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Work in Progress: The Effects of Representation in Worked Example Videos

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Introduction:

This ongoing work seeks to examine the idea of role modeling through worked example videos in an open educational resource, and to observe its effect on the retention of women and students of color in engineering. Engineering has long struggled with the recruitment and the retention of underrepresented groups. Though there is significant literature examining why women and students of color either leave engineering degree programs or simply don't choose to pursue engineering degrees in the first place, the problem of underrepresentation of these groups in engineering has persisted for decades.

The idea for this work was born out of a need to expand the worked problem set, including worked problem videos, as part of the lead author's open educational resource for engineering statics and dynamics. By including a diverse set of students as the problem solvers in the videos used in class, the author would not only get some help expanding the tool, but also do so in a way that expanded the diversity of possible role models that the students were exposed to as part of their class experience. The rest of the paper explores the theoretical foundation of the project, the methodology used, some preliminary assessment results, and the future avenues of research for the project.

Background and Literature Review:

<u>Open Educational Resources and the Mechanics Map Project:</u>

The line of research discussed in this paper was born out of a necessary expansion of the Mechanics Map Project [1], an online resource for engineering statics and dynamics. With more that ten years of development, the Mechanics Map is a website that aims to serve as a complete web-based textbook for the engineering statics and dynamics courses containing written explanations, video lectures, worked example problems with both written and video solutions, and a full set of available homework problems with solutions available for instructors. The resource is used at some level in more than two dozen classrooms each year across the globe, and averages about 5000 visitors every week.

Licensed under a Creative Commons Attribution Share Alike license (CC BY-SA 4.0), the Mechanics Map is free to use for anyone with an internet connection for access and use, and allows for anyone to modify, repurpose, or share the content so long as they also license their derivative work under a similarly permissive license. The aim of the resource is to serve as a quality open educational resource for engineering mechanics courses.

According to Creative Commons:

> *Open Educational Resources (OER) are teaching, learning, and research materials that reside in the public domain or have been released under an open license that permits their free use and re-purposing by others* [2].

The project is part of the larger open education movement, pushing to improve the access and affordability of education using openly licensed educational content. Along these lines, the use of OER in the classroom has been shown decrease DFW rates (that is the rates of students receiving Ds, Fs or withdrawing) among Pell Eligible student populations in those classrooms [3]. In this way, OER can push forward DEI goals by removing the “pay to win” element that can be present in classrooms requiring expensive commercial textbooks or supplemental materials.

Belongingness in Engineering:

Engineering has long been a field dominated by white men. For example, in 2017, the National Science Foundation estimated that women only represented about 16% of the engineering workforce, despite representing about half of the college educated workforce as a whole [4]. Looking to both black and Hispanic populations, we can observe similar trends, where their representation in engineering is significantly below their representation in the broader college educated workforce. Additionally, in the university setting, women and students of color have been shown to have lower retention rates than their white male counterparts [5].

The reasoning behind why women and students of color leave engineering at a higher rate is of course complicated and varied, but many studies have pointed to a lack of perceived belonging within the engineering community as a factor that is driving out both women and students of color [6]–[8]. Belonging fits in as part of the larger idea of identity, where both professional factors (such as grades and feedback from faculty) as well as personal factors (such as gender and race) play into the identity and sense of belonging for the student [9]. In the context of engineering programs, many women and students of color will simply have fewer examples of people that share key aspects of their identity, which can lead to a sense in these students that they do not belong in engineering.

The Importance of Role Models:

Related to the idea of belonging is the idea of the role model. A role model is someone that a student can relate to and who they can seek to emulate. One of the key elements of a role model is that they share some element of their background with the student, and it’s been shown that having women or people of color available as role models increases the retention rates of those groups in STEM subjects [6], [10], [11].

While ideally the faculty body in engineering programs would provide ample role models for women and students of color, the reality is that the faculty in engineering programs generally reflect the profession, which is itself dominated by white men. Pushes to diversify the faculty body are certainly commendable, but faculty turnover is generally slow, and it will take significant time before the faculty body is representative of the general population even if progress is being made.

Smaller programs in rural areas, such as the one in which the author teaches, can further exacerbate these issues if there are no women and/or no faculty of color at all represented in the engineering faculty body at a program. Compounded with the fact that students may often be the only woman or student of color in the class, and these environments can be particularly isolating for underrepresented students.

Methods:

At the time of the start of this project, the author of the paper was looking to improve the Mechanics Map and student feedback indicated that the top priority was the expansion of the worked problems sets, including a greater variety of worked problems. With this expansion, the author would need to come up with new problems, develop written solutions, and finally develop new worked example videos that went through the process of solving those problems. That last task of developing the new videos, is the most time consuming of the three elements, but it also represented an opportunity to try out something new and to ask research questions that could impact future development of the tool. Those research questions are as follows

1. Does the perceived identity of the presenter have any impact on the sense of belonging of the student watching the video?
2. Can the presenter in this video serve as a role model to help promote a greater sense of belonging among underrepresented groups in the classroom?

Before the start of the project, lead author, who is a white male, had personally recorded the vast majority of the worked problem example videos as well as the video lectures. In the collection of existing worked example videos, some consisted of the instructor working out problems on a white board, while others were simply a screen capture with voiceover explanations. Both formats included audio explanations, but the instructor was only visible in the white board style videos. The author has been using the open textbook as the basis for a flipped classroom, so students in the statics and dynamics classroom would watch the videos on a regular basis as part of the class. As part of a regular exercise to gather student feedback on the tool, the author had identified the need for more worked examples across the entirety of the textbook.

The simplest way to expand the tool would have been for the author to simply create new problems, come up with the solutions, and record the videos himself, but this expansion also represented a possible opportunity to diversify the representation students were getting as part of the course. The instructor teaches at a small campus in a rural area, where the diversity of the faculty is limited. The author wrote a small proposal to pay for undergraduate student assistance, focusing on recruiting a diverse set of undergraduate students to solve the problems in the videos, and to see if this had any effect in the classroom.

Developing the Worked Example Videos:

After having the proposal funded, the author began the process of recruiting students to help with video creation. The students recruited for the project were students that had completed engineering statics and dynamics with As or Bs, with the group of students consisting of at least 50% women and at least 50% underrepresented racial groups. In the end, the author was able to recruit a group of seven students that fit this criterion through a combination of past students of the instructor himself and from referrals from other mechanics faculty.

With the students recruited, the author set out creating problems and written solutions for the students to record. The students were invited to also come up with worked problems of their own, but no students ended up creating their own problems, so all problems ended up being instructor generated. It is hypothesized that using the instructor generated problems was simply the path of least resistance for the student workers, and that specifically assigning problem generation, rather than simply making it an option, would be needed to get student generated problems in the mix in the future.

For the worked example videos, the students were recorded on video solving problems on a wall mounted Microsoft Surface Hub. This setup was similar to the white board setup used by the instructor initially, where the person solving the problem is visible on camera. However, the Surface Hub allowed for tablet computer like functionality in scrolling, zoom, and in copying and pasting. This setup was chosen over a screen capture setup the instructor had used for more recent videos, as it was hypothesized that having the student faces visible would make student identity a more visible part of the video.

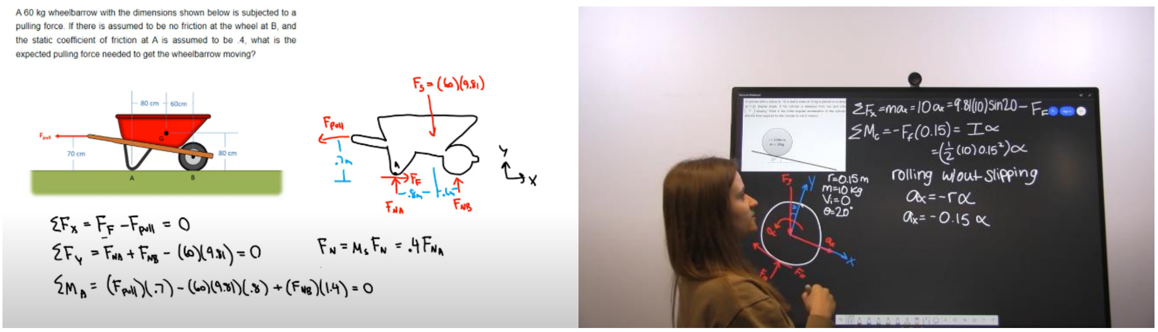


Figure 1: Example screenshots of an instructor generated screen capture video (left) and a student generated Surface Hub video (right)

Over the course of the 2021-2022 academic year, the instructor and students were able to add a total of 42 worked example videos to the Mechanics Map. By Fall 2022 the full set of problems was incorporated into the instructor's classes.

Though the student team included at least 50% women and 50% students from underrepresented racial groups, not all students on the project produced an equal number of videos. In fact, there were two students, both women, who produced more than 80% of the new videos. Most of the rest of the group only produced a handful of videos before becoming busy with other obligations. Unfortunately, high achieving students often have very busy schedules. This led to the representation of students in the videos being almost entirely women, but less than half of the videos were produced by students of color. For this reason, as well as for reasons discussed later, the author decided to focus on the belongingness of women, rather than the belongingness of racial minorities. In future work, the author hopes to be able to address both groups, as was originally intended.

<u>Deployment in the Classroom:</u>

The author offered a single section of engineering statics during the fall 2022 semester that served as the preliminary data gathering period to evaluate the project. The course enrolled 15 students total, including three Caucasian women and one African American male (all other students were white men). The instructor teaches the class using a flipped classroom model, having students read a section of the online textbook and take a short quiz before class. The videos that were developed were included as part of this pre-class preparation. During the class, the instructor starts with a single overview slide, and allows for any general questions. After that, students have time to work on homework problems, with 1-3 problems being relevant to any one day's reading. Students are encouraged to work in groups, and the instructor is available to assist students as they work on the homework problems.

Over the course of the semester, students in the statics classroom were exposed to 31 of 42 new problems developed, which is why the evaluation focused on statics rather than dynamics. In particular, one new chapter was added to statics on internal forces, and all worked example videos covered during the one-week period were done by the student group.

Survey Instrument:

A short, anonymous survey was developed by the instructor designed to gauge the usage patterns of the tool in the classroom, as well as to gauge aspects of student sense of belonging in the class. This instrument did ask about gender, but did not ask about race, as that would de-anonymize the results with only a single non-white student. The complete survey instrument is included in Appendix A.

The survey was offered by the instructor to the students in classroom at the end of the internal forces section, which included entirely student generated videos. This timing was chosen as it was believed the student generated videos would be fresh in everyone's mind.

As per IRB guidance, the survey was distributed with a script indicating that participation was voluntary, anonymous, and would not impact student grades in any way. As consent forms could not be collected with the anonymous nature of the survey, filling out the survey indicated consent, while returning a blank survey indicated non-consent to participation. 12 of the 15 students in the class returned the completed survey, with a survey completion rate of 80%.

Results and Analysis:

The first question in the survey asked students the amount of time spent using the tool per week. Results are summarized in Figure 2, and generally indicate that students were using the tool as intended.

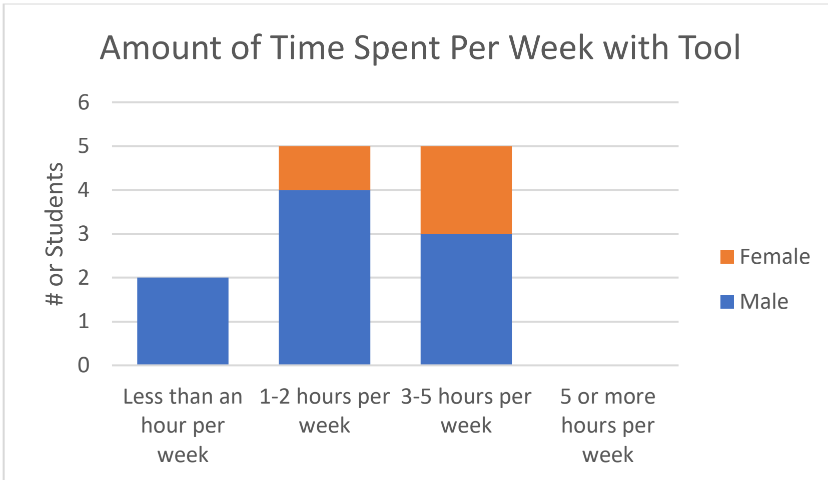
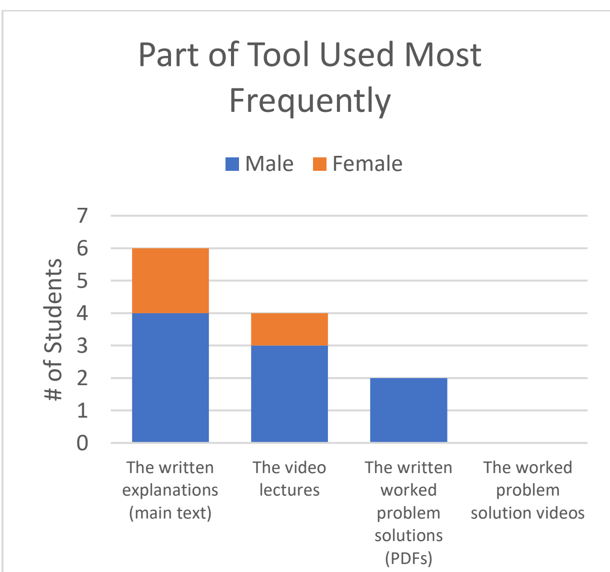


Figure 2: Student Responses to the Question: "Please estimate the amount of time per week that you spend looking through and using the Mechanics Map. This includes text and videos included in the tool and includes any time you spend using the tool during problem solving in class."

Results in the figure are broken down by gender, as they will be for all questions, though there is no clear pattern in the results by gender. With responses to this item, it can be seen that the majority of the students did spend at least a few hours a week using the tool as intended.



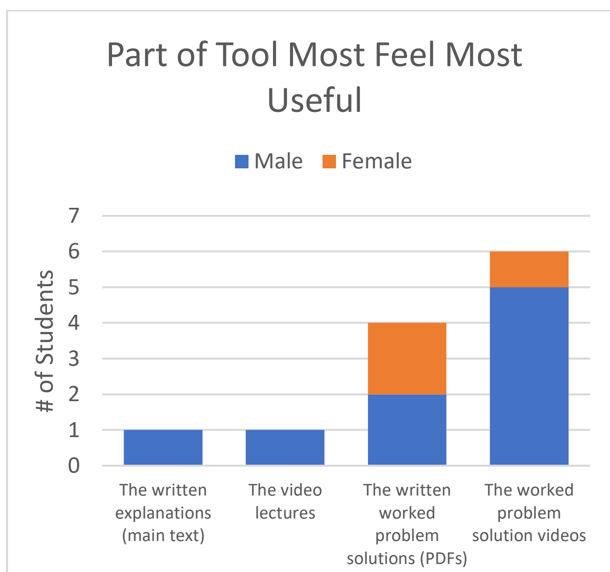


Figure 3: Student Responses to the Questions: "Which of the following parts of the tool do you use most frequently?" and "Which of the following parts of the tool to you feel are most useful?"

The next two questions in the survey asked about the most frequently used aspects of the tool as well as the most useful aspects of the tool. The results to these questions are shown in Figure 3. These results show an interesting dichotomy, where students report using the written explanations and video lectures most frequently, however they report finding the worked examples most useful. This could be a result of the written explanations and video lecture being the logical starting point for a section, and thus the first thing students go to with each new unit. Perhaps students only really accessed the worked examples after facing difficulty answering homework problems or pre-class quiz problems. In this case, the just-in-time resource may be used more infrequently but also be seen as valuable when needed. This does confirm earlier anecdotal data the author had gathered indicating that students felt that the worked problem videos were the most useful aspect of the tool, though the mismatch does also warrant more investigation. As with the first question, no immediate patterns jump out when responses are sorted by gender.

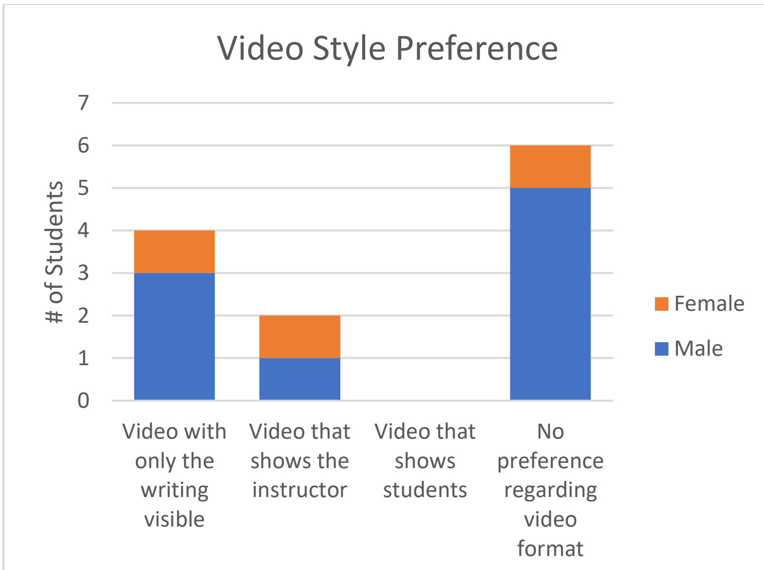


Figure 4: Student Responses to the Question: "For the worked example videos, which format do you prefer?"

Next, Figure 4 shows student preferences in terms of video format. As is seen in the results, half of the students indicated no preference in the style of video, with the other half being split between a preference for videos with only the writing visible and videos featuring the instructor. When asked why they had a given preference, students preferring the writing only solutions indicated that they disliked having a person get in the way of the writing, and for the students who preferred the videos with the instructor they indicated that the hand gestures and other body language helped them better understand the problem. Interestingly, no students surveyed indicated a preference for the student generated videos, which is the video type being investigated by this study in the first place. Anecdotally, this may be a result of the instructor simply talking more during the problem-solving process than students typically did in the videos. Student workers were all encouraged to vocally explain as much as they could while problem solving, however the instructor was still more practiced in this and generally seemed to speak more during the videos than the students did.

Figure 5: Student Agreement with the Following Statements: "I am confident in my ability to successfully complete my engineering degree", "I feel a sense of belonging in engineering", "If I am having trouble understanding materials in my engineering classes, I have people I can go to for help" and "I have mentors or peers in engineering that serve as role models for me"

Figure 5 shows the responses to questions targeted at ascertaining the sense of belonging by the students. Though there was one significant outlier (a single male student with low confidence and matching low sense of belonging), data indicates that most of the students indicted positive measures of belonging in engineering. Additionally, the three women in the survey indicated strong measures of belonging across the board.

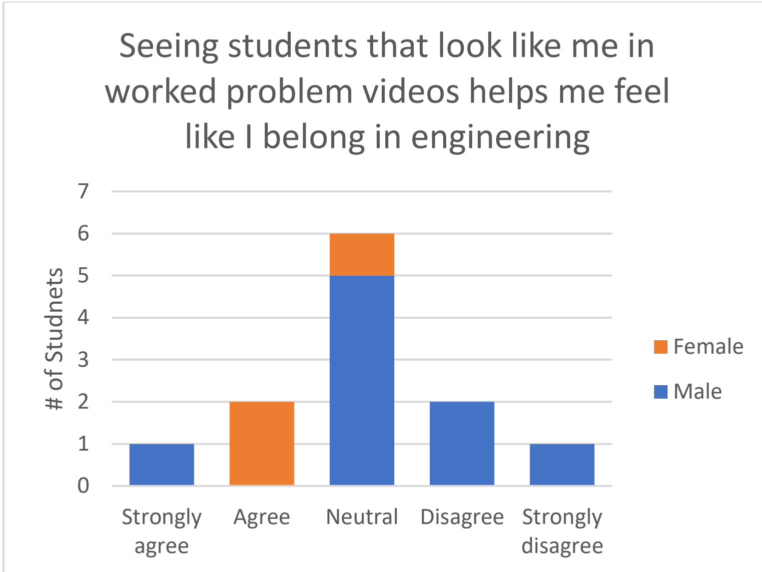


Figure 6: Student Agreement with the Following Statement: "Seeing students that look like me in worked problem videos helps me feel like I belong in engineering."

Finally, Figure 6 shows the responses to the last question on the survey. This question cuts to the core of the second research question, determining if the students in the videos can stand in as role models for underrepresented groups of students in the class. Though the generalized responses to this question are mostly neutral with equal amounts agreeing and disagreeing, it should be noted that two of the three students that agree with the statement were women. This contrasts with the lack of preference for the student generated videos; however, it does agree with the existing literature showing the importance of role models and representation for underrepresented student groups as is discussed in the literature review.

Conclusions and Future Work:

This work represents some preliminary work to support the use of diverse sets of students in worked example video sets as a way diversify the role models available to underrepresented student groups in engineering. Though the small sample size limits the generalizability of the conclusions that can be drawn from this work, there was enough data to show promise for the strategy in the future and to warrant further study. The results from the women surveyed in the study reenforced the literature showing that role models are important for underrepresented student groups, and although students did not indicate a preference for the worked example problems done by students, most students did not have a strong preference for any one format at all. Additionally, the only mentioned drawback of the video format used, namely that students in the foreground impeded what was being written, could be easily eliminated with alternate recording setups such as a lightboard or with a camera-within-screen-capture type setup. As these videos are needed as part of the flipped classroom setup anyway and including a diverse set of students represents non-intrusive method of bringing a more diverse set of faces into the classroom, continuing this style of student focused videos seems worthwhile.

For future work in this area, the most obvious next step is to gather data from a larger sample of students. The existing data was gathered from a sample of convenience, but also represents the type of environment that often struggles the most with representation. By gathering data from a larger sample, particularly with an improved survey instrument with pre-established validity and reliability measures, the author would be able to determine statistically what impact the strategy has on belonging for underrepresented student groups. Should the results of a more comprehensive study show positive impacts of the videos, the strategy could easily be rolled out to a wider audience. Because of the open nature of the tool and the already established audience, the impact of any changes would immediately be felt beyond the author's own class. Additionally, worked examples are a part of pretty much every mechanics course out there, and the open license on the videos allows many more instructors to adapt the videos to fit within their own course structure.

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Appendix A: Survey Instrument

Worked Example Videos Survey

Study: Work in Progress: The Effects of Representation in Worked Example Videos

Principle Investigator: Jacob Moore

1. Please estimate the amount of time per week that you spend looking through and using the Mechanics Map tool. This includes text and videos included in the tool and includes any time you spend using the tool during problem solving in class.
   - Less than an hour per week
   - 1-2 hours per week
   - 3-5 hours per week
   - 5 or more hours per week
2. Which of the following parts of the tool do you use most frequently?
   - The written explanations (main text)
   - The video lectures
   - The written worked problem solutions (PDFs)
   - The worked problem solution videos
3. Which of the following parts of the tool to you feel are most useful?
   - The written explanations (main text)
   - The video lectures
   - The written worked problem solutions (PDFs)
   - The worked problem solution videos
4. For the worked example videos, which format do you prefer?
   - Video with only the writing visible (screen capture or doc-cam)
   - Video that shows the instructor (person with white board / smart board)
   - Video that shows students (person with white board / smart board)
   - No preference regarding video format
5. In one or two sentences, explain why you prefer the video format you picked for the previous question. If you did not have a preference, you can just answer this question as “not applicable”.

6. What is your gender?
    - Male
    - Female
    - Prefer not to answer

Identify your level of agreement with each of the following statements

7. I am confident in my ability to successfully complete my engineering degree.
    - Strongly agree
    - Agree
    - Neutral
    - Disagree
    - Strongly disagree
8. I feel a sense of belonging in engineering
    - Strongly agree
    - Agree
    - Neutral
    - Disagree
    - Strongly disagree
9. If I am having trouble understanding materials in my engineering classes, I have people I can go to for help.
    - Strongly agree
    - Agree
    - Neutral
    - Disagree
    - Strongly disagree
10. I have mentors or peers in engineering that serve as role models for me.
    - Strongly agree
    - Agree
    - Neutral
    - Disagree
    - Strongly disagree
11. Seeing students that look like me in worked problem videos helps me feel like I belong in engineering.
    - Strongly agree
    - Agree
    - Neutral
    - Disagree
    - Strongly disagree