Problem Solving When Using Student-Written YouTube Problems

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Abstract

Problem solving is a signature skill of engineers. Here, problem solving is employed when students apply course concepts to reverse engineer YouTube videos and solve new student-written, homework-style problems (YouTube problems). Replacing textbook problems with YouTube problems, this research focuses on examining the rigor of YouTube problems as well as students' problem-solving skills on textbook and YouTube problems. A quasi-experimental, treatment/control group design was employed and data was collected and evaluated using multiple measurement instruments. First, rigor of homework problems was examined using the NASA Task Load Index. Also, problem solving was assessed using a previously-developed rubric called PROCESS: Problem definition, Representing the problem, Organizing the information, Calculations, Evaluating the solution, Solution communication, and Self-assessment. PROCESS was modified to independently measure completeness and accuracy of student responses, as well as identify errors committed in material and energy balances. In the treatment group, students were assigned ten textbook problems and nine YouTube problems. While the control group obtained higher PROCESS scores at the beginning of the study, both groups exhibited similar problem-solving skills near the end. Also, the rigor of student-written YouTube problems was similar to textbook problems related to the same course concepts.

Introduction

In June 2018, over four billion people had access to the Internet, which represents about 55% of the world's population [1]. Almost all current undergraduate students began interacting with digital technology at a young age and today many everyday tasks revolve around utilization of devices such as cell phones, tablets, and computers. These students are often referred to as the Net generation, digital natives, or millennials [2]. Near instant access to course-related information, such as looking up unit conversions, finding physical properties, or verifying an equation, offer technology-savvy students some advantages in learning course content. Some learning differences are being identified between digital natives and past generations. In many cases, digital show a preference for visual compared to textual modes of learning, are strongly motivated by projects having a real-world component, and possess shorter attention spans [3].

Homework problems from textbooks allow students, especially in engineering, to practice problem solving. However, because solutions manuals are often available on the Internet, students can locate and copy the correct solution putting little effort into learning new material or developing problem-solving skills [4, 5]. Copying the solution manual solutions as a form of studying can inhibit success in a course [5]. Therefore, finding new ways to develop interesting and textbook-quality homework problems to both engage and educate digital native students is a central theme of this work.

Recent surveys predicted that between 2015 to 2020 more than 36% of jobs across all industries require complex problem-solving as a core skill [6]. Not only is complex problem solving relevant in workspace today, along with creativity and conceptual thinking, complex problem-solving skills are predicted to be the most prevalent type of skills to thrive in the workforce in 2030 [7]. Most instructional approaches limit students' ability to transfer learning by focusing on only course-specific information. Recent efforts to incorporate the Accrediting Board for Engineering and Technology (ABET) standards to emphasize problem solving and knowledge of current issues have found that infusing real world situations into engineering education helps students' understanding become more integrated [8, 9]. Therefore, tying engineering problem solving with real world environments aligns well with current and future workforce needs.

In addition to real world situations, senses play a vital role in learning. Vision trumps other senses in creating both short term and long-term learning [10]. Visual representation is an important part of successfully solving complex problems. Visual learning methods open new ways of problem solving, thinking, as well as enhance the education and practice of science and engineering [11-17]. In addition, the seemingly endless information on the Internet, and specifically YouTube videos, provide an array of contexts to connect engineering fundamentals to visual situations, which can be motivating and interesting. Therefore, the engagement and productive learning from searching for, identifying, watching, and translating YouTube videos ties in well with cutting-edge research in neuroscience and learning science [10, 18, 19].

Active learning and student-centered pedagogies lead to improved learning compared to traditional teacher-centric techniques, such as lecture [20-22]. Also, involving students' enthusiasm is advantageous to learning [23]. Pedagogies are adapting to current students' strengths by integrating their digital habits into the higher-education classroom. In fact, technology in the classroom is expected by many digital natives (e.g., clickers, tablets, just-in-time teaching, YouTube) [5, 14, 24-28]. Implementation of technology as a form of active learning is a useful approach because it connects students and learning [29, 30]. Therefore, engaging the current generation of students using technology, like YouTube, in a positive way is one motivation directing this project.

The YouTube pedagogy, discussed here, started as a way to introduce and engage students in thermodynamics and material and energy balance courses. Originally called YouTube Fridays, the first five minutes of Friday class sessions were dedicated to course related videos selected by a group of students. At the end of the semester, surveys showed that the vast majority of students felt they had better understanding of the field of chemical engineering from participating in YouTube Fridays [28]. In subsequent semesters, students selected YouTube videos and created engineering estimate problems related to the course material. Surveys showed that the majority of the students felt they had a better understanding of the course topic of thermodynamics, could relate thermodynamics to real world phenomena, and felt confident solving engineering estimate problems. The vast majority of survey feedback about YouTube Fridays was positive and provided students a mechanism to apply classroom concepts to open-ended, real world situations [24]. Since open-ended problems provide good practice of engineering fundamentals, replacing closed and dated textbook problems were the next evolution.

The YouTube pedagogy provides an alternate to professor-centric lectures, screencasts, and textbook problems. Here, the students are not required to create videos and rarely do; watching videos or generating a single video has shown little or no improvement of students' conceptual learning [31] The videos continue to be taken from YouTube or other websites in the public domain. Writing a YouTube problem involves small groups of students who reverse engineer a video to create a homework problem and solution.

Video title: How it's made - Crayons
Video link: http://www.youtube.com/watch?v=m5f7NuGkhX0

Problem Statement:
(60 Points)

As stated in the video a large scale factory can produce 30,000 crayons/hr. This problem focuses on a much smaller scale factory, "Liberatore's Colors." The feed to the reactor is 150 mol/hr. Within this stream, there is 60 mole percent steric acid ($C_{18}H_{36}O_2$), 33.75 mole percent paraffin wax ($C_{20}H_{52}$), and the balance is Dr. Liberatore's own secret ingredient, the catalyst, Liberatorium. The reaction proceeds as follows,

$$110\ C_{18}H_{36}O_2 + 49\ C_{20}H_{52} \rightarrow 74\ C_{40}H_{82} + 220\ H_2O$$

Dr. Liberatore's sixth or even seventh sense can just tell that the single pass conversion of steric acid is 72%. After the crayons are made, the excess reactants continue to a separator where water is completely removed from the system with a small amount of Liberatorium. The composition of this waste stream is 99.8 mole percent water, and the balance Liberatorium. The crayons leave the separator as product. The fresh feed to the system is combined with a recycle stream that leaves the separator and contains the excess steric acid, paraffin wax, and Liberatorium; which then gets fed to the reactor. The fresh feed contains steric acid, paraffin wax, and Liberatorium.

- (5 points) Label the PFD with the component molar flow rates of each stream.
- (37 points) Find the flow rate of each component in the reactor effluent
- (12 points) Find the flow rate of the fresh feed
- (6 points) Find the volumetric flow rate of the Product Stream in SCMM.

Figure 1. Student written reaction-recycle problem for material and energy balances course [32].

More recently, YouTube problems are a set of new homework-style problems formed by reverse engineering a video to apply course concepts and utilized in subsequent classes or future offerings of a course. A How It's Made video for crayons inspired an interesting homework problem for a reacting system with recycle (Figure 1). The problem statement is similar in length to the average textbook problem and includes a balanced chemical reaction, multiple parts/questions, and a process flow diagram, which was omitted from the figure. The idealized reaction and separation scheme are common for sophomore level problems. The crayon problem's final part asks for the volumetric flow rate of the product stream in standard units. Since the product is a solid (crayons), using standard temperature and pressure to compare volumetric flow rate reveals a misconception.

YouTube problems will be considered as an alternative to textbook problems. In this paper, the goal is to evaluate quality of YouTube problems and study how YouTube problems influence students' problem solving. Setup of the YouTube intervention will be introduced first, followed by description of tools used for evaluating student outcomes, and finally analysis and conclusions complete this paper.

Materials and Method

Previous studies created a YouTube pedagogy and presented various successful studies across several engineering courses [14, 24, 28, 32]. Over 400 student-written YouTube problems have been created in recent years [14, 24, 32]. While the writing is largely open ended, a small number of boundaries keep the students focused. The assignment is initiated by students watching

YouTube videos and selecting one to reverse engineer for the course. From the video, students write a course-related problem to be complete, correct, and appropriately difficult to assign as a homework problem for the course.

New research questions focus on examining the effects of student-generated YouTube problems on the development of problem-solving skills of students. The central hypothesis is that student-generated problems based on YouTube videos (YouTube problems) promote better problem-solving skills than traditional textbook problems. Therefore, research questions seek to examine the quality of problem-solving skills as well as the effects which solving YouTube problems have on students' problem-solving ability.

To answer these research questions, we employed a quasi-experimental, treatment/control group design (Table 1). Random selection and assignment were not considered due to only one section of the course offered per semester. A similar population of students studying the same course content and using the same text, but not employing the YouTube problem solving intervention, served as the control, thereby providing a quasi-experimental comparison design (Table 1). Cohort size was 90 students for the treatment group at a large public research university and 23 students for the control group at a private university. To balance sample sizes, we randomly selected ~30 students' work from the treatment group to participate in the study although all students completed all measures (Table 1).

Table 1. Summary of assignment of problems to the treatment and control group

Cohorts	YouTube Problems	Textbook Problems	Student Generated Problems	Students	Students scored
Treatment	9	10	1	90	30
Control	0	10	0	23	20

Faculty teaching the Material and Energy balance course at both institutions had previous experience teaching the course, and they collaborated to ensure similar content delivery and the same control homework problems. Both treatment and control groups were assigned other homework questions from textbooks or other sources in addition to the homework problems as part of the study. Homework problems assigned to students covered a wide range of topics in Material and Energy Balance course (Table 2). We considered two possible conditions — textbook homework (traditional homework problems) and YouTube problems. YouTube problems used in this study were written by previous students and assigned to current students as homework problems. Instructor selects the YouTube problems mapped to the course's content. Here, YouTube problems were implemented for three course topics, namely material balance with reaction, material balance with reaction and recycle, and material balance for multiphase systems (Table 2).

YouTube problems assigned as homework covered three broad topics in the course (Table 2). Each of the three topics were represented by three YouTube problems. Participants in the control group solved only textbook problems. For participants in the treatment group, homework assignments, normally 3 to 5 problems per week, varied between only textbook problems, only YouTube problems, and a combination of textbook and YouTube problems. During the initial weeks of the course, both groups solved only textbook problems as another measure of group equivalency. Since both treatment and control group use the same textbook [33], common problems were assigned, collected, and scored. During the weeks where both groups complete textbook-only assignments, we compared the effects of solving YouTube problems on students' problem solving in general and on identical problems.

Table 2. Number and type of homework problems assigned within certain topics of a material and energy balances course.

Topic	**Textbook**	**YouTube**
Non-reacting material balances	3	0
Material balances with reactions	1	3
Material balances with reaction and recycle	1	3
Material balances for multiphase systems	1	3
Energy balance	3	0
Transient	1	0

Students' problem-solving skills can be measured using a 7-stage rubric: Problem definition, representing the problem, organizing information, calculations, evaluating the solution, solution communication, and self-assessment (PROCESS). This tool, developed by Benson and collaborators, measures the conceptual skill and analytical skill required in the process of problem solving [34-38]. The PROCESS tool has been used in engineering courses and on problems based on real-world scenarios similar to YouTube problems [34-38]. PROCESS evaluates both problem-solving process and final solution.

PROCESS was modified to assess the problem-solving process for solved handwritten homework problems, which differs from its original use where participants solutions were collected on tablets and custom software to see erasing and other details [36, 38]. The tool was modified to suit material and energy balance problems. The modified PROCESS consists of a 6-stage rubric assessing: Problem definition, Representing the problem, Organizing information, Calculations, Solution completion and Solution accuracy. Each item in the revised PROCESS consists of four scaling levels ranging from 0 to 3 with zero being the minimum attainable score for each item. Any identification regarding group identity was removed prior to scoring and replaced with a project-assigned ID number to maintain privacy and to mask group membership from raters. All students' solutions were scored using the PROCESS rubric after the semester. Thus, PROCESS scores do not reflect or have an effect on students' course grades.

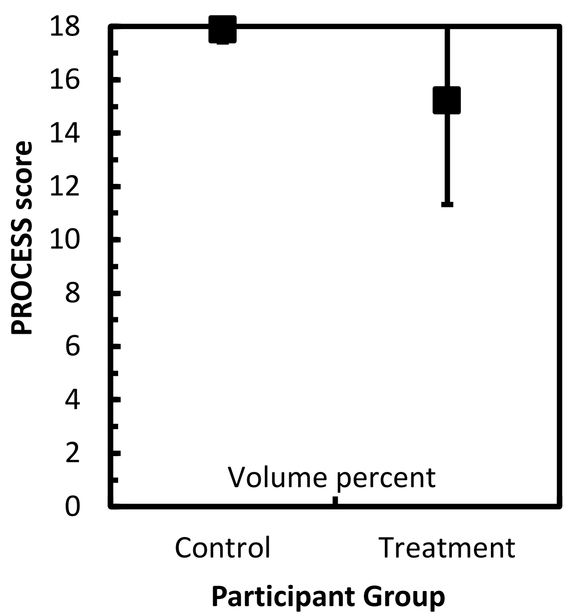
Raters' scores for a subset of student solutions were analyzed to determine how consistently raters measured student problem solving ability. Traditional statistical (Cohen's kappa) and item response measures (Rasch many facet model) of inter-rater reliability were computed for the five raters. The rater reliability assessment (discussed in detail in another conference presentation) was carried out in two rounds until raters' scores exhibited consistency and accuracy in assessing student problem solving ability. This reliability assessment enhanced the validity of using the PROCESS tool to score MEB problems.

The rigor of student-created problems compared to textbook problems was evaluated using the NASA Task Load Index (TLX). For over three decades, this tool has measured workload by assessing six constructs mental, physical, and temporal demands, frustration, effort on 6-point rating scale, where 1 is the least difficult and 6 being the most demanding [39-44]. For example, the NASA TLX can capture the length and difficulty of material and energy balance problems. Students completed the NASA TLX for all treatment and control problems discussed earlier.

Results and Discussion

To establish a baseline for comparison, we investigated the equivalence of the treatment and control group based on their problem-solving ability. Treatment and control groups completed three textbook problems early in the term. These problems were all non-reacting material balance problems. PROCESS was used to assess solutions of participants of both groups for the three problems completed near the beginning of the course (Figure 2).

PROCESS score ranges from 0 to 18; higher scores would be expected for less complicated problems, such as non-reacting material balances. The control group exhibited higher average scores than the treatment group (Figure 2). Furthermore, treatment group showed higher a standard deviation of than the control group (Table 3). Assessment before the YouTube intervention suggests better solving ability of the control group. Also, treatment group had higher standard deviation indicating a wider range of scores. To determine whether the difference in group problem solving was statistically significant, we used the independent t-test as a measure of equivalency. The small to very small p-values gives a p-value exhibit a statistically significant between the control and treatment groups. The difference will be more quantitatively accounted for during further studies.



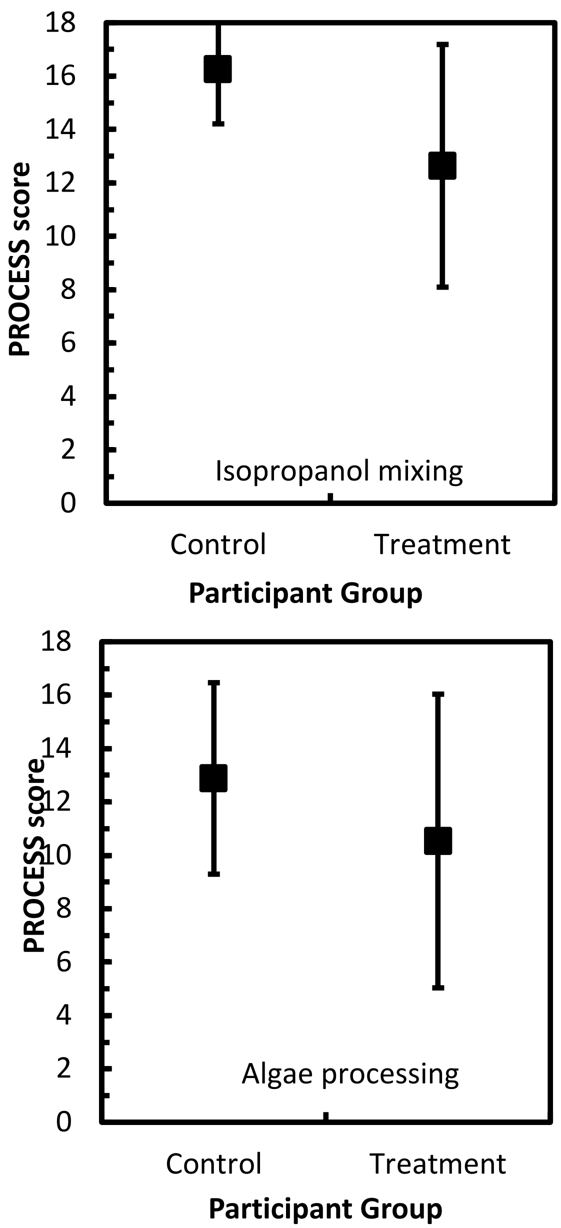


Figure 2. Average PROCESS scores versus participant group at the beginning of the study for three non-reacting material balance problems: (top) Volume percent, (middle) Isopropanol mixing, and (bottom)Algae processing. An average of 21 problems were scored for each participant group.

By the end of the study, the treatment group had completed nine YouTube problems while the control group completed only textbook problems. Two textbook problems involving energy balances completed by both treatment and control groups near the end of the study were considered (Figure 3). The control group displayed slightly higher average PROCESS scores than the treatment group (Figure 3). The treatment group also exhibited slightly wider range of scores with larger standard deviations than the control group. (Table 3). Additional t-tests found p-values of 0.52 and 0.27, which shows control and treatment groups have similar problem-solving ability.

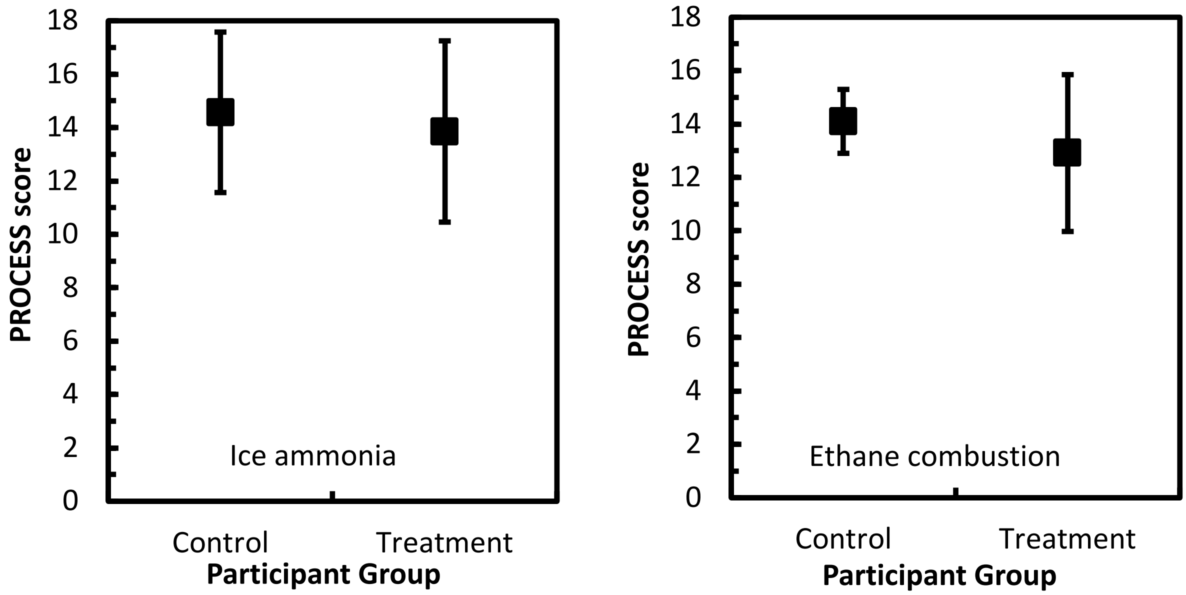


Figure 3. Average PROCESS scores versus participant group at the end of the study for two energy balance problems: (left) Ice ammonia and (right) Ethane combustion. An average of 22 problems were scored for each participant group.

Comparing average PROCESS scores in the beginning of the semester (Figure 2) to those at the end of the semester (Figure 3), it could be seen that the average PROCESS scores for both the treatment and the control group were lower near the end of the study. One possible reason is the difficulty of the topics. Throughout the study, the control group attained higher average PROCESS scores than the treatment group, which may be because control group was in their sophomore year while the treatment group's students were primarily freshman. The convergence of PROCESS scores between the two groups indicates that YouTube problems do not have a detrimental effect on students' problem-solving skills and may be beneficial in that the lower scoring treatment group gained sufficient problem-solving skills to eliminate the gap observed on the pre-tests. Additional scoring and a second annual cohort are being collected to more definitively answer these questions.

Table 3. Summary of PROESS assessment obtained at the beginning and end of study.

Time of study	Problem title	Group	Mean	SD	t	df	p
Beginning	Volume Percent	C	17.9	0.5	2.9	25	0.007*
		T	15.2	3.9			
	Isopropanol Mixing	C	16.3	2.0	3.6	46	0.0007*
		T	12.6	4.5			
	Algae Processing	C	12.9	3.0	1.8	51	0.07
		T	10.5	5.5			
End	Ice Ammonia	C	14.6	3.0	0.68	53	0.5
		T	13.9	3.4			
	Ethane combustion	C	14.1	1.2	1.25	31	0.27
		T	12.9	2.9			

*Indicates a statistically significant difference, C indicates Control group, T indicates Treatment group.

An examination of within group effect size changes provides another perspective on the effects of the YouTube problems on problem-solving ability. Hedge's g was used to calculate effect size changes and the pooled PROCESS scores and standard deviations were used (the average of three scores for the pretesting incidence and two scores for the post). The control group exhibited a negative, medium effect size change in problem-solving skill between the baseline problems and the later problems listed in Table 3 (Hedge's g = -0.67). The treatment group, on the other hand, realized a small, positive effect size gain (Hedge's = 0.16). While the students who completed YouTube, problems gained slightly in their problem-solving skill level, they at the least maintained the skill level they recorded earlier on the easier problems. The control group, however, once faced with more rigorous problems, actually decreased in their problem-solving skill level. This suggests that the YouTube problems could be contributing to long term, positive effects on student problem-solving ability.

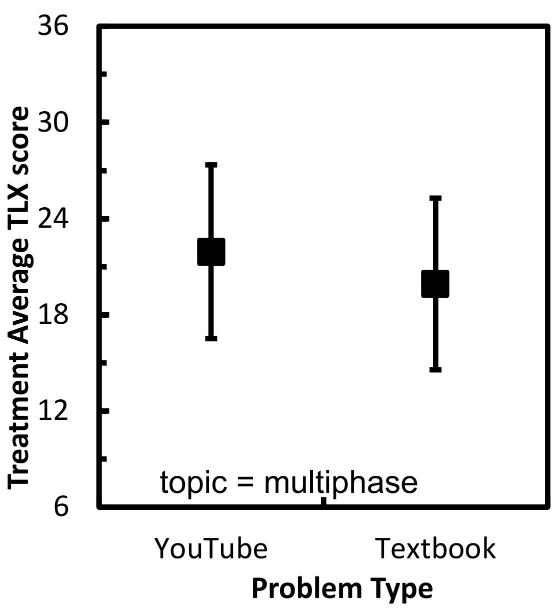


Figure 4. Average TLX score versus problem type for multiphase problems. An average of 47 responses were aggregated for each problem type.

The NASA TLX measures difficulty on 6 categories with subscales from 1 to 6 resulting in an aggregate rating between 6 to 36. More demanding tasks earn higher scores. The difficulty of YouTube and Textbook related to multiphase system finds little difference (Figure 4). Participants in the treatment group rated YouTube problems to be slightly more difficult than textbook problems (Figure 4). A t-test yielded p-value of 0.08 and t-value of 1.8 indicating negligible difference in difficulty between YouTube and Textbook problems. All nineteen problems will be compared and presented in a future study.

Conclusion

In summary, homework-style, YouTube-inspired problems have been implemented in an undergraduate course in material and energy balances. Example problems as well as responses and evaluation have helped measure the effect of YouTube problems on students' problem-solving skills. An established rubric called PROCESS was revised to match the specifics of this study and implemented to assess problem-solving ability across problems and groups. Analysis from PROCESS the at the beginning of the study indicates better problem-solving skills for participants in the control group, suggesting group inequivalence on the variable in question. However, after YouTube intervention, the treatment and control groups exhibited nearly equivalent problem-solving skills on two problems near the end of the study. In addition, NASA TLX measured the rigor of both YouTube and Textbook problems indicated a similar rigor for both problem types. Data presented for this paper represented were collected for the first year of YouTube intervention and similar intervention is being carried out for the second year. Further studies will account for disparity of participant groups.

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