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Work in Progress: Creative Projects Supplementing Exams so Students Can Better Demonstrate Their Understanding

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In response to a transition to remote and hybrid learning from the COVID-19 pandemic, as well as an environment with generally higher levels of stress that can cause students difficulty to prove their knowledge and ability, many instructors have tried to find ways of changing their means of evaluating student performance and understanding. Some methods have included weekly quizzes as opposed to larger exams, oral discussion exams instead of written tests, and replacing exams with larger projects. The efforts being made to broaden potential approaches to evaluation may have short-term benefits to provide workable assessment tools for the current environment, but will also provide insight into the effectiveness of each approach to be considered when regular in-person instruction begins again.

At Northeastern University in a fluid mechanics course, students were assigned a short project in addition to each exam, with each project due date being within a week of its respective exam. The project allowed students the opportunity to present their conceptual understanding and knowledge in a creative format, being able to make a comic, video, or simulation addressing concepts from that part of the course. The projects provided a means for students to either reiterate their grasp on the course concepts in either a follow-up or lead-in to their performance on the exam, or to better show their understanding in a different, less-stressful, more open format in potential response to their previous performance. The introduction of the projects also served to reduce the number of exams in the semester, and could be completed remotely.

This Work-In-Progress paper will discuss the efforts to implement this project in a remote/hybrid instruction fall semester, including comparison between student performance on the exams and projects, and feedback from students.

Background

A transition to online learning driven by the COVID-19 pandemic in the spring 2020 semester, continued through an entirely online semester in the summer, provided some preparation for hybrid teaching in fall 2020. Exams, the likely planned means of assessment and which had originally been planned and scheduled to be held in-class, were now taken online. While this could require some adjustment and planning, the impact could potentially be minimal; studies have previously determined that students should be able to achieve the same score on a test whether taken through the computer or taken on paper.[1-3] Some concerns persist in that the change in format may allow more technology-skilled students to gain a boost compared to other students,[4] as well at the inequality in digital and internet resources between students, which could lead to an imbalance in performance,[5] all of which is before considering any potential increased chance of student cheating on exams.[6]

Primarily, however, additional perspective for the fall 2020 semester was provided based on events not directly related to coursework. With the backdrop beyond the classroom of a global pandemic, a movement for racial justice, and a divisive election, students had a number of real-world factors that could easily impact their classroom performance.[7] For the research team, in end-of-semester surveys from both the spring and the fall, as well as in multiple office hours and email communications, students had expressed that they felt stressed and found it extremely difficult to focus on coursework; even with flexibility built in to help accommodate them, along with clear guidelines to help shepherd their performance, their personal belief that they would not perform well was likely to persist. These fears were similarly noted by other researchers studying student concerns and university approaches in the COVID-19 environment.[8,9] Their feedback implied that student performance would not be reflective of their actual ability and understanding, particularly on exams given the general time window and nature by which they are given.

Some instructors found different approaches to exams in preparation for their own classes. The transitions allowed for instructors to consider opportunities to better assess student learning and consider student stress in how that may limit performance.[10] Some approaches focused on implementing oral exams, with some potential success dependent on how the exams were proctored;[11] oral exams also have a limitation in the size of the class that such an approach can be reasonably conducted with. In many alternative approaches, instructors' efforts involved replacing exams with a project. Frequently, the projects were explicit in that student work needed to cover the course learning outcomes, as would be expected given their use to replace exam assessment.[12] Similar efforts in utilizing projects were conducted in a fluid mechanics course at Northeastern University, with the difference the projects were implemented with the intention of supplementing assessment from exams.

Previous Work and Current Approach

Previously, the author had developed a curriculum project in a transport course at Northeastern University that had allowed students to employ a range of creative tools to showcase their understanding and communicate the course concepts.[13] The project included the options for students to make comics, videos, simulations, and games, all of which had general guidelines to follow, directing students to focus on some technical component of the course in their work. In analyzing student performance from the projects, the research team had previously determined that students significantly improved on their exams when conducting the projects, with the exam average improving from 63.4 to 78.4, with the median grade improving from 63 to 83. Meanwhile, students had provided extremely positive feedback in the use of the projects and encouraged its continued implementation.

The research team had utilized these projects in a heat and mass transfer chemical engineering course previously over the course of several years, but only first implemented them into a fluid mechanics course during the summer 2020 remote learning semester. Student comfortability

with the projects and concern with exams, given the real-world environment impacting their ability to focus and learn, suggested that the projects might offer a means of improved assessment.

In fall 2020, Northeastern University began a hybrid learning model, in which students could take classes synchronously either through in-person instruction or remote attendance. Space restrictions and social-distancing limited the number of in-person attendees; the students who could attend in-person would have to rotate between coming to class one day and remote attendance the next. Some students, particularly international students not permitted to return to the country, would participate fully remotely, as would any student who elected not to return to campus. Despite the potential with a hybrid semester, the research team was hesitant for a complete transition to project-based assessment and the elimination of all exams. This reluctance was primarily based on the desire to ensure assessment of mathematical approaches and derivations of novel problems, which were not always well integrated into students' projects and could potentially limit their creativity in being able to showcase and communicate their understanding.

In response to the hybrid learning plan, and in order to ensure that students had means to demonstrate their understanding in case an exam was too stressful and restricted their ability to apply their knowledge, curriculum projects were implemented into the semester to provide a structure allowing students to have two opportunities to apply their knowledge. While students would be tested through two exams during the semester, they would also complete a project to be submitted within a similar timeframe that would cover similar concepts as the exam. These projects were allowed to be more free-form and creative, with directions to cover general topics as opposed to specific problems. Thus, students could demonstrate that they did have understanding of the subject matter in case their exam performance indicated otherwise, and they would have more freedom to showcase their knowledge through a potentially less stressful means.

Additionally, this assessment plan would allow the research team to reduce the number of exams traditionally used in the course from three to two over the course of the semester.

Methods

The course in fluid mechanics was broken down into two conceptual halves. The first half, approximately seven weeks long, applied a microscopic perspective, focusing on fluid properties of viscosity and surface tension, forces including shear stress, and momentum shell balances. The second half, also seven weeks long, applied a macroscopic view, addressing laminar and turbulent flow in pipes, Reynolds number, friction factor, Bernoulli's equation, pumps, and packed beds.

Student assessment was scheduled to align with this natural split, with two exams scheduled for the middle and end of the semester. Additionally, students were assigned two projects to

coincide with the subject matter, with submission deadlines approximately within a week of each exam. Each exam would account for 29 percent of a student's semester grade, while each project would account for 13 percent. These percentages reflected that exams could cover a broader range of course topics than a student could develop a project to address the same number of specific topics.

Students were presented with four project types to select from:

- a video, minimum length of three minutes
- a comic, minimum length of four pages
- a simulation, with at least two flexible input parameters
- a game, either physical board or card game with all necessary components or a directly playable digital version

Students were instructed that all material should represent original work. Additionally, they were informed of the grading structure for the assignments:

- Clarity of the concept objective (10%)
- Originality of presentation/delivery/instruction (20%)
- Clarity of communication (30%)
- Technical content (40%)

Art or aesthetics would also be considered in evaluation of the projects, but would have a limited impact on the grade. For example, students making a comic were not allowed to present simple stick-figures for any characters, but would not be judged for poor artistic skills.

The original plan was to hold the exam a week before the final project was to be submitted, thus allowing students to follow their exam performance by showcasing their understanding. However, university restrictions and a late final exam schedule required a readjustment, resulting in one supplemental project being submitted after the exam and the other project submitted before the other exam, as noted in Table 1.

Table 1. Exam schedule and project submission deadline.

Exam #1 (microscopic fluid mechanics)	October 14
Project #1 (microscopic fluid mechanics)	October 22
Project #2 (macroscopic fluid mechanics)	December 7
Exam #2 (macroscopic fluid mechanics)	December 16

Students were provided the schedule of the exams and projects at the beginning of the semester, and were shown some examples of past student project work to help explain the overall project concept. Students were allowed to work in groups of two or work alone, with the opportunity to work in a different group or on entirely different project types for each assignment. Students

were given explicit instructions that project #1 had to focus on a topic on microscopic fluid mechanics, while project #2 had to address macroscopic fluid mechanics. Topics may include but are not limited to boundary layers, pipe flow, friction factor, Bernoulli, head loss, pumps, valves, and/or packed beds.

On both exams, students were provided two larger calculation/derivation questions, as well as a series of short conceptual answers. These were conducted in an open-note format with all students logged into the class remotely, and able to ask clarifying questions of the instructor through the chat function. Students could receive partial credit for explaining how they would have solved or intended to solve the exam problem in the event that they ran out of time or became stuck trying to solve.

Initial Results

A total of 93 students across two sections of the fluid mechanics course completed the semester. Students formed 54 teams for the first project and 55 teams for the second project, with a range of different project types selected, as indicated by Table 2. The majority of students chose to complete the video or comic project type options, in part given some students' limited ability to develop code for a simulation, and the ease with which a video or comic could be completed remotely as opposed to collaborating on a physical game.

Table 2. Number of project groups for each project type, based on a total of 93 students.

	Project #1	**Project #2**
Video	18	12
Game	5	5
Comic	27	33
Simulation	5	5

Student projects varied wildly depending on the project type selected. A few examples of each included:

- a video in which sock puppets representing characters from the TV show "Friends" evaluated momentum down a slope, deriving both the stress and velocity profile
- fluid mechanics versions of the board/card games "Racko" and "Guess Who", for which conceptual and theoretical problems needed to be solved and corresponded to certain values that could be played in the game itself
- a photocomic infographic explaining Bernoulli's principle, and a digital comic depicting a student solving for a pump curve with the help of a fairy godmother
- a simulation allowing the user to assemble a flow system with multiple pipe lengths and fittings before solving for the work required for flow

Visual examples of some of the projects are included in Figure 1.

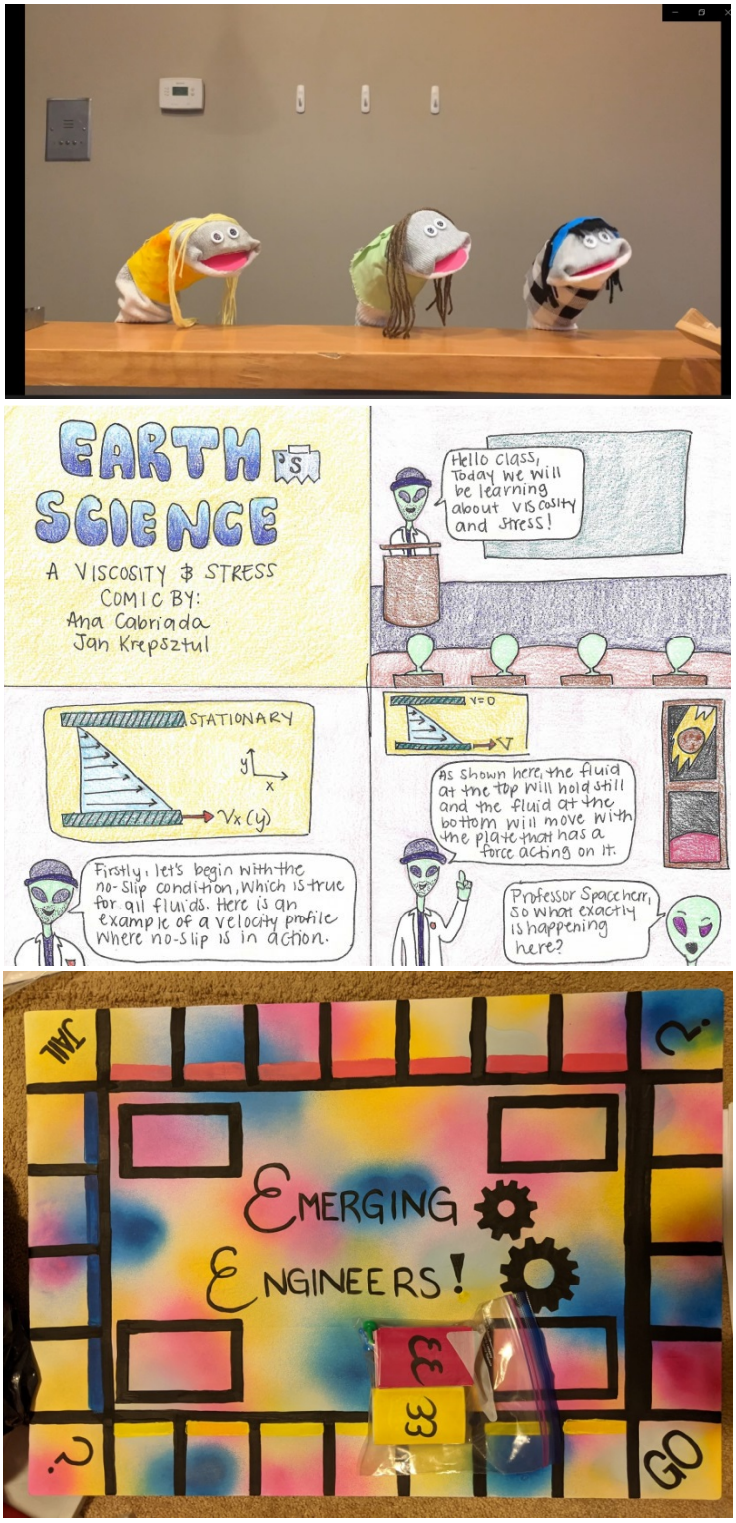

Figure 1. Examples of student project work, including (from top to bottom) a screenshot of a video explaining momentum balances using sock puppets, a page of a comic explaining viscosity

and stress using aliens, and a board game requiring fluid mechanics calculations on foamboard with cards.

The time required to grade the projects was roughly equivalent to the time necessary to evaluate an exam for all students in the course. A broad, general rubric was utilized to evaluate the project submissions. Each of the main categories for assessment (clarity of the concept objective, originality of presentation/delivery/instruction, clarity of communication, and technical content) were rated on a scale of 0-10, and then multiplied by that category's weighting (10%, 20%, 30%, and 40%, respectively) to determine the overall grade. This scale allowed for interpretation of the depth and breadth of the technical content addressed, for example, and whether all content was correct and clearly presented. A more complete rubric will need to be developed for future iterations of the supplemental project to be provided to the students and further help their understanding of how the project should be approached.

Student performance between the exams and the projects varied significantly. Student grades for the exams and projects are presented in Figure 2.

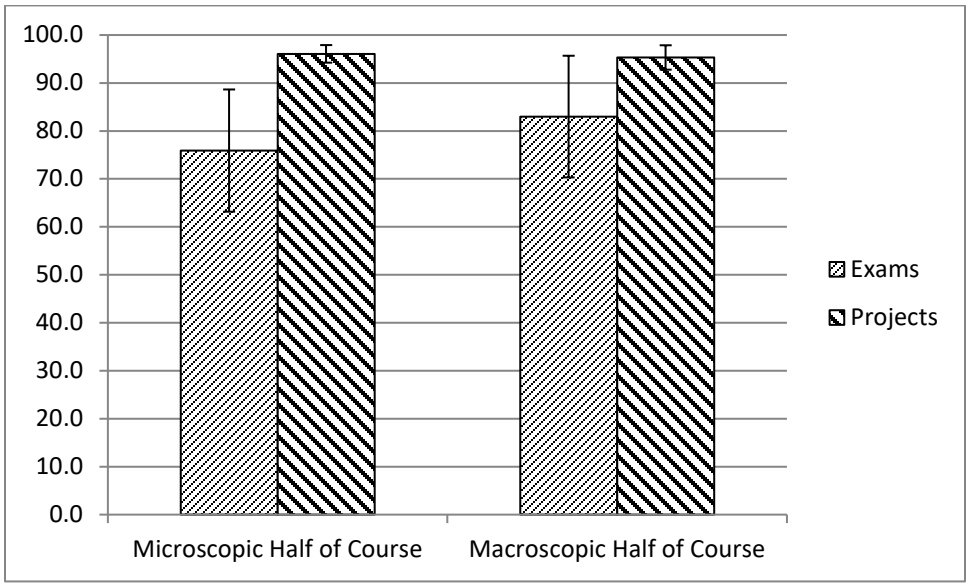

Figure 2. Exam and project averages for assignments in both the first and second half of the course.

A stark difference was notable between the exams and projects. Students received an average of 75.9 ± 12.7 on the first exam, and 83.0 ± 12.7 on the second exam. In comparison, the projects averaged to 96.1 ± 1.8 and 95.3 ± 2.5 respectively. All exams and projects were graded by the instructor to maintain consistency in evaluation. The individual components of each project (objective clarity, originality, communication, and technical content) were assessed specifically to produce the overall project grades, as presented in Table 3.

Table 3. Averaged component grades of each project.

	Objective	Originality	Communication	Technical Content
Project #1	97.0 ± 5.6	96.3 ± 3.4	95.5 ± 3.7	96.2 ± 2.9
Project #2	97.4 ± 4.4	95.2 ± 3.2	94.4 ± 3.5	95.6 ± 4.0

High grades on the student projects could potentially have indicated that the creativity or communication counteracted poor understanding of the technical content, and thus a high grade was still obtainable. However, the component grades reflect that student understanding was consistent with the overall quality of the projects as well.

One clear potential factor in large differences between exam grades and project grades could stem from the nature of the grading process. Exams can be evaluated more objectively, with detailed rubrics for calculation and derivation problems, as well as points distributed for short answers based on specific terms or details provided in the students' answers. Open-ended projects which encourage for student creativity can have distinct expectations for each category, but are far more subject to the grader's personal assessment of the quality of the work and the overall subjectivity.

However, student project work was consistently strong. Having the space to develop full discussions and presentations on specific concepts permitted a deeper level of explanation than would have been possible during a timed exam. Similarly, students could draw connections between multiple concepts, while their selection of which concepts to focus their projects on drove them to develop deeper understanding so that they could explain and communicate the concepts better.

Students were generally positive with respect to the projects as determined through post-semester surveys for which they were encouraged to describe their feelings and supply feedback. A general summary of the student responses to two main survey questions is presented in Table 4.

Table 4. Summarized student feedback on the use of the projects (n= 92).

	Did you find that the projects were helpful in terms of your understanding the concepts you addressed?	Did you find that the projects helped you to better communicate chemical engineering concepts?
Yes	90%	95%
Somewhat	9%	1%
No	1%	4%

Several distinct themes emerged of student responses emerged. Several students focused on the communication benefit to their understanding.

- “They forced me to explain what I was learning.”
- “After each project I was more confident in the topics that I talked about.”
- “Teaching is definitely the best way to access whether or not you truly understand a topic.”
- “I definitely found the projects helpful because we were forced to decide for ourselves ‘Okay how much of what he taught in class do we actually understand?’ and ‘Will we be able to explain the topics in this format so others can understand it as well?’ ”
- “I think you should continue to give them as part of the course in the future. The projects make sure that 1) your students understand the topics and 2) that you're teaching them in an effective way and can see where they may need help.”
- “The projects helped me to be more of an "active" learner; and helped me to determine whether or not I was truly understanding the concepts from the notes, as well as the practice problems.”

Some students recognized that the projects did not provide the same connections to all course topics like exams would:

- I suggested that we should select topics that we found difficult so that we can use the project to better understand the concepts. This is why we decided to focus on friction factor and Bernoulli's as one of our project themes.
- “Somewhat, maybe some of the project types are better suited for certain topics”
- “Yes, however it was very specific to one topic so I feel like I better understand the ones I focused on but really only those.”
- “I did find that they were helpful, however I think that being assigned a topic could be a good way to enable students to become very familiar with a topic they would have otherwise not chosen”
- “The harder project I choose definitely improved my understanding. The easier one, only a little.”

The creative nature of the projects and extended time duration of the assessment, as compared to a timed exam, were particular points of support:

- “Yes I found the projects helpful for understanding the concepts I addressed better because I was able to take more time to think deeply about the concepts and how to portray them in a way that's easy for others to understand as well.”
- “The projects allowed me to have a creative outlet in an what could have been a very challenging and structured engineering course.”

Several students also directly commented that the projects helped provide a lower-stress approach to the course:

- “They were a relatively low stress grade as well. I had a lot of fun making them, especially the first project, and it helped me wrap my head around concepts.”
- “I loved working on the projects! They were a lot less stress than the tests and I definitely got a deeper understanding of the concepts that we worked with. It was fun to design the projects and see it through to the finished product. I wish I could see more of what my classmates did as well!”
- “I thought they were fun and liked the chance to have a sizable part of the course grade not based on exams.”
- “I really appreciated the course projects. As someone who often gets anxiety surrounding tests, I appreciated this alternative to extra exams/ another way to demonstrate my understanding of the material. I also really liked all of the different options that we had for projects (games, comics, codes).”
- “I am also much more comfortable communicating visually or through short blurbs of text than I might be with only words.”
- “I think they are a great idea and allow for students to have some fun and express a more creative side which is relatively rare in most engineering classes. It also is a beneficial grade booster and gave students the opportunity to display their knowledge in a different manner than a test.”
- “The projects were a wonderful idea and it took an immense load of stress off of me personally and I think it was far more helpful than any quizzes or other difficult assignments would have been.”
- “It is a nice grade boost (which was definitely needed), informative and fun as well. I appreciate the ability to apply our knowledge in different ways and show what we know.”
- “I really liked the two projects as opposed to exams, it made me a lot less stressed in this class than I thought I would be.”

Not every student responded positively, although these comments were few compared to the majority of the class:

- “It felt like I was repurposing what I had learned into a different format for grading and reviewing concepts, not necessarily that it helped increase understanding.”
- “Even if they didn't (help) I had fun making them.”
- “I didn't love the projects just because I am not a terribly creative person at all. However, that is not to say that the project is a bad assignment, just it did not combine with my strengths as a student well.”

Overall, student feedback was positive, and pointed to multiple benefits of introducing projects for assessment to supplement their exams, including the opportunity that the projects allowed them to continue learning certain topics in a seemingly lower stress assessment to be able to communicate them more effectively. As one student summarized, “the projects were a great way

to stay learning while taking a slight break from the rigor of classes." The majority of comments encouraged the projects to continue in future iterations of the course.

Students did not have the opportunity to review each others' projects, in part because of a desire to ensure the content was correct and thus not misleading to any students, as well as to ensure that all the content was fully appropriate in both content and presentation. If students gave permission for their work to be shared with future iterations of the course, then all projects that are correct and appropriate will be used to help provide additional learning tools for other students in a broader range of topics beyond what they personally work on, as well as to showcase examples of what the projects could entail.

Conclusions

This study remains a work-in-progress for several reasons. First, the research team was switched to teaching different courses in the spring 2021 semester, and so could not perform follow-up investigations in fluid mechanics to improve upon the means of assessment with the supplemental projects or to determine if the results were reproducible. Second, it would be particularly useful to implement projects like these as a course assessment for more direct comparison to exam performance without the background real-world impacts that easily could have affected exam performance and made the results more pronounced. Third, the projects could potentially be better aligned to be more specific to certain course objectives, in order to better evaluate student understanding on distinct topics instead of broadly covering microscopic or macroscopic approaches to fluid mechanics. Fourth, changes could be implemented to adjust the schedule of the projects in relation to the exams, particularly given student comments that the projects helped them to learn, suggesting that projects might help prepare students for the exams and thus have additional benefits. Finally, the project rubric should be more thoroughly reviewed to determine how in-depth student understanding is being evaluated. The nature of a creative project allows more subjectivity in terms of assessment to be introduced, and better detailing the expectations for assessing communication and technical content are likely necessary.

However, the initial implementation of the supplemental projects appeared to be successful both in terms of student assessment and in terms of alleviating some degree of student stress. High student performance on the projects did not align with student exam performance, but did permit students an opportunity to supplement assessment from exams with a creative approach that helped further indicate their conceptual understanding. While further work and improved implementation of this supplemental project approach are necessary, the initial results and student feedback were encouraging.

Further investigation with respect to integrating these supplemental projects into coursework will examine the amount of time that students devote to working on the project as compared to their preparation for the exam, in order to better evaluate the demand that supplemental projects place

on the students. More thorough survey questions with respect to the project will be developed as well, to better understand and assess students' experience.

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