agreement with statement "I have the knowledge required to solve this problem."

Related to the "successful recall" theme (Table 2) a majority of students (82/111 or 74%) believed that they had the knowledge required to solve the problem (Figure 3). Interestingly, there was a statistically significant dependence between students who believed they had the knowledge to solve the problem and those who agreed with "*When I am asked to solve a problem using centroids I am often asked to do so mathematically (i.e. using integrals)*", $X^2(16, n = 111) = 34.87$, $p = <0.001$. There was no significant association between having the knowledge required and problems solving success, however, $X^2(4, n = 111) = 8.1$, $p = 0.09$. These results, along with the prior analysis, seem to indicate that the participants have solved these kinds of problems before but that they struggle to apply working knowledge of how to do so. Similar to prior work [17], themes such as loss of prior knowledge, taking too long in the curriculum between seeing examples of this work, and a lack of applications being taught are challenges that are also alluded to by the analysis of this particular population of students.

Table 3: Associations with GPA

Statement	$X^2(1, n = 111)$	*p*-value
Centroids are an important topic in engineering.	12.67	<0.001
I have seen many different applications of centroids in engineering.	8.91	<0.001
I have a good grasp of the knowledge required to solve this problem.	10.31	<0.001
I have the knowledge required to solve this problem.	10.06	<0.001
The symbols and language used in the problem confused me.	9.81	<0.001
I did not know how to set up and approach this problem.	6.79	0.01
I have a thorough understanding of centroids.	3.38	*0.06*

Table 3 examines associations between GPA and participant agreement with various Likert-scale items from the survey. As is observed in Table 3, many of the survey responses were associated with GPA in a statistically significant manner. Students with a higher GPA were more likely to believe centroids were an important topic in engineering, to have recognized seeing more examples of the applications of centroids, and to believe that they had the knowledge required to solve the problem. Students with a higher GPA were also less likely to agree with the statement *"I did not know how to set up and approach this problem"*. As one might expect, given that grades and GPA are seen by students as a measure of their performance and understanding, students with higher GPA were more likely to self-report that they possessed the knowledge and skills to solve this problem, even though they could not do so. These clear associations with GPA, coupled with the fact that students could not actually solve the problem, lend weight to discussions in the field regarding the perceived and real value of grades, and the need to teach for deeper learning and transfer.

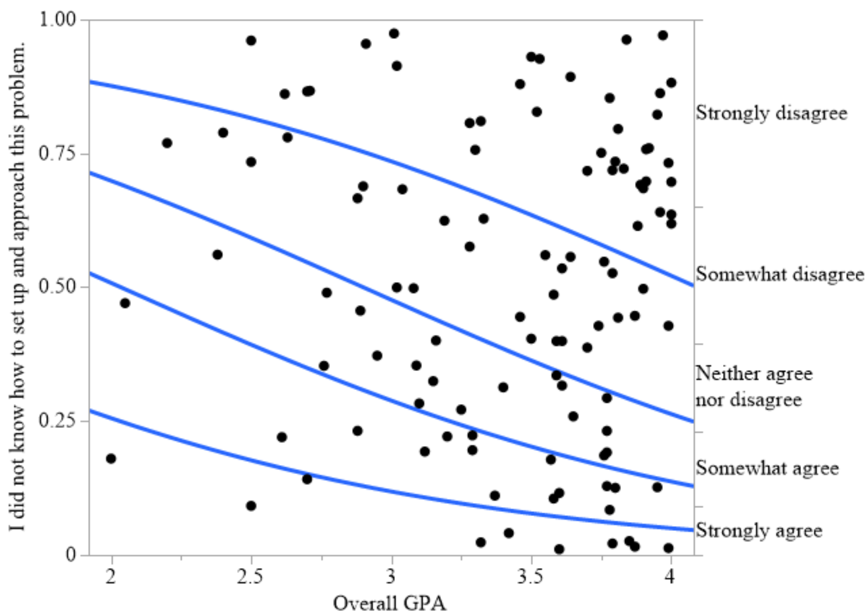

Figure 4: Logistic plot of GPA and agreement with statement "*I did not know how to set up and approach this problem*", $X^2(1, n = 111) = 6.79, p = 0.01$.

Interestingly, there was no statistically significant difference in GPA based on whether students felt they had a thorough understanding of centroids, $X^2(1, n = 111) = 3.38, p = 0.06$. Given that there was no association between GPA and problem-solving success, and that most students (95/111) could not solve this problem correctly, it is possible that the responses to this question were biased. The (post-activity) survey was completed after the students determined whether they had answered the question correctly or not and centroids were a key area of difficulty for most students (65 or 59%). Given this stated difficulty with centroids, it is possible that the students' inability to find the centroid in this application led to them stating their lack of understanding of this topic no matter what their GPA was.

Another interesting observation related to GPA was that students with a higher GPA were statistically more likely to agree that they knew how to approach and solve the problem (Figure 4, $X^2(1, n = 111) = 6.79, p = 0.01$). Given that we know most of these students did not actually solve the problem, however, we must consider whether these students truly understood the problem and tailored their approach, or whether they were simply following the engineering problem solving method that is typically drilled into students in foundational courses – are these students really in possession of a deeper understanding or are they just better at solving the typical problems we set them using the engineering approach?

In terms of the larger participant demographics, no statistically significant associations were found between gender and any Likert-scale response questions. There was, however, a statistically significant difference in GPA between genders, with female students in the sample having a higher GPA than male students (determined using ANOVA, $F(1.04, 0.24) = 4.40, p = 0.04$, male GPA 3.36±0.51 and female GPA 3.62±0.38, mean ± standard deviation).

Similarly, no statistically significant associations were found with URM status or international student status and any of the Likert-scale responses. LGBTQ+ status and year of study were also investigated and again, no statistically significant results were found - although the populations of both groups were small enough to call into question their analysis in general.

Table 4: Statistically significant associations with "I have seen many different applications of centroids in engineering."

Likert-scale Statement	$X^2(16, n = 111)$	*p*-value
I feel confident solving problems involving centroids.	47.49	<0.001
I have the knowledge required to solve this problem.	27.54	0.036
The symbols and language used in the problem confused me.	24.65	*0.076*
I have a thorough understanding of centroids.	31.15	0.013
I did not know how to set up and approach this problem.	29.421	0.02

When we examine student experience with problems concerning centroids, n=6 students responded negatively when asked if they had ever been asked to solve problems involving centroids before. One of these students did self-identify as being able to solve the problem correctly, however. Amusingly, while these n=6 participants stated that they had not solved centroid problems in the past, all 6 of them agreed that they had seen centroids before in at least their engineering statics class. It should be noted that centroids are (definitely) a topic in our engineering statics course and problems concerning them are explicitly included in both in-class active learning and take-home assignments. Centroids are also covered in our physics and solid mechanics curriculum, which most of the students in this study have also participated in.

Further examination of the data presented in Table 4 yields results that would perhaps have been expected; students who agreed that they had seen centroids many times before were statistically more likely to feel confident solving problems involving centroids, to agree that they had a thorough understanding of centroids, and to disagree that they did not know how to approach the problem. As one would expect, the group that felt that they had seen more problems involving centroids were less likely to agree that the symbols and language used in the problem confused them – further evidence of the importance of teaching applications and using concepts in multiple courses where the symbology and language used might differ.

Table 5. Breakdown of participants' preferred method for calculating centroids (*n*=111).

Method	Count of Responses	% of Total
Composite shapes	75	68%
Integration	11	10%
Lookup tables	8	7%
Unsure of any method	9	8%
Ask the course instructor	5	5%
Response Not Coded	*3*	*2%*

The problem used in this study (Figure 1) requires use of integral calculus to determine the location centroid of the non-standard shape described in the figure. As prior work had indicated that students preferred not to use integration to find the location of the centroid, this preference was also investigated here by asking participants; "*If you were asked to find the centroid of a new shape, what would be your preferred method for doing so?*". A summary of responses to this question is presented in Table 5. A striking majority of participants (75/111 or 68%) preferred to use the method of composite shapes to find an unknown centroid. Only 11 participants (10%) indicated a preference for using integration. As might be expected, a larger proportion of these participants who preferred to use integral calculus were successful in solving the overall problem (5/11). This finding is consistent with prior work which also indicated student discomfort with using mathematical formulations for determining the centroid and a preference for more geometric approaches [15]-[17].

Based on the responses to this question (preferred approach to determining the centroid) in general, an overarching theme observed was a significant lack of knowledge retention regarding centroids as a topic. As with responses to questions related to why students could not solve the problem (see Table 2), responses again focused on challenges or difficulties such as memory loss, confusion, and the passage of time since the topic of centroids was last studied, in addition to the method that participants would prefer to employ.

Interestingly, there was a statistically significant association between participants' agreement that they "*did not know how to set up and approach [the] problem*" and their preference "*to solve a problem like this using another approach*", $X^2(16, n = 111) = 29.34$, $p = 0.02$. A major finding of this work, and an expected result based on prior work, appears to be that students who participated in the study are uncomfortable using integral calculus to determine the location of the centroid. Given that this same challenge has been cited over several years of similar investigations [15]-[17], students' lack of a thorough understanding of integral calculus and its applications would seem to be a deficiency in our program.

When asked "*What aspects of the language or symbols used in the problem statement confused you?*", a total of 12 participants responded to this question, 9 of which indicated that they did not know what the symbol gamma (γ) was used for. The lack of responses to this question in general was surprising given that prior work [15]-[17] had suggested that the symbols used in this problem, and in particular γ, were a challenge for some students. It is possible, however, that this cohort of participants had a different background with respect to symbols used than prior research samples, or that participants did not get far enough into the problem to become confused by the symbols used.

Even with this low response rate to the unstructured question regarding confusing aspects of the problem, there was a strong association between students who agreed that they had difficulty setting up the problem and those that experienced confusion with the language and symbols used. Agreement with Likert-scale items "*I did not know how to set up and approach this problem*" and "*The symbols and language used in the problem confused me*" showed a statistically significant association: $X^2(16, n = 111) = 63.762, p < 0.001$. It is impossible to parse whether these students faced challenges with the symbols or language of the problem specifically, however, as these issues are conflated in this question and were not parsed out by participants in their responses.

Summary of Findings

In this study we investigate student ability to transfer their learning and solve an engineering statics problem. The rigid body equilibrium problem used in this work requires determination of the centroid of an irregular shape by integration and was shown in prior work to pose a significant challenge to students. The goal of this study was to investigate the specific challenges students faced when solving this problem and generalize these challenges across a larger sample.

Findings of this study are consistent with prior work in evidencing the variety of difficulties that students face when asked to solve this problem. In particular, issues with prior knowledge and a lack or loss thereof, a preference for determining centroids via methods other than integration, and a lack of deeper understanding of the topic of centroids in general were found to be major factors in students' inability to correctly solve the problem. Most students were unable to correctly solve the statics problem and the loss or lack of prior knowledge of how integral calculus can be employed to find the location of the centroid appeared to be the primary challenge faced by this population of students.

In this study, and prior work by the authors, various challenges that students face when tasked with transferring learning have been identified. Many of these challenges are well-described in the literature and best practices for overcoming them have already been proposed and evidenced. Future work will focus on implementing these best practices in the classroom, in order promote the successful transfer of learning and promote problem solving success, and measuring their effectiveness .

Acknowledgements

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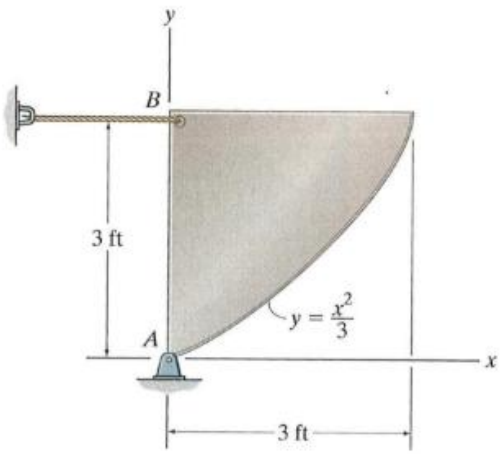
Appendix A: Post-Activity Survey

Think about this problem that we solved earlier in class:

A steel plate (γ=490 lb/ft^3) has a thickness of 0.5 in and is supported by a pin at A and a rope at B. Determine the magnitude of the reaction forces at the pin and the tension in the rope.



Were you able to solve this problem correctly? i.e. did you determine the correct numerical answers? *Reminder: the correct numerical answers were T = 45.97 lb, F*Ax*=45.97 lb, F*Ay*=122.52 lb, |F*A*|=130.84 lb*

- ○ No
- ○ Yes

Please write a brief reflection on why you believe you could not solve this problem.

Unstructured, open response

Thinking about the topic of centroids, rate the degree to which you agree with the following statements.

a) Centroids are an important topic in engineering.
b) I have been asked to solve problems involving centroids before.
c) I have been asked to solve problems involving centroids in multiple, different courses.
d) I have seen many different applications of centroids in engineering.
e) I have a thorough understanding of centroids.
f) I feel confident solving problems involving centroids.

Likert-scale responses: Strongly disagree, Somewhat disagree, Neither agree nor disagree, Somewhat agree, Strongly agree

When I am asked to solve a problem using centroids I am often asked to do so mathematically (i.e. using integrals).

Likert-scale responses: Strongly disagree, Somewhat disagree, Neither agree nor disagree, Somewhat agree, Strongly agree

If you were asked to find the centroid of a new shape, what would be your preferred method for doing so?

Unstructured, open response

Please list all of the courses you have taken in which you have learned about centroids or been asked to apply your understanding and knowledge of centroids.

Unstructured, open response

Thinking about this problem and your solution, rate the degree to which you agree with the following statements.

a) I have the knowledge required to solve this problem.
b) I have a good grasp of the knowledge required to solve this problem.
c) It has been a while since I have been asked to solve this kind of problem.
d) My instructor told me I would probably not need to solve a problem like this again.
e) I would prefer to solve a problem like this using another approach (i.e. not by hand).
f) The symbols and language used in the problem confused me.
g) I did not know how to set up and approach this problem.

Likert-scale responses: Strongly disagree, Somewhat disagree, Neither agree nor disagree, Somewhat agree, Strongly agree

What aspects of the language or symbols used in the problem statement confused you?

Unstructured, open response

Please use this space to provide any additional comments you have relating to this problem and the topic of centroids.

Unstructured, open response

Consent Documentation & agreement to be part of the study included here.

Demographic Data Collected *(various drop downs and suggested options)*

a) Gender: How do you identify?
b) Do you identify as part of the LGBTQIA+ community?
c) What is your age?
d) What is your race/ethnicity? Check all that apply.
e) Is English your first language?
f) What year are you in college?
g) Are you a transfer student?
h) Please indicate your anticipated GPA this semester
i) Please indicate your overall undergraduate GPA