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Problem Solving and Difficulty Perception in YouTube Problems Involving Reacting Systems with Recycle

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Problem Solving and Difficulty Perception in YouTube Problems Involving Reacting Systems with Recycle

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Abstract

Complex problem-solving is a vital skill prevalent to thrive in the workforce along with creativity and conceptual thinking. Homework problems allow engineering students to practice problem solving and writing new problems can be a creative process for students. Our previous research found that implementing alternative, student-written homework problems, referred to as YouTube problems, led to better learning attitudes. YouTube problems are course related; homework-quality problems generated by reverse engineering publicly available videos. Comparing learning experiences of students solving YouTube versus Textbook problems is the focus of the current study. Impacts of solving YouTube problems are examined based on perception of difficulty as well as students' problem-solving skills displayed by students. To enable testing, students were assigned one textbook and three YouTube problems. Perception of problem difficulty across problems was examined using the NASA Task Load Index. Additionally, problem solving aptitudes while solving homework problems was assessed using a previously validated rubric called PROCESS: Problem definition, Representing the problem, Organizing the information, Calculations, Solution completion, and Solution accuracy. A new case study compares Textbook and YouTube problems related to reacting systems with recycle, which is one of the most difficulty course concepts. A correlation between problem rigor and problem solving was found.

1. Introduction

Textbook homework problems allow students, especially in engineering, to practice problem solving, which is a critical skill across industries [1]. However, the online availability of solution manuals to textbook problems has intensified questions about faithful completion of assigned coursework [2]. Access to solution manuals on web sites, such as Chegg and Course Hero, can cause significantly harm in the development of students' problem-solving ability [3]. In fact, many students do not consider copying homework from a solution manual as a form of cheating [4].

Students prefer visual learning methods over text in many situations, and projects with a real-world aspect are highly motivating also. [5]. Moreover, visual learning methods open new ways of problem solving and thinking, as well as enhance the education and practice of science and engineering [6-9]. The seemingly endless information on the Internet, and specifically YouTube videos, provide an array of contexts to connect engineering fundamentals with 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 [10-12].

YouTube pedagogy aligns with other authentic instructional approaches that allow students to explore, and meaningfully construct concepts that involve real-world problems [13, 14]. YouTube pedagogy is built on constructivist theory that is hypothesized to promote cognitive processes and offer students opportunity to construct learning ideas based on events in a video and provides solutions to the engagement challenges experienced by instructors. [15]. With high adaptability in variety of subjects, students have affirmed better understanding and improved course connection with real-world resulting from YouTube pedagogy [16, 17].

The YouTube pedagogy uses videos that are accessible in the public domain, and students create novel problems that elucidate engineering concepts [7, 17, 18]. Student-written problems are called YouTube problems that are initiated by students selecting a YouTube video to reverse engineer. 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. Thus, the YouTube pedagogy creates new problems that can significantly mitigate the issue of the solution manual dilemma.

Student-written YouTube problems fall under a category of contextual problems that possess the potential of improving learning outcomes [19, 20]. In previous implementation where solving YouTube problems substituted homework from textbook, students recorded improved learning attitudes [21, 22]. YouTube problems are qualitatively similar in content with textbook problems and could be administered as in class, homework, quiz, or exam problems. This study is limited to deployment of YouTube problems as homework pertaining to reacting systems with recycle — a topic in Material and Energy Balances course.

2. Methodology

2.1 YouTube Problems

The YouTube pedagogy was implemented in a Material and Energy Balances course, which is an introductory freshman/sophomore-level course in most chemical engineering programs. While many problems that were not part of the current study were completed by students, we considered only problems covering the topic of reacting material balances with recycle. Homework problems considered consisted of three YouTube problems written by previous students and one problem from textbook. The analysis constituted of set of 55 students randomly selected from a public university across two years.

2.2 Assessing Problem-Solving Ability using PROCESS

Problem solving skills displayed while students completed the four homework problems considered were measured using a modified PROCESS rubric consisting 6 stages: Problem definition, Representation, Organization, Calculations, Solution completion and Solution accuracy [18, 22]. Modified PROCESS is a slight variation of the original version which assessed solution on tablets while a custom software used to detect erasing and other details during problem solving [23, 24]. PROCESS was tailored to incorporate relevant steps needed to solve material and energy balance problems [22]. Each of the 6 items in the revised PROCESS consists of four scaling levels ranging from 0 to 3 with zero being the minimum attainable score. PROCESS score is an aggregate of scores earned in all 6 items of PROCESS rescaled from 0 to 100.

Prior to scoring with the modified PROCESS, anonymity of students was maintained by replacing participants' names with a project-assigned ID number. In addition, assessment with PROCESS rubric was conducted after the semester does not reflect or have an effect on students' course grades. To eliminate rater bias during assessment, an interrater reliability was conducted across raters prior to scoring and detailed in a previous paper [25].

2.3 Assessing Problem Difficulty with the NASA TLX

In the case of problem solving, researchers must know how difficult the problem is in order to make a valid assessment of performance, i.e., comparing performance across problems, problem types, and participants. NASA TLX (Task Load Index) provides an appropriate gauge of problem difficulty [26-30]. NASA TLX measures workload by assessing six constructs: three measuring demand put on the participant by the task, and three measuring stress added by the participant as a result of interacting with the task. The three measures of task demand are mental demand, physical demand, and temporal demand while stress measures include effort, performance, and frustration.

Students' NASA TLX rating for each problem were utilized as a measure of rigor [31]. Each of the 6 constructs in NASA TLX had a 6-point rating scale, where 1 is the least difficult and 6 the most demanding. To ease analysis, aggregated NASA TLX was from 0 to 100 where more demanding problems were rated higher scores. Difficulty of a problem was assessed by averaging participants TLX scores for each problem.

3. Results

YouTube pedagogy is a constructive learning process involving visuals. The core hypothesis is that student-generated YouTube problems facilitate improved problem-solving skills when compared to conventional Textbook problems. Assessing the efficacy of YouTube problems involving reactions with recycle addressed two primary research questions:

1. Does solving YouTube problems improve students' problem-solving skills compared with solving problems from textbooks?
2. Are YouTube problems and Textbook problems involving reactions with recycle perceived by students to be equally as rigorous?

3.1 Problem-Solving Ability

First, problem solving exhibited in handwritten homework solutions were assessed by multiple raters using the PROCESS rubric. Throughout this paper, YT1, YT2 and YT3 represented YouTube problems, and TB was the Textbook problem. PROCESS scores earned by students were compared across 4 problems via a two-tailed t-tests and significance criteria of $p < 0.05$.

Table 1. PROCESS scores for 1 textbook (TB) and 3 YouTube problems.

Pair	YouTube	Textbook	p
YT1-TB	92 ± 9	80 ± 21	0.0002*
YT2-TB	89 ± 12	80 ± 21	0.01*
YT3-TB	84 ± 14	80 ± 21	0.4

*denote statistically significant differences

For two YouTube problems, YT1 and YT2, PROCESS scores earned were significantly higher than score earned in TB (Table 1). One possible explanation is that YouTube problems involve real world situations, which has been related to better learning outcomes in other studies [19, 20]. The visual aspects of YouTube problems which enhance learning attitudes and help students understand better may also be contributing factor to better problem solving [17, 21, 32].

Ranking the individual stages of the PROCESS found consistency between YouTube and Textbook problems involving to reacting systems with recycle. Solution accuracy was the most difficult item (Table A.1). Solution accuracy likely registered the lowest scores, since any incomplete or incorrect steps in earlier stages of problem solving, such as Organization or Calculations, propagated.

3.2 Problem Difficulty with NASA TLX

NASA TLX surveys were collected and analyzed for the four problems of interest. Although mean NASA TLX scores differed by problem, no statistically significant differences between mean scores recorded between the three YouTube problems (YT1, YT2, and YT3). However, when comparing the Textbook (TB) to YouTube problems, students reported a substantially higher NASA TLX scores for the Textbook problem (Table 2). Finding the rigor of Textbook problems higher for reaction with recycle topic initiates exploring all of the Textbook and YouTube problems regardless of course topic and concepts.

Table 2. NASA TLX scores for 1 textbook and 3 YouTube problems.

Pair	YouTube	Textbook	p
YT1-TB	47 ± 18	63 ± 15	0.0001*
YT2-TB	51 ± 17	63 ± 15	0.001*
YT3-TB	53 ± 16	63 ± 15	0.003*

*denote statistically significant differences

All YouTube and textbook problems regarding reaction with recycle had the same order of importance for each item in the NASA TLX (Table A.2). In addition, across all four problems, item analysis defined mental demand and effort as the most significant factors contributing problem rigor. Physical and temporal demand were among the least significant categories, as anticipated, since completing tasks required less physical exertion and adequate time – around one week was allotted for each homework assignment.

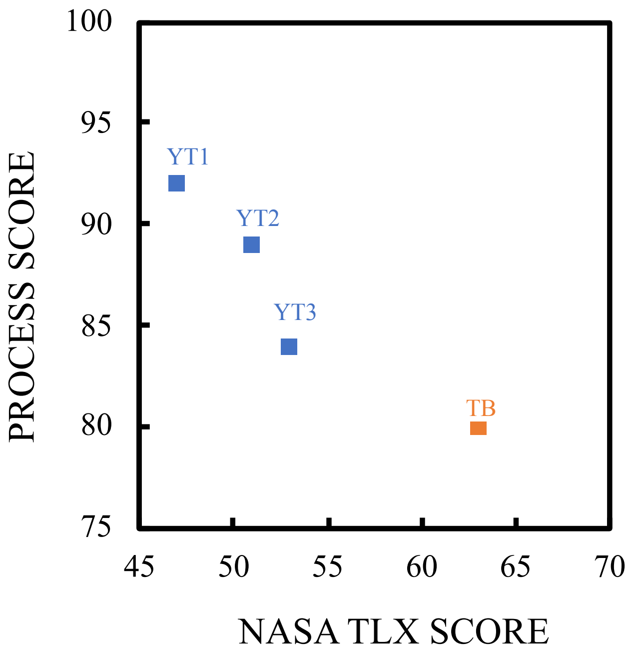

Figure 1. Relationship between PROCESS and NASA TLX scores for YouTube and Textbook problems.

A negative correlation between mean PROCESS and NASA TLX scores recorded across all homework problems completed. Students earned lower PROCESS scores in problems that were rated with higher NASA scores (Figure 1). NASA TLX - PROCESS correlations Reaction with recycle problems yielded a strong Pearson coefficient (r = -0.94). Overall, findings reveals that higher perceived level of difficulty of problems lead to lower performance, which is logical [33].

4. Conclusion

In an undergraduate Material and Energy Balances course, YouTube-inspired, student-written problems were assigned and solved by two cohorts. Here, the homework problems addressed specific course concepts related to reacting systems with recycle. Four reaction with recycle problems — one from the textbook and three from an archive of student-written YouTube problems — were used to assess students' perceptions of problem difficulty and problem solving.

An established problem-solving rubric, PROCESS was implemented to assess students' handwritten solution. When 55 students solved YouTube problems, their problem-solving abilities were found to be statistically higher or comparable to those shown for the textbook problem. Solution accuracy stage in PROCESS was identified as the most difficult item compounding from missing or incorrect steps at earlier stages.

Rigor of problems was assessed using NASA TLX through 6 constructs. Participants reported a substantial difference in rigor between YouTube and textbook problems in their overall scores. Similar to previous work, item analysis identified mental demand, effort, and frustration as the most significant factors to problem difficulty in solving MEB problems. In addition, a negative correlation was measured between problem solving ability and perception of problem difficulty.

Students' YouTube problems may easily be applied in other courses and fields as part of a classroom project or as a substitute for conventional homework problems. Replacing textbook problems with YouTube problems may help instructors tackle the issue of solution manual dilemma. Future work will compare problem solving across all problems and both cohorts.

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Appendix

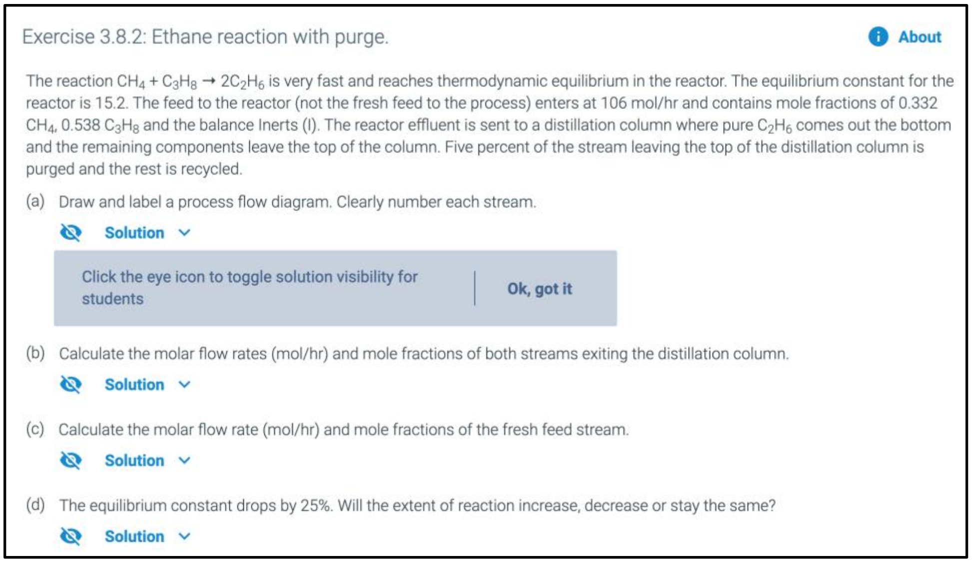
YT1. CO2 Hydrogenation to Methanol
https://www.youtube.com/watch?v=GzjpmmtGBqU
Carbon dioxide is hydrogenated to produce methanol and water. Balanced equation:
$CO_2 + 3H_2 \rightarrow CH_3OH + H_2O$
The initial stream entering the system contains hydrogen and carbon dioxide. A feed stream is sent to a reactor. The total flow rate of the feed stream is 200 mol/s, and the mole fraction of carbon dioxide is 0.259 with a balance of hydrogen. The effluent stream contains carbon dioxide, hydrogen, water, and methanol. This stream is sent to a separator where methanol and water exit as product. Carbon dioxide and hydrogen are then recycled and sent back the feed stream. The single pass conversion of CO_2 is 82%. Round all answers to 3 sig figs.
a.) Label and number the streams of the process flow diagram. (Methanol=M, Water=W, Hydrogen=H, Carbon dioxide= CO_2)
b.) What is the component molar flow rates of the reactor effluent stream (mol/s)?
c.) What are the component flowrates of the stream entering the overall system?
d.) If the fractional conversion of CO_2 decreases what happens to the mole fraction of Hydrogen entering the overall system?
Increase Decrease Stay the same

YT2. Carbon Dioxide reacted to form Pure Methanol
http://www.youtube.com/watch?v=i5SqwSU8ns4
Petroleum can be produced from pure methanol. Before this process can take place, methanol must be produced. Typically, this is done from fossil fuels, but a more ecological method is reacting Carbon Dioxide (CO_2) and Hydrogen gas (H_2) to form Methanol (CH_3OH) and Water (H_2O). For this to happen, a fresh feed stream of gases containing CO_2 and H_2 is mixed with a recycle stream and sent to a reactor. The stream flowing into the reactor contains 98.5 mol/hr CO_2 and 115% excess H2. The single pass conversion of CO_2 is 72.1%. The reactor effluent which contains CO_2, H_2, CH_3OH, and H_2O is sent to a distillation column. All the methanol is removed in one stream and all other components are removed in a separate stream. This stream is split into a recycle and a purge. The purge stream contains 25% of the H_2 and CO_2, and 100% of the H_2O. The recycle stream is mixed with the fresh feed going into the reactor.

a) Draw and label a PFD and write a balanced chemical equation. Number the streams and label all the species in each stream.
b) Determine the component molar flow rates of the components exiting the reactor (mol/hr)
c) Determine the molar component flow rates of the recycle stream and the fresh feed stream (mol/hr)
d) If the percent excess H_2 is decreased to 50% and all else stays the same, how will the overall conversion of H_2 change?
Increase Decrease Stay the same

YT3. 100 Tons of Dynamite
https://www.youtube.com/watch?v=I98YuLvTsAs
Jimmy works for DynoWorks and is tasked with a controlled explosion of 100 tons of dynamite. First Jimmy must produce the nitroglycerine. Nitroglycerine ($C_3H_50_3(NO_2)_3$) is made by reacting glycerol ($C_3H_80_3$) with nitric acid (HNO_3) in the presence of sulfuric acid (inert) according to the equation below.
$C_3H_80_3 + HNO_3 \rightarrow C_3H_50_3\ (NO_2)_3 + H_20$
The single feed to the reactor (not the fresh feed) is 100 tons/hr and is 49 wt% glycerol (MW 92 g/mol), 36 wt% nitric acid (MW 63 g/mol), and 15 wt% sulfuric acid (MW 98 g/mol). All the glycerol is consumed in the reactor. The single pass conversion of nitric acid is 0.65. The single stream exiting the reactor is passed through a separator into three streams, nitroglycerine exits as the product stream, water exits as a waste stream, and another stream containing the remaining components. 10% of the stream exiting the separator containing sulfuric acid and nitric acid is purged. The recycle stream is mixed with a fresh feed of glycerin, nitric acid, and sulfuric acid.
a) Draw and label the process flow diagram, number the streams, and label the species in each stream.
b) Determine the component molar flow rates (kmol/hr) of the stream exiting the reactor.
c) Determine the component molar flow rates (kmol/hr) of the recycle stream and the fresh feed stream.
d) If the single pass conversion of nitric acid decreases by 5%, does the molar flow rate of nitroglycerine (circle one):
Increase Decrease Stay the same

Figure A.1 Problem statements for Reacting systems with recycle topic 3 YouTube problems (YT 1 -3).



Exercise 3.8.2: Ethane reaction with purge.

About

The reaction $CH_4 + C_3H_8 \rightarrow 2C_2H_6$ is very fast and reaches thermodynamic equilibrium in the reactor. The equilibrium constant for the reactor is 15.2. The feed to the reactor (not the fresh feed to the process) enters at 106 mol/hr and contains mole fractions of 0.332 CH_4, 0.538 C_3H_8 and the balance Inerts (I). The reactor effluent is sent to a distillation column where pure C_2H_6 comes out the bottom and the remaining components leave the top of the column. Five percent of the stream leaving the top of the distillation column is purged and the rest is recycled.

(a) Draw and label a process flow diagram. Clearly number each stream.

Solution

Click the eye icon to toggle solution visibility for students | Ok, got it

(b) Calculate the molar flow rates (mol/hr) and mole fractions of both streams exiting the distillation column.

Solution

(c) Calculate the molar flow rate (mol/hr) and mole fractions of the fresh feed stream.

Solution

(d) The equilibrium constant drops by 25%. Will the extent of reaction increase, decrease or stay the same?

Solution

Figure A.2 Textbook problem statement completed for Reacting systems with recycle topic (TB)

Table A.1 Difficulty ranking of items in PROCESS across problems

Items	TB	YT1	YT2	YT3
P (Problem Identification)	5	4	5	6
R (Representation)	6	6	5	5
O (Organization)	3	3	3	3
C (Calculation)	2	2	2	2
S (Solution Completion)	4	4	4	4
S (Solution Accuracy)	1	1	1	1

Table A.2 Components of NASA TLX ranked in order of significance

Items	TB	YT1	YT2	YT3
Mental Demand	1	2	2	2
Physical Demand	6	5	4	4
Temporal Demand	4	4	5	5
Performance	5	6	5	6
Effort	2	1	1	1
Frustration	3	3	3	3