IMPACT OF YOUTUBE HOMEWORK PROBLEMS ON STUDENTS' LEARNING ATTITUDES

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INTRODUCTION

The chemical engineering curriculum traditionally begins with a course in material and energy balances (MEB). MEB plays an important role in building a foundation for continued success and engagement in engineering.[1, 2] Students are required to learn to read problem statements, construct a picture of the system, and logically solve problems that involve basic concepts of mathematics, chemistry and physics.[1-6]

Nearly all current undergraduate students began interacting with digital technology at a young age and are often referred to as digital natives.[7] Compared to previous generations, digital natives show more inclination to visual over text-based modes of learning, are motivated by projects with real-world components, and have shorter attention spans.[8] Examples of incorporating visual modes of learning into the modern classroom include the use of technology-aided assignments such as requiring students to complete homework problems and find course-related information on devices such as cell phones and laptops.

While homework problems from textbooks are designed to allow engineering students to practice problem solving, easy access to solution manuals has created an issue.[3, 9] Besides being an issue of academic integrity, copying solutions rather than putting effort into learning course concepts and developing problem-solving skills could inhibit success.[3] In fact, problem-solving skills have been identified as a major concern for students learning MEB.[6]

To promote the development of student learning outcomes, courses need to incorporate engaging and authentic learning opportunities.[10-12] The YouTube™ pedagogy, discussed here, has students actively creating new course content, which falls under the guise of research-based best practices commonly called active learning.[13-15] This YouTube pedagogy started as a way to introduce and engage engineering students. Students reported a better understanding of the course topic and the ability to relate course material to real world phenomena since YouTube pedagogy provided students with a mechanism to apply classroom concepts to open-ended, real world situations.[16-19] More recently, the YouTube pedagogy offered a framework for instructors to crowdsource the writing of new and unique homework problems. Student-written problems have been archived and subsequently used as alternative homework problems in this study.

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Despite the seemingly common-sense adoption of multimodal homework problems in the modern classroom, more research is needed into its efficacy and impact on student outcomes. One outcome receiving increased attention regarding student success is student learning attitudes. Several studies report how positive attitudes toward science lead students to pursue science careers.[20] Learning attitudes have a significant positive correlation with academic success and self-directed learning ability.[21, 22] Additionally, teaching strategy can influence students' attitudes which consequently affects learning gains or outcomes.[23] Since earlier work shows that integration of technology in teaching has some correlation with attitudes,[24] it is essential to assess students' attitudes when implementing novel pedagogical approaches. This study explored how incorporating YouTube homework problems into an MEB course might influence learning attitudes toward chemical engineering.

MATERIALS AND METHODS

This research explored the hypothesis that a YouTube pedagogy-infused course can promote meaningful gains in student attitudes toward chemical engineering course material. The broader research project is examining problem-solving skills when completing traditional textbook or YouTube problems.[19] Thus, measuring students' attitudes toward learning complements and expands upon other research focusing on problem solving.

Learning Attitude Assessment

The Colorado Learning Attitudes about Science Survey (CLASS) was administered in a pre/post participation design. Though CLASS was initially designed for physics,[23] numerous studies have adaptations for chemistry, biology, astronomy and math.[25, 26] Essentially, CLASS measures attitudes about a science subject, so adaptation involved changing the science topic from physics to engineering. The adapted survey started from version 3 of CLASS for Physics,[3-5] where the instrument developers established expert responses on 36 of the 41 eligible questions (one question is an attention check question). Two chemical engineering (ChE) faculty reviewed the modified instrument to verify that the expected expert responses for the CLASS for Physics survey were still valid for the engineering-related content of the modified CLASS (Table 1).

Leveraging earlier work by Adams et al, CLASS statements were grouped into eight categories in addition to computing an overall "learning attitude" score (Table 2).[25] Each category consisted of four to eight statements that describe a specific aspect of student thinking with some statements appearing more than once.

Following other studies using CLASS, a 4-point scale of strongly agree, agree, disagree, strongly disagree was available; a neutral option was not included. Using an established scoring protocol, strongly agree and agree were considered to be the same selection and similarly, disagree and strongly disagree were also considered equivalent.[25] For example, statement 1 states "A significant problem in learning engineering is being able to memorize all the information I need to know." If a participant provided the desired response to the statement (i.e. "disagree" or "strongly disagree"), the participant earned 1 point. However, if a participant's response agreed or strongly agreed with statement 1, the participant scored 0 points. CLASS scores for each participant represented the number of times a participant gave a desired response expressed as a percentage. The five items without an expert consensus were not used to calculate any CLASS scores. An attention check item (question 31) was used to remove 26 surveys (7% of total). Students typically completed the instrument in under 10 minutes.

Analysis compared group CLASS scores of students at the beginning and end of the course. Normalized gain and effect size analysis quantified magnitude of change in learning attitudes of participants. Paired surveys were investigated but the number of responses was small. Thus, pre/post comparison used all CLASS scores. Since the number of pre/post responses were dissimilar, Hedges' g was adopted to measure effect size weighted according to the relative size of each sample.[27]

Participant Demographics

CLASS responses were collected from two Materials and Energy Balances courses at a large public research university taught in consecutive years. Students in each course solved nine YouTube problems in addition to 10 textbook problems (with changes in numbers used for calculations to reduce the solutions manual dilemma discussed earlier). Each cohort, about 90 students with most in the second semester of the freshman year, studied the same course content, used the same textbook,[28] and were taught by the same instructor (one of the authors of the course textbook). The cohorts were equivalent in number of valid survey responses received, composition of male and female students, and distribution of highest level of math course completed (Table 3). Additionally, there were no statistical differences between cohort performance on the pre ($t(144) = 0.379$, $p = 0.705$) or post ($t(144) = 0.352$, $p = 0.727$) assessments. Given the comprehensive equivalency between groups, the data were combined and analyzed together.

A paired analysis utilized valid survey responses from only 40 students that completed both pre and post CLASS survey (Appendix, Table S.1).[6-8] Survey results revealed a good agreement ($p > 0.05$) in mean overall CLASS scores between paired data and unpaired responses. Due to agreement be-

TABLE 1
Statements in the version 3 of CLASS with corresponding desired responses.[25]

#	Statements	Expert Response
1	A significant problem in learning engineering is being able to memorize all the information I need to know.	Disagree
2	When I am solving an engineering problem, I try to decide what would be a reasonable value for the answer.	Agree
3	I think about the engineering I experience in everyday life.	Agree
4	It is useful for me to do lots and lots of problems when learning engineering.	NA
5	After I study a topic in engineering and feel that I understand it, I have difficulty solving problems on the same topic.	Disagree
6	Knowledge in engineering consists of many disconnected topics.	Disagree
7	As engineers learn more, most engineering ideas we use today are likely to be proven wrong.	NA
8	When I solve an engineering problem, I locate an equation that uses the variables given in the problem and plug in the values.	Disagree
9	I find that reading the text in detail is a good way for me to learn engineering.	NA
10	There is usually only one correct approach to solving an engineering problem.	Disagree
11	I am not satisfied until I understand why something works the way it does.	Agree
12	I cannot learn engineering if the teacher does not explain things well in class.	Disagree
13	I do not expect engineering equations to help my understanding of the ideas; they are just for doing calculations.	Disagree
14	I study engineering to learn knowledge that will be useful in my life outside of school.	Agree
15	If I get stuck on an engineering problem my first try, I usually try to figure out a different way that works.	Agree
16	Nearly everyone is capable of understanding engineering if they work at it.	Agree
17	Understanding engineering basically means being able to recall something you've read or been shown.	Disagree
18	There could be two different correct values to an engineering problem if I use two different approaches.	Disagree
19	To understand engineering, I discuss it with friends and other students.	Agree
20	I do not spend more than five minutes stuck on an engineering problem before giving up or seeking help from someone else.	Disagree
21	If I don't remember a particular equation needed to solve a problem on an exam, there's nothing much I can do (legally) to come up with it.	Disagree
22	If I want to apply a method used for solving one engineering problem to another problem, the problems must involve very similar situations.	Disagree
23	In doing an engineering problem, if my calculation gives a result very different from what I'd expect, I'd trust the calculation rather than going back through the problem.	Disagree
24	In engineering, it is important for me to make sense out of formulas before I can use them correctly.	Agree
25	I enjoy solving engineering problems.	Agree
26	In engineering, mathematical formulas express meaningful relationships among measurable quantities.	Agree
27	It is important for the government to approve new scientific ideas before they can be widely accepted.	Disagree
28	Learning engineering changes my ideas about how the world works.	Agree
29	To learn engineering, I only need to memorize solutions to sample problems.	Disagree
30	Reasoning skills used to understand engineering can be helpful to me in my everyday life.	Agree
31	We use this statement to discard the survey of people who are not reading the questions. Please select strongly agree-option 4 for this question to preserve your answers.	Strongly agree only
32	Spending a lot of time understanding where formulas come from is a waste of time.	Disagree
33	I find carefully analyzing only a few problems in detail is a good way for me to learn engineering.	N/A
34	I can usually Figure out a way to solve engineering problems.	Agree
35	The subject of engineering has little relation to what I experience in the real world.	Disagree
36	There are times I solve an engineering problem more than one way to help my understanding.	Agree
37	To understand engineering, I sometimes think about my personal experiences and relate them to the topic being analyzed.	Agree
38	It is possible to explain engineering ideas without mathematical formulas.	Agree
39	When I solve an engineering problem, I explicitly think about which engineering ideas apply to the problem.	Agree
40	If I get stuck on an engineering problem, there is no chance I'll figure it out on my own.	Disagree
41	It is possible for engineers to carefully perform the same experiment and get two very different results that are both correct.	N/A
42	When studying engineering, I relate the important information to what I already know rather than just memorizing it the way it is presented.	Agree

TABLE 2
Categories of survey questions from CLASS.[25]

Categories	Statements within Category	Number of Statements
Real World Connection	28, 30, 35, 37	4
Personal Interest	3, 11, 14, 25, 28, 30	6
Sense Making/ Effort	11, 23, 24, 32, 36, 39, 42	7
Conceptual Connection	1, 5, 6, 13, 21, 32	6
Applied Conceptual Thinking	1, 5, 6, 8, 21, 22, 40	7
Problem Solving General	13, 15, 16, 25, 26, 34, 40, 42	8
Problem Solving Confidence	15, 16, 34, 40	4
Problem Solving Sophistication	5, 21, 22, 25, 34, 40	6
Not Scored	4, 7, 9, 31, 33, 41	6

TABLE 3
Comparison of participants across two academic years. Cohort 1 and 2 represent participants in the 2018 and 2019 academic years, respectively, while combined is an aggregate of both cohorts.

		Cohort 1	Cohort 2	Combined
Survey responses across semester	Pre	72	74	146
	Post	19	28	47
Cohort information	Total	90	92	182
	Female%	42	38	40
% by highest math course enrolled	Calc1	68	65	66
	Calc2	13	17	15
	Calc3	12	11	12
	Diff eq +	7	7	7

tween paired and unpaired analysis of CLASS responses, further analysis in the current paper utilized all valid data points for the unpaired set.

RESULTS AND DISCUSSION

First, overall CLASS scores and subcategories were analyzed for pre and post periods. Many studies have identified low level of mathematics preparation as a bottleneck that may limit retention, motivation, and success in engineering courses.[29, 30] Thus, a relationship between prior math experience and learning attitudes was examined. Two tailed t-tests, normalized gains, and effect size analysis were used to quantify the significance of changes in CLASS scores.

Summative CLASS Scores

Box whisker plots visualized the range of student responses on the CLASS scores of students collectively reported over the two years of the study (Figure 1). Whiskers signified the minimum and maximum CLASS scores. For the pre-condition, 75% of the 146 students (3rd quartile) expressed attitudes that were in alignment with desired beliefs at least 72% of the time. This finding indicated a relatively high, positive attitude toward learning chemical engineering. At the end of the study, students' perceptions of learning engineering better aligned with experts with an improvement in 3rd quartile score of 6%. Similarly, the 1st quartile and median scores increased 2 to 3% in overall learning attitudes. A 7% smaller interquartile range in the post CLASS scores showed a more positive uniformity towards learning in engineering.

While CLASS has not been used to measure learning attitudes in engineering, responses in the current study were comparable to CLASS data collected in introductory physics classes. CLASS scores in previous studies averaged ~ 62 ± 9% for the pre condition.[31-34] In the current study, higher pre-condition CLASS scores were measured (Appendix, Figure S.1). Findings from previous literature suggested that students in a traditional classroom type show a decline in learning attitude.[31] However, students in an interactive classroom implementing either a modified peer instruction in conjunction with clickers or studio classroom format showed increases in learning attitudes.[32-34] Consequently, positive shifts in overall CLASS scores of about 4% were measured for students undergoing YouTube pedagogy, which aligns well with other active learning pedagogies.[31-34] Since other active learning techniques were employed throughout the course, including an interactive textbook, the shifts in attitude likely have some confounding factors related to these multiple active learning techniques.

Assessing Growth in Student Learning Attitudes

Results from the pre-course assessment of attitudes toward learning engineering revealed that students entered the MEB course with mean overall positive attitudes – 78% agreement with experts. Upon undergoing a YouTube pedagogy-infused course, students' attitudes rose by 4% (Table 4). The differ-

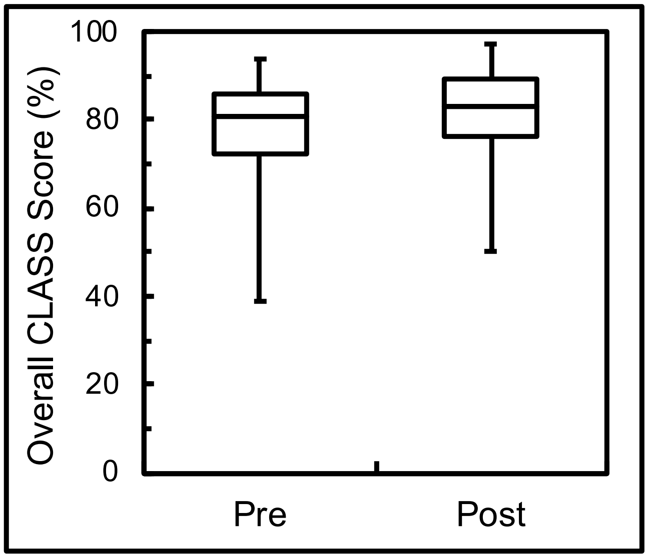

__Figure 1.__ Box plots comparing overall CLASS score for participants at the beginning (Pre) and end (Post) of the semester. The number of valid responses used for Pre and Post are 146 and 47, respectively.

ence in overall CLASS scores between the start and end of semester was not statistically significant ($p > 0.05$). However, in three categories – real world application, personal interest, and problem solving general – students showed statistically significant increases between pre and post surveys. Similar to previous results that reported the majority of student feedback about this YouTube pedagogy was positive, engaging students through YouTube pedagogy may be responsible for significant increases in learning attitudes associated with real world connection, personal interest, and problem solving aspects of engineering work.[16] In addition, team-based learning that students experience when creating YouTube problems may contribute to stimulating a higher connection of course content with real world scenarios that aligns with other findings.[35]

The effect of YouTube pedagogy on learning attitudes was quantified using normalized gains and Hedge's g effect size. Hedge's g effect sizes of about 0.2, 0.5, and 0.8 are often considered as small, medium, and large, respectively.[27] Participants interaction with YouTube pedagogy displayed small effect size gains ($g = 0.28$) in overall learning attitudes. Similar small effect size gains were measured in every subcategory within CLASS (Table 4). Participants showed 14% normalized gains in overall attitudes over the duration of the semester. Similarly, positive gains throughout the subcategories of CLASS were also displayed while the highest gains were measured in real world connection and personal interest, 54% and 70%, respectively (Table 4).

Relationship Between Engineering Learning Attitudes and Math Level

Correlation between prior math experience and engineering learning attitudes was measured (Figure 2). The four math courses required by most accredited engineering programs were considered, i.e. Calculus 1 to 3 and Differential Equations. Students with the greatest mathematics experience tended to align more with experts' beliefs, which is in agreement with previous studies where level of math preparation was identified to determine success and retention rates of engineering students.[29, 30] Positive attitude shifts between pre and post ($p > 0.05$) were measured for students who belong to each math level category. Overall, the most significant normalized gains (~20%) with medium effect size gains (Hedges $g = \sim 0.5$) in learning attitudes were measured for students who had completed the lowest (Calculus 1) and highest (Differential Equations) level of math. While literature suggests that students in engineering with low math level are prone to drop out due to low retention and motivation,[30] solving YouTube problems positively impacts students' attitudes, especially those with low math levels.

TABLE 4[11-12]

Pre and post mean CLASS scores for 146 and 47 participants at beginning and end of course, respectively.

Categories	Pre (%)	Post (%)	p	Normalized Gain	Effect Size (g)
Overall	78 ± 11	81 ± 9	0.09	0.14	0.28
Real world connection	87 ± 19	94 ± 13	0.02*	0.54	0.39
Personal interest	90 ± 16	97 ± 7	0.004*	0.70	0.49
Sense making/efforts	86 ± 17	91 ± 11	0.06	0.36	0.32
Conceptual connection	73 ± 24	79 ± 24	0.1	0.22	0.25
Applied conceptual thinking	60 ± 24	66 ± 25	0.1	0.15	0.25
Problem solving general	88 ± 15	93 ± 8	0.03*	0.42	0.37
Problem solving confidence	87 ± 19	90 ± 13	0.3	0.23	0.17
Problem solving sophistication	76 ± 25	82 ± 20	0.1	0.25	0.25

* indicates statistically significant differences ($p < 0.05$).

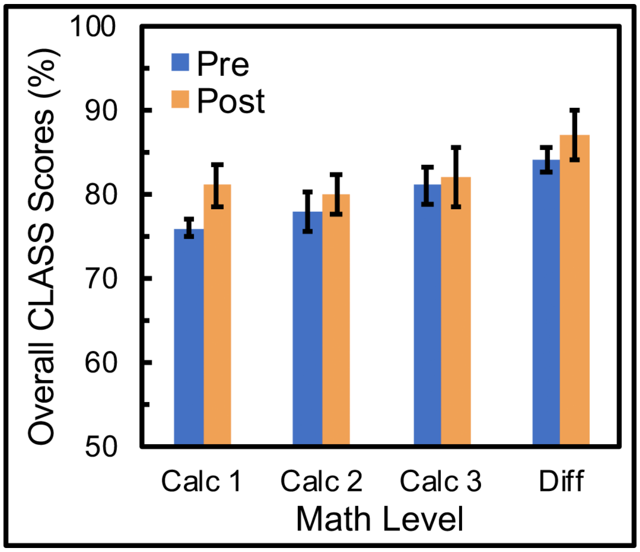

Figure 2. *Distribution of pre and post responses in Overall CLASS scores across students with varying prior math knowledge. Calc1= Calculus 1, Calc 2 = Calculus 2, Calc 3 = Calculus 3, Diff = Differential Equation. Error bars represent standard errors.*

CONCLUSION

Student-written problems[13-14] involving videos were implemented to replace traditional textbook homework problems. Previous studies demonstrated that YouTube pedagogy possesses potential for engaging and promoting students' problem-solving skills. However, changes in pedagogy may affect learning attitudes in addition to problem solving skills. Thus, the impact of replacing textbook problems with YouTube problems on learning attitudes was explored. An established survey, CLASS[15-16] was modified for engineering from physics, and the survey adopted to measure learning attitudes using a pre/post framework.

CLASS responses from two cohorts of students undergoing YouTube pedagogy revealed that the majority of students had positive attitudes at the start of the semester. By the end of the semester, attitudes toward learning chemical engineering concepts increased slightly in each category and the range of responses between students became smaller. Student attitudes measured in the current study were found to be higher than those in other studies, whereas measured gains were comparable to other studies. YouTube pedagogy contributed to positive normalized gains in attitude with a small effect size within a 15-week semester. Significant gains were recorded in three subcategories of CLASS: personal interest, relation to real world, and problem solving general. While the YouTube pedagogy could be directly related to gains in subcategories, such as relation to the real world, other active learning techniques were used in the course and may have also contributed to the positive attitude gains measured. In addition, math experience showed some correlation with learning attitudes and tended to be predictive of a larger shift in attitudes.

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APPENDIX

Supporting Information

TABLE S.1
Pre and post paired mean CLASS scores for 40 participants at beginning and end of course.

Categories	Pre (%)	Post (%)	p	Normalized gain	Effect size (g)
Overall	80 ± 8	82 ± 10	0.3	0.07	0.15
Real world connection	91 ± 16	95 ± 12	0.2	0.47	0.32
Personal interest	95 ± 11	96 ± 8	0.6	0.25	0.13
Sense making/efforts	90 ± 13	91 ± 10	0.7	0.14	0.13
Conceptual connection	78 ± 19	80 ± 23	0.7	0.08	0.08
Applied conceptual thinking	64 ± 21	67 ± 25	0.6	0.10	0.16
Problem solving general	92 ± 10	92 ± 8	1.0	0.04	0.04
Problem solving confidence	89 ± 14	89 ± 14	1.0	0.00	0.00
Problem solving sophistication	80 ± 20	82 ± 21	0.7	0.09	0.08

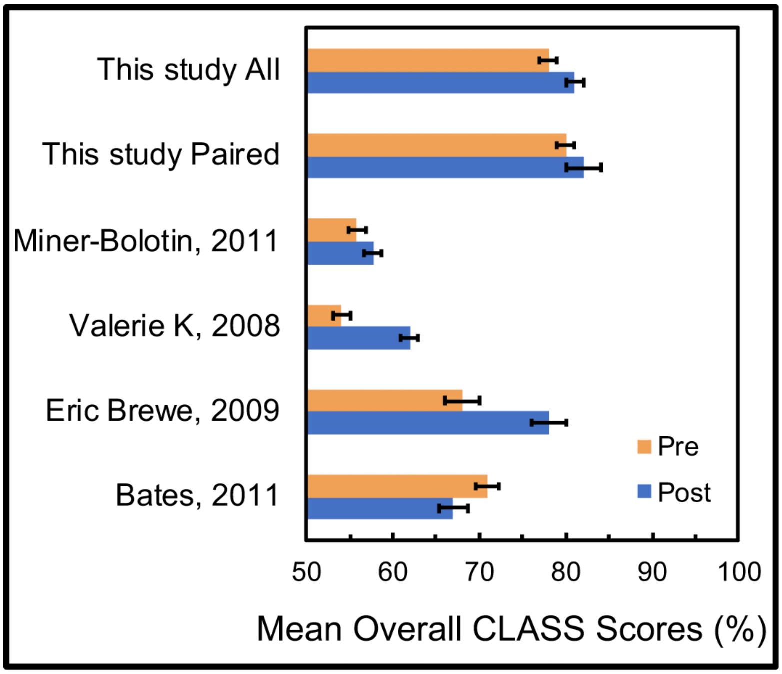

Figure S.1. Comparison of Overall CLASS responses for students undergoing YouTube pedagogy to other studies in literature that responded to CLASS-Physics. Error bars are standard errors.