2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #32515

The Engineering Epic Finale – An Authentic Alternative Assessment Method for Final Exams

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Abstract

Inspired by an article in The Chronicle of Higher Education in 2015 titled "Final Exams or Epic Finales" (https://www.chronicle.com/article/Final-Exams-or-Epic-Finales/231871), three instructors of middle-level multidisciplinary engineering courses at Elizabethtown College, a small, private, regional liberal arts college, replaced their traditional final exams with self-described "epic finales" or final "celebrations of learning." We seek to share our experiences from several years of implementation as many in the engineering education community consider alternative final exams coming out of COVID.

We have implemented epic finales in Strength of Materials, Thermodynamics, Introduction to Environmental Engineering, and Civil Engineering Materials. Our experiences include in-person and virtual implementation. In this paper, we share our exercises, details of the semi-structured time block used, our grading approaches and rubrics, student and instructor reactions, challenges and opportunities identified, and guidance on the circumstances under which we recommend using this approach.

Of note, student feedback indicating that students felt 'like a real engineer' and thought they would remember this exercise far better and for far longer than wiping their mind of the cramming before a typical exam. While the level of technical analysis during the exercise did not rise to the level of a typical final exam, in all courses, students had been tested on most of the content during partial exams. Instead, students had to display a higher level of 'real world' skills including problem-solving on an open-ended question, researching a new topic, synthesizing course content, modeling and making tractable a complex problem, self-regulated organization and group management, coordination and communication between groups of students, prioritization of which information they needed to solve the problem, and considerable time constraint.

Our intention with this paper is provide instructors with our lessons learned over several years of implementation and the guidance to implement a practical, creative, and fun alternative 'epic finale,' under COVID circumstances and beyond.

Motivation

The original motivation for this work was to provide an authentic and integrative experience for the students. The instructors wanted to focus on how course topics interconnect using realistic scenarios, and in some cases enable the students to engage ABET Outcome #1 (identify, formulate, and solve a complex engineering problem), Outcome #4 (make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts) and Outcome #7 (an ability to acquire and apply new knowledge as needed). Also, the instructors sought to reduce student anxiety over final exams by keeping the assessment low stakes and emphasizing the knowledge and skills the students had gained over the semester. Given that this assessment was implemented in some of the courses pre-COVID,

during the Spring 2020 semester, and Fall 2020 semester, the epic finale approach was also valued for its capacity to reduce academic integrity violations.

Institutional Context

Elizabethtown College is a liberal-arts higher-learning institution located in south-central Pennsylvania. Its School of Engineering, Math and Computer Science offers ABET-accredited BS degrees in engineering and computer engineering. Engineering students typically choose a concentration that requires upper-level coursework in biomedical, civil, electrical, environmental, industrial and systems, mechanical engineering, or mechatronics. Upper-level courses within concentrations enroll around ten to twenty-five students, who meet twice a week for 80 minutes per class session.

The epic finales described in this paper were implemented in upper-level engineering courses. The second half of some of these courses were offered remotely during the Spring 2020 semester due to the COVID-19 pandemic.

Alternative Engineering Final Exam Approaches

Other engineering education researchers have explored alternatives to traditional final exams as a means of reducing the stress, providing real-world experiences, and reducing academic integrity violations. University of Maryland engineering faculty wrote engineering exams in a "Great Literature" format to provide humor. Like traditional final exams, students needed to filter unnecessary data and pull out essential information to use in their analysis. They also were required to make educated assumptions in their problem solving [1]. Another study conducted at the University of Wisconsin examined making comprehensive engineering exams optional to students as a way to reduce student workload and alleviate stress. The authors found that this approach reduced stress for students with juniors and seniors and those with a high course average being more likely to opt out of final exams. First-year and Sophomores as well as students seeking to improve their overall course grade were more likely to opt into taking a final exam [2]. Other engineering faculty have sought to reduce academic integrity violations while providing a real-world collaborative experience during final exams by switching final exams to a group-testing format finding that preference for this approach varied among students [3]. With this paper we seek to add an alternative final exam approach that other engineering educators may consider for their courses.

Details of Implementation

Three separate instructors have modified this approach to fit their courses, their intended outcomes, and their teaching philosophies. In this section we will present a concise overview of each implementation, with details provided in attached appendices.

Strength of Materials (Spring 2018)

The first implementation was in a Strength of Materials course after the instructor looked for an opportunity to implement an 'epic finale' inspired by reading the article in the Chronicle of

Higher Education years earlier. On the final exam day, she rode a bicycle into the final exam and asked the students to tell her the three locations most likely to fail during a specific use-case, and the values of the corresponding safety factors. The exercise was semi-structured including small group work, large group work, limited time asking the instructor questions, and limited time using the internet. A partially affective rubric was used to score the students, and the final exam was only worth 10% of the final grade. The students had been individually assessed on all of the prior material on partial exams. At the end of the exam, students were asked to individually answer some technical prompts (e.g., How would your approach change if you had more time? What additional information would you want? Which of the results are you least confident in and why?) and to reflect on the exercise itself. The experience and feedback were overwhelmingly positive. While the instructor did not teach this course again due to rotating instructor coverage, she implemented this approach in her Thermodynamics course.

Details are presented in Appendix A.

Thermodynamics (Spring 2020)

While an epic finale approach was already planned, the instructor felt it was particularly appropriate given the quick pivot online during COVID in Spring 2020. All students had been assessed individually on partial exams and a cumulative FE-style quiz. The epic finale was conducted virtually on Zoom and was less structured. Students were placed into random breakout groups and asked to figure out how a hospital ventilator works with schematics drawn, components identified, and technical considerations and related to thermodynamics and other engineering courses they had taken. Then each group was asked to identify and analyze three alternative technologies that were currently being explored to address the COVID ventilator shortage experienced at that time. In a group, students had to present in a written communication how the devices work, the main technical consideration and issues, and the stage of development. Individually, they were asked to use their judgement to determine the feasibility of implementation and identify the most promising alternative, as well as reflect on the pros and cons of the epic finale experience.

Details are presented in Appendix B.

Introduction to Environmental Engineering (Fall 2018 and 2020)

Students who took the Strength of Materials epic finale requested that format in Introduction to Environmental Engineering because they enjoyed it so much. In both implementations, the Introduction to Environmental Engineering instructor created a fictional scenario involving a county plagued by environmental problems. Students were treated as a team of consulting engineers tasked with assessing the risks posed to the community and devising solutions to address the pollution issues. Students received the final celebration assignment prompt and had 20 minutes to read through it and ask clarifying questions. The students had two hours to work through the team final. Like the Strengths of Materials epic finale, the final 20 minutes of the final exam time were used for the students to reflect on the activity individually.

Details are presented in Appendix C.

Civil Engineering Materials

The epic finale was implemented as an assessment tool that required students to integrate knowledge on the two main learning modules covered in Civil Engineering Materials. The assignment consisted of an authentic problem in which students playing the role of design engineers were asked to evaluate the load-carrying capacity of an existing structure, and design structural members for a building expansion. Students successfully completed the assignment individually, remotely, and synchronously.

Details are presented in Appendix D.

Methods

The authors chose to focus on a qualitative analysis using the written student feedback generated from this activity as a response to reflection prompts or open-ended feedback solicitation. A quantitative analysis of the outcomes demonstrated by the students was performed internally at a course level for grading the assignment as well as for ABET Outcomes assessment but was not considered for this combined analysis because the courses, tasks, and instructor goals were too varied. The student feedback on the general assignment approach, however, was consistent enough across the multidisciplinary courses to qualitatively assess.

The authors used an inductive semantic thematic analysis process. The student feedback was anonymized and combined, after which the authors familiarized themselves with all of the student comments. The primary author performed the analysis by highlighting the text that jumped out as interesting and relevant, and grouping these comments together under identified themes. The primary author then reviewed, revised, and named the themes. At that point, the other two authors reviewed the coding and the themes and performed another round of revision, after which the themes were finalized.

Results

Over three courses with four unique interpretations, the epic finale approach was shown to be of high value to the students and instructors. Overall, the feedback from the students on the epic was strongly in support of this approach in both in person and remote learning settings. Given that these finales were set up to count as only 10-15% of the overall grade, students course grades were minimally impacted and individual assessments in the courses were maintained.

Student feedback

Themes emerged in student feedback, which was overwhelmingly positive. Admittedly, it is no surprise that the students are going to enjoy a lower-stress, lower-grade-percentage epic finale experience. It was interesting to see the themes from the feedback, as a few of the themes surprised us as instructors. Below is a comment from one student that encapsulates many of the common themes:

This team was assigned randomly, and I have never worked with, so it was great to see us all get to work right away and come together to produce high quality work. I also believe this final method is a better real-world preparation than other finals. I can see a boss coming up to a team and asking for a report on a topic the company is interested in producing by the end of the day rather than handout a test where you cannot use resources or notes. Overall, this not so stressful environment taught me more lifelong skills of research, teamwork, and reporting in three hours than most classes do in a semester.

Building engineering professional identity

I think these are the types of things we will be doing out in the workforce, so to do it in a classroom setting as a wrap up and being able to apply the skills we learned, really teaches us about what we know and how to function effectively in a group to meet a common goal with a deadline

I think that this format for a final works very well to demonstrate a student's understanding of the theory and fundamentals behind the content of the course. The student needs to be able to take their new skills and knowledge and be able to apply it to something where they have no prior experience. This helps to prepare them for life after college in the workplace.

Real-world application

Engineers are problem solvers and what we did today is engineering in a true sense- looking into the world and seeing how we can help.

In my mind, it makes sense that the final exam should be a real world application of the material studied throughout the semester. The exams during the semester, after each unit, should test our knowledge of the topic, whereas the final should test the application and show connections to daily life. I think this reinforces the importance of the material and is a nice conclusion that summarizes the course.

Learning during the exam

I usually don't learn at all during a final exam, I usually just show what I already learned throughout the semester. With the epic finale, I felt like I learned real application and engineering skills. This is the first time I actually learned some skills and gained knowledge DURING a final. It was also really cool to see how much all of us learned and how it can apply in real-life.

We were still able to actually learn in the finale, instead of going over old notes that we already took a test on. I didn't know anything really about ventilators or the mechanics behind it, but now I do.

Research, creativity, and critical thinking

I also think that researching advanced and specific topics is valuable exercise because it teaches you to obtain knowledge on your own and gives you a better understanding of the world that you live in. It also teaches you to think critically and evaluate the information that you are receiving very quickly

I felt that I could show my creativity and what my mind can do which in college I do not believe there is enough freedom to express oneself in the classroom.

Teamwork

It also displayed not just out thermodynamics abilities, but our skills to be leaders and work in a team, which are essential to be a great engineer. I think out project came out very well and I'm proud of how much we accomplished and learned in just 3 hours

Also, the group setting allows for a variety of ideas and backgrounds to come together in a unique way. The benefit of this is then used to solve a real-world problem and lets you think about how else your engineering background can be used to make changes in the world.

Memorable and positive feelings about the subject

Having this experience has certainly made me feel more positive towards the subject matter, and realize retaining and using what you learned can be really fun. Simply taking a [traditional] written exam would not have been nearly as rewarding. It simply would have caused a lot of stress, anxiety, and negative feelings causing me to want to forget all of the things I just forced myself to learn.

As cliché as it wounds it was a happy experience to end out the year rather than a test and goodbye. Working as a class was fun and it was interesting to see how much we analyzed in about an hour and a half. I feel more confident about what I learned coming out of this final.

Lower stress: this was one of the most common and strongest themes in the student feedback.

Finals week is usually one of the most stressful weeks every semester of every year of college. I would say that this epic finale was way more fun any final I've ever taken. People usually overly stress out and physically hurt themselves trying to prepare and get a good final score, which I think is ridiculous.

Some students also pointed out drawbacks to the epic finale approach, and many of these are echoed by the faculty. In particular, students noted that a traditional final exam is sometimes an opportunity to show mastery of the material by the end of the course, to show cumulative knowledge, or to test on a final unit of material. Students also noted that forming an epic finale that covers all of the course material or relates and probes the technical content deeply may be a challenge (yes, students, it is!). One student expressed concern that with the group nature of some of the work, students may 'ride the coattails' of classmates. However, that student noted, and the instructors have observed, that this has not happened during our experiences. The peer-accountability, the quick pace, the interesting topics, and the buzz and excitement in the room have thus far carried along even the least motivated students.

Ultimately, one student astutely put it this way:

I think this model of final increases the amount of gained knowledge and demonstrates the purpose of education extremely well, but at the cost of self-reliance and reiterating critical material from the course. The main idea, much like all of engineering, is the balance of the two. Do the costs of this model outweigh the benefits gained, or the opposite? I think that we gained much more in this case than was lost, particularly with the COVID situation. But perhaps a different topic would require a different balance.

A longer collection of student comments related to these themes is presented in Appendix E.

Instructor Feedback from the Authors

While in many cases the level and breadth of technical analysis during the exercise did not rise to the level of a typical final exam, in all courses the students had been tested on most of the content during partial exams. Instead, students had to display a higher level of 'real world' skills including problem-solving on an open-ended question, modeling and making tractable a complex problem, self-regulated organization and group management, coordination and communication

between groups of students, prioritization of which information they needed to solve the problem, and considerable time constraint.

Attention was paid to which ABET Outcomes our department had selected for each course, and the epic finale was an opportunity to engage with the outcomes around complex real-world problem identification and formulation (ABET #1), making informed judgements based on broad impacts (#4) and acquiring and applying new knowledge (ABET #7). In addition, the epic finale approach enabled engagement with the highest levels of Bloom's Taxonomy where students were asked to make assumptions to make problem tractable, decisions between alternatives, make judgements about their information sources, and deeply integrate knowledge from several prior topics in the course.

Instructor feedback to the students was presented either on paper or through Canvas using a rubric and/or written comments on the assignment. As with most final exams, it is unknown if students reviewed or reflected on the instructor comments. Although students had not done an activity similar to this prior to the final exam, in all courses students had previously during the semester been asked to work in teams either on a project or a laboratory, research or learn some material on their own, and communicate findings in writing and/or orally. Students had been given formative feedback on these tasks, and neither instructors nor students felt they were ill-prepared to tackle the final exam task.

Overall, instructors were pleased with the lower stress level of the students going into this type of final, as well as the energy, excitement, and collaboration in the classroom. One instructor states:

I have never seen so much focus and energy in the classroom. It was wonderful. It truly was a celebration of learning. It was rewarding to see the students work together and help one another.

Also, instructors took joy in the challenge of creating the assessments. Two of the instructors personalized the assessment to include the names of all the students in the course. While is some cases, the scenario designs took more time and effort than a traditional final exam, the instructors enjoyed designing this non-traditional assessment. With respect to grading, the instructors reported the process taking the same amount of time or less than a traditional final.

Conclusions, Recommendations, and Future Work

An epic finale is not the right fit for every course, but the authors have found great success using the approach in the courses described. We recommend that instructors consider using an epic finale approach under the following conditions:

- You feel comfortable with where the students are at the end of the semester and/or have had the opportunity to individually test the students on all content prior to the final exam. One instructor notes:

  In Introduction to Environmental Engineering, I had a strong group of students who had performed consistently well as a class on the previous two exams. I also felt more

comfortable using this format because I had already tested all the material except one chapter which I tested individually at the beginning of the final exam session.

- You have time to dedicate to exam preparation: while this approach was a lot of work on the front end, the grading went a lot faster for the instructors with team epic finales.
- You prepare the students, so they understand the structure and expectations for the epic finale.
- You have academic integrity concerns with your testing structure and parameters.

This approach may not be appropriate in courses where:

- The class size is large.
- The final exam is needed for assessment of individual achievement on specific course content.
- You want to retain the final exam as part of a grace policy that allows student to demonstrate content mastery at the end of the course to help the exam average.

Based on the student feedback, the authors strongly recommend that instructors consider the mental health of their students. Results suggest that epic finales may have an outsized positive impact on student stress and mental health during finals compared to the relative trade-offs regarding the course assessment goals. All three of these faculty and several others in our department are also exploring mastery-based assessment methods in a similar effort to lower student stress [4].

In the future, the authors will continue to use the epic finale approach. In more recent offerings (Spring 2021), two of the authors used the epic finale approach with a total of three distinct courses (Structural Engineering, Thermodynamics, and Biomaterials). These authors slightly revised their approach considering the student feedback described here (in the case of Thermodynamics, the task was made much more technical in nature). One additional instructor at Elizabethtown used the approach for the first time in one course. New and next iterations on this approach include sourcing and sharing ideas for the task from KEEN's Engineering Unleashed website (engineeringunleashed.com) and combining the epic finale approach with a mastery-based course structure.

References

[1] P.D. Schreuders and A.T. Johnson, "An Alternate Presentation Method for Final Examinations," in 1999 ASEE Annual Conference, Charlotte, North Carolina, 1999.

[2] A. Gregerson and S. Franey, "Optional Final Exams as an Assessment Tool in Engineering Curricula," in 2012 ASEE Annual Conference & Exposition, San Antonio, Texas, 2012.

[3] Y. Yihun, R. Nair and J Herron, "Changing the Paradigm "Cheating In a Traditional Exam Setting" Into a Possible Productive Team Work Arena and the Associated Student Perception," in 2017 ASEE Midwestern Conference, Stillwater, Oklahoma, 2017.

[4] K. M. DeGoede, "Competency Based Assessment in Dynamics," in 2018 ASEE Annual Conference & Exposition, Salt Lake City, UT, 2018.

Appendix A - Strength of Materials Implementation

Course Description and Students

The epic finale approach was used originally in Strength of Materials in Spring 2018. The four-credit course is offered every year, with roughly 20-25 students. The course catalog description states that topics include axial stress and strain, torsion, pressure vessels, stresses in beams, combined multiaxial stresses, failure criteria, linear elastic fracture mechanics, fatigue, and materials science structure-function relationships. The course includes a two-hour lab each week, including Finite Element Analysis. Students typically take three partial exams covering all these topics prior to the final exam and spend the last week of class performing and presenting a failure analysis.

Learning Objectives Assessed

The epic finale was designed to address most of the topics covered in the course. The ABET Outcome for this course was also considered: ABET 1 – identifying, formulating, and solving complex engineering problems by applying principles of engineering, science, and math. Students were assessed on their ability to (1) formulate a tractable problem for a real-world scenario with little information given, (2) assess risk of failure on a relatively complex machine considering all the modes discussed in class, and (3) make judgements about the appropriateness of their assumptions and conclusions. Additionally, students needed to work collaboratively to break a large problem down into smaller components, share information, and check one another's work.

Assessment Design

The instructor rode a bicycle into the classroom on the morning of the epic finale, leaned it against the board, and told the students that their task, as an entire class, was to determine the three lowest safety factors for the bicycle under standard loading conditions (an average-sized adult riding normally). In addition, the students were asked to identify the location and likely failure mode of the three lowest safety factors. They were asked to consider every loading and failure scenario covered in the course.

The epic finale was 10% of the overall grade. It was designed for entire class and individual portions of the grade, with a mix of technical and affective components (Table A1).

Table A1. Rubric for assessment

Percentage	Description	Characteristics
70%	0. Process	Participation, attitude, making assumptions, applying coursework appropriately, teamwork
10%	1. Group Results	The final answers to the failure risk analysis
10%	2. Technical Reflection	Strong answers to two individual prompts (below)
10%	3. Assignment Reflection	Thoughtful reflection about the epic finale experience

Implementation

In the spirit of the Chronicle of Higher Education article, the students were told the general approach for the epic finale but were not given specifics. They were told that this was not a traditional exam, that they did not have to study in the same way, but they should look back over what they have done in the course. They were also told there would be affective/process portions of the grade.

The first hour of the three-hour final exam slot was used for re-taking previous partial exam skills. The second two hours was semi-structured, broken into segments summarized in Table A2. The instructor shared the epic finale scenario with the class and gave them a chance to ask a few clarifying questions. The students then quickly discussed their approach, organized themselves into teams with specific tasks, and spread out across the classroom and white boards. Much of the work was done standing at the whiteboards or examining the bicycle; the instructor had placed some measurement devices, pressure gages, extra markers, etc. in the room before the exam. The final results were presented orally at the whiteboards (Figure A1). Finally, the students individually wrote their reflections on a worksheet with about ½ a page for each reflection, to give the students an idea of the approximate length expected.

Table A2. Timeline of the 2-hour epic finale

30 min	Introduce problem Large group work
30 min	10 minutes of internet access Small group work
30 min	10 minutes of Q&A w/instructor Large group work, present results
30 min	Time to write up reflection Celebrate!

Individual Reflection Prompts:

- Of the safety factors you estimated as a class, which are you the least confident about and why?

- If you had several days to do this analysis, how would you approach it differently?

- Please reflect on this 'Epic Finale' experience. Compare and contrast this experience with a typical engineering final in some of the following respects: the type of learning that occurred, skills developed, how well it helped you ultimately learn the material in class, pros/cons, anxiety, enjoyment, etc. What ideas might you have for an 'Epic Finale' in Statics? Thermo (if you've taken it)? Basically… should I do this again? Why or why not? If so, what should I change? Why?

Outcomes

The grades resulting from the epic finale were higher than a typical final exam, as expected. As only 10% of the overall grade, the instructor planned from the outset of the course to use this 10% in place of a ‘participation’ portion of the grade, and the total partial exam percentage was increased relative to prior years.

The instructor was pleased with how the class took ownership of the task, divided the work, checked over one another’s results, and worked at a very rapid pace to accomplish a great deal in a short time. The room was buzzing with energy and activity for the entire two hours, with students writing at the boards, examining the bicycle, huddled around certain analyses offering suggestions, etc. Student feedback was overwhelmingly positive. The comment that most stuck with the instructor was a student saying, “this is the first time I’ve felt like a real engineer.”

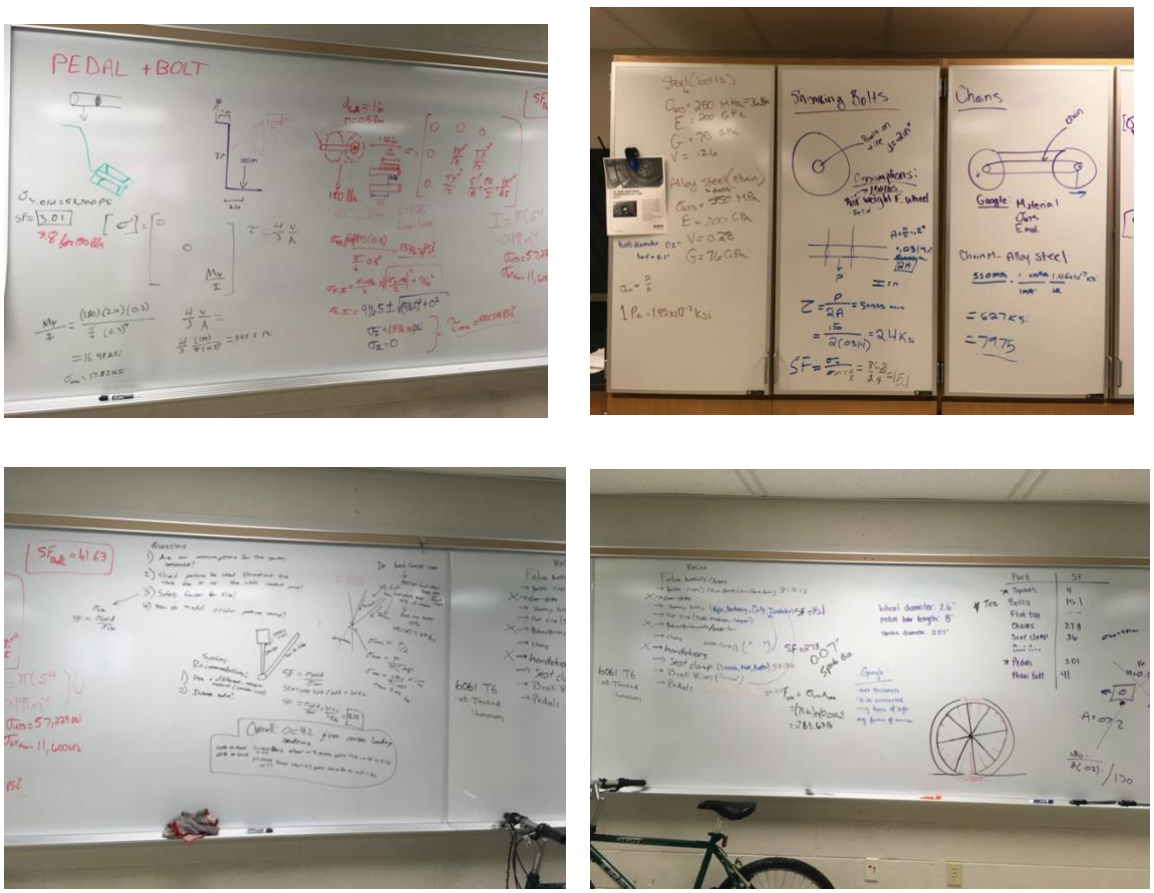

Figure A1. Images from the epic finale whiteboards

Appendix B - Thermodynamics Implementation

Course Description and Students

The epic finale approach used virtually in Thermodynamics in Spring 2020. The three-credit course is offered every year, with roughly 20-25 students. The course catalog description states that topics include properties of ideal gases and liquid-vapor mixes and the laws of thermodynamics applied to analysis of closed and open systems, including power and refrigeration cycles, psychrometrics and combustion. Emphasis on macroscopic thermodynamics and engineering applications. To assess individual technical competence, students typically take individual weekly quizzes, two partial exams covering most of these topics, and an FE-style cumulative quiz covering all topics during the last week of the course.

Of note, this course pivoted online almost exactly midway through the semester due to COVID-19. As most everyone in higher education experienced during those months, the students and instructor were under a great deal of stress and uncertainty, while experiencing a steep learning curve with remote teaching and learning. Opportunities for exam corrections on the partial exams and cumulative quiz were given generously, and one course topic was dropped. Especially with concerns about academic integrity and online exams, the instructor felt the epic finale approach was an excellent assessment alternative.

Learning Objectives Assessed

While an epic finale had always been planned for this course, with the pivot to remote learning midway through the semester, the instructor took a different approach in this epic finale. Instead of being focused on detailed technical analysis, the epic finale was designed to connect the course content with relevant current events and address one of the course outcomes ABET 7 – acquiring and applying new knowledge. Students were asked to demonstrate their ability to (1) research a new topic relevant to current events, (2) connect that topic to the course content of thermodynamics (components such as pumps and valves, humidification), and (3) make judgements about the feasibility and promise of related technical designs. Additionally, students had to work collaboratively in a relatively new (at that time) virtual environment on Zoom.

Assessment Design

The instructor chose to focus on the impending ventilator shortages that were occurring in the early stages of the COVID-19 pandemic. She asked the students to research how a ventilator works, draw a schematic, and relate the ventilator design to thermodynamics and other courses the students had taken. Secondly, students were asked to research and evaluate three potential solutions to the ventilator shortage (at that time, devices such as breast pumps were being retrofitted, engineers were designing simple devices to provide ventilation, etc.).

The epic finale was 10% of the overall grade. It was designed for small group (60%) and individual (40%) portions of the grade, with a mix of technical and affective components (Table B1). One of the reflection prompts asked students to explain how a ventilator works individually as a check on their individual ownership of the exercise.

Table B1. Rubric for assessment

Percent	Description	Submission	Characteristics for full marks
20%	How a ventilator works	Group, report out orally to instructor, upload work	Good schematic, technical, quantifications, related to other courses, evidence of understanding how this works as a technical engineer
20%	New or modified technologies		Found 3 good alternatives or new devices, know who is working on them, what stage they are at, how they work from a technical perspective, pros and cons of each device
20%	Approach and attitudes		A reasonable approach, everyone pitching in, good project management, making the best use of time, listening to each other's ideas, not having anyone dominate
10%	Individual explanation of how ventilator works	Individual, reflections about 200 words uploaded through Canvas	Shows full individual understanding
10%	Which alternative is most promising and why		Reasonable selection and strong justification
10%	What still needs to be done on this design before use on patients		Well thought-out and detailed, considers testing to be done, potential issues with design
10%	Pros/cons of epic finale		Specific and thoughtful

Implementation

Students were told the general approach for the epic finale but were not given specifics. Some of the students had been in prior courses with epic finales, so at this point there was greater understanding of what form the epic finale might take.

The three-hour exam time was mostly unstructured, broken into three segments summarized in Table B2. Details of the assignment were presented in a Canvas assignment that launched at the start of the exam period. After going through the assignment and giving students a chance to ask questions, the instructor formed random breakout rooms of 3-4 students. All work was conducted remotely via Zoom. Students were asked to report out to the instructor as a group as she rotated through the breakout rooms, and to submit screen captures of their work on Canvas. Students were encouraged to use any resources, but they had to be cited. In the final segment, all students returned to the main Zoom room to write and submit their individual reflections.

Table B2: Timeline of the 3-hour epic finale conducted on Zoom

45 minutes	Introduce problem, randomly assign groups of 3-4 students into breakout rooms Research on how a ventilator works Instructor rotate through breakout rooms listening to discussion, getting reports
90 minutes	Research and analyze three proposed solutions to the COVID ventilator shortage Instructor rotate through breakout rooms listening to discussion, getting reports
45 minutes	Individual reflection back in large Zoom room, on Canvas

The assignment statement:

For this Epic Finale (or 'Celebration of Learning'), you are going to apply your engineering mindset and thermodynamics knowledge to research a relevant current issue.

You will be randomly assigned to teams and will document your process and results, and report-out as a small group to the instructor. You will then individually reflect on your results and experience. The instructor will bounce between breakout rooms to observe, answer questions where appropriate, etc.

Your task is this:
In the first 45 minutes of the exam, figure out how a hospital ventilator works. What are the main components? Draw and label a schematic for a ventilator system. Get ballpark values for the pressures, cycle timing, etc. How does a ventilator relate to Thermodynamics and to any other engineering courses you've taken? Be prepared to explain what you've found to the instructor in a few minutes.

In the next 1.5 hours of the exam, your group will research and analyze three new devices or alternative technologies that are under consideration for adaptation to address a ventilator shortage in combating COVID-19, and explain how these devices work (again, with schematics and technical analysis), what stage of development and who is working on them and evaluate the feasibility of this idea. You will also report on this to the instructor as she bounces around.

For this portion of the assignment, upload all of your work as a picture, word document, scan, etc. Only one person needs to do this for the group but **make sure everyone's name is on the upload, in the text entry, in a comment, etc.**

Your grade on this portion will be based on your uploaded group's work, your reports out, and observations of your team and individual approach and attitudes in solving the problem.

In the remaining exam time, you will perform an individual reflection with a few guided questions (a separate assignment).

Individual Reflection Prompts:

1. In your own words, briefly explain how a ventilator works (50-100 words).
2. Which of the alternatives do you think shows the most promise, and why? (200-300 words)
3. Considering the alternative you chose, what additional information would you want to know or what still needs to be done before you would approve it for use? i.e., what tests would you want to run? What do you think needs more engineering? (200-300 words)
4. Finally, reflect on the experience of this Epic Finale compared to a standard final exam. What are the pros and cons? Be specific and explain why you think this. (200-300 words)

Outcomes

Students performed well on this task. The more detailed rubric helped distinguish levels of individual technical understanding and allowed the instructor to assess more granularly over a range of performance without being overly onerous. The group component ranged from B to A, while the individual component ranged from C+ to A+.

The instructor was pleased with how interested the students were in researching the topic, how well they handled the relatively new (at that time) format of Zoom, breakout rooms, remote group work, screen sharing, working together on shared documents, and informally presenting as a group in Zoom. The instructor was especially pleased with the lower stress approach for students given the challenges with COVID, as well as the alternative to academic integrity concerns during a high-stakes final exam. Once again, student feedback was overwhelmingly positive.

Appendix C – Introduction to Environmental Engineering Implementation

Course Description and Students

The epic finale approach was used twice in an introductory environmental engineering course in Fall 2018 and Fall 2020. In this course the instructor referred to the finale as a "Celebration of Learning." The three-credit course is offered every other year. Both years there were fifteen students in the class at the time of the Epic Finale. The class covers environmental measurements, environmental chemistry, mass and energy balance, risk analysis, solid waste management, water quality assessment and management and air quality assessment and control. Depending on the year, students take two or three exams covering all these topics.

Learning Objectives Assessed

The Celebration of Learning (epic finale) was designed to include 80-90% of the topics covered in the course. Students were assessed on their ability formulate and solve problems involving (1) the fate and transport of environmental pollutants using equilibrium chemistry, the Streeter Phelps model, and Gaussian plume model. (2) assess risk for carcinogens and non-carcinogens, and (3) perform basic design calculations for treatment solutions. Throughout the exercise, students needed to demonstrate their proficiency in unit analysis and environmental measurements. Additionally, students need to work collaboratively to solve problems and check one another's work.

Assessment Design

In the Fall of 2018, several students approached the instructor about the possibility of doing this style of assessment in place of a traditional final exam. Students had completed this type of assessment for their Strength of Materials course and enjoyed the experience. After consideration, the instructor agreed and designed a project where teams completed analysis and design work. Students were given a scenario involving a county plagued by interconnected air, water, and soil pollution issues. The scenario was framed as the county asking the students, playing the role of consulting engineers, to assess the extent of the pollution and devise treatment strategies using provided data.

The Celebration of Learning was weighted as 15% of the overall grade. Given that the instructor's originally intended to give a traditional final exam, she wanted to retain an individual assessment of water treatment skills during the Celebration of Learning. It was designed for individual and team portions of the grade with individual and team grades comprising 30% and 70% over a students' epic finale grade, respectively (Table C1).

Table C1. Individual and team composition in Fall 2018

Activity	Individual	Team	% Epic Finale Grade
Water Treatment Quiz	X		10

Participation	X		10
Collaboration		X	10
Procedural Correctness		X	40
Thoroughness		X	20
Reflection	X		10

Implementation in 2018

In the final week of the semester one class period was used to go over the plan for the Celebration of Learning. Students were provided with a document that detailed the how the schedule, scope of content, and expectations for the Celebration of Learning. They had the opportunity to ask questions. During the same class session, the students also went over a study guide listing all the topics covered in the class. The instructor also provided some review problems from topics covered earlier in the semester.

The three-hour final exam slot was broken into segments summarized in Table C2. The first twenty minutes were used to conduct individual assessments on water treatment process trains. This allowed the instructor to quiz topics not assessed during the semester. Then the instructor shared the epic finale scenario with the class allowing the students time to read the information and ask clarifying questions. The students then divided themselves into teams spreading out across the classroom space. The teams had two hours to work through their scenarios and check their work. They submitted their respective portions of the analysis and design at the designated time. During the last twenty minutes, they answered two reflection prompts.

Table C2. Timeline and order of activities in Fall 2020

Order	Description of Activity	Time Allotted
1	Water Treatment Quiz	20 minutes
2	Scenario Overview, Clarifying Questions	20 minutes
4	Break into Teams, Strategize, Complete Scenario Tasks	2 hours
5	Reflection	20 minutes

Implementation in 2020

In Fall 2020, due to COVID-19 restrictions, the course was offered remotely during the last two weeks of class. As such, the final exam period was scheduled to be remote at the beginning of the semester. Knowing that the final exam would be remote from the outset of the semester, the Epic Finale was planned and incorporated into the syllabus. Because the professor desired to provide individual assessment of all skills during the course while it was in person, the Epic finale was meant to be cumulative and cover the breadth of material in the course in a collaborative manner. Given the challenges of administering an engineering exam involving quantitative analysis remotely, the epic finale approach worked to reduce academic integrity

violations. The scenario used in 2020 was similar in scope to the Fall 2018 activity. Key differences were that no quiz was given during the first 20 minutes because all the skills had been previously assessed (Table C3). Also, students submitted their work on Canvas allowing for the instructor to provide annotated feedback to the students after the final exam.

Table C3. Timeline and order of activities in Fall 2020

Order	Description of Activity	Time Allotted
1	Scenario Revealed, Clarifying Questions	20 minutes
2	Break into smaller teams using Zoom Breakout Rooms, strategize and complete activity	2 hours 20 minutes
3	Reflection	20 minutes

Compared to the 2018 Celebration of Learning, the weighted at 10% of the overall grade and individual and group contributions to the overall grade were modified (Table C4). However, the 70% group/30% individual portion was retained.

Table C4. Grade distribution for Fall 2020

Weighting Category	Individual	Group	% Epic Finale Grade
Participation	X		15
Collaboration		X	10
Procedural Correctness		X	40
Thoroughness		X	20
Reflection	X		15

Another key difference from the 2018 implementation was how the students self-organized. Given that the Epic Finale was offered remotely, students recognized the challenges and limitations of working together remotely. To compensate for this, they appointed a leader to organize teams. This student created a Google Doc listing the different topics and skills covered in the class and had all the students sign up on the sheet for the topic they preferred. The leader then made sure each team had the same number of students and at least one person with a tablet that could be used to easily share calculation with their team. The leader shared these groups with the instructor so she could quickly establish breakout rooms in Zoom to maximize the exam slot time for completing the activity.

Outcomes

The student performance on the Celebration of Learning exceeded the average final exam grade in previous offerings of the course. Therefore, the Celebration of Learning maintained or improved students' overall grades. However, with it counting only 10 or 15% of the overall course grade it did not impact students' overall grades more than a third of a letter grade.

The instructor was pleased with how the students organized themselves and made sure that each person was contributing. Students were active and engage throughout the entirety of the session. Interestingly, students did not necessarily work with their usual friend group. Overwhelmingly, students reported enjoying this activity and preferred it over a traditional exam. They felt that it reduced stressed and allowed the students to see the interconnectedness of the course topics.

However, the students from the Fall 2020 course expressed some of the limitations of conducting this type of activity over Zoom. Some of them expressed how they wished they could have done this activity in person. Students could not quickly and easily move from team to team to check on one another's progress and review.

Appendix D - Civil Engineering Materials

Course Description and Students

Civil Engineering Materials is an upper-level 3-credit course focused on structural steel and reinforced concrete. This course introduces design philosophies and the application of standard specifications and building codes to quantify loads, conduct structural analysis, and design tension members, compression members, beams, simple connections, slabs, and frames. Assessment tools include weekly homework assignments, five written exams, a design project, and a design challenge (i.e., epic finale). This course has been offered once, in Spring 2020. The first three exams were given in person, and the students had access to standard specifications and building codes while completing the tests. The second half of the course was offered remotely due to the COVID-19 pandemic; therefore, the format of the last two exams was different. Both included written open-book open-ended design problems, and oral examinations focused on critical thinking.

Nine students took the course and participated in the epic finale. All were junior or seniors enrolled in the civil engineering concentration. As a prerequisite, these students successfully took a mechanics of materials course.

Learning Objectives Assessed

The epic finale was used as a tool to assess the students' ability to integrate knowledge from the two main course modules (i.e., structural steel design and reinforced-concrete design) to solve an authentic problem. Students were specifically assessed on their ability to analyze and interpret results from computational models of structural systems under combined loading, evaluate the load-carrying capacity of a supposedly existing reinforced-concrete frame, and design structural steel members by applying the load and resistance factor design philosophy through current US standards and design codes.

Assessment Design

The epic finale was presented as an additional opportunity for students to demonstrate that they have met the course learning objectives. The problem statement welcomed students to play the role of designers working on an engineering project with the goal of evaluating and designing the expansion of an existing building. A relatable scenario was presented to describe the need to construct a two-story steel frame attached to a reinforced-concrete structure.

First, the students were tasked with analyzing a reinforced-concrete frame and assessing whether it could withstand additional loads produced by the expansion. Students were not expected to create a computational model of the system, but rather explore and obtain information (e.g., layout, dimensions, loads, and material properties) from a computational model shared by the instructor. The software used to conduct structural analysis was utilized several times throughout the semester; therefore, students were familiar with it. After assessing the demands on the existing structure and demonstrating its ability to support the expansion, students were tasked with designing steel members. It was required to produce an economical solution.

Students were required to record and submit their calculations (including any assumptions made), provide a list of the steel sections to be used, and demonstrate that the existing structure was able to safely carry the additional loads. The epic final was worth 15 % of the final course grade, and the scoring criteria focused on effectively conducting structural analysis and design.

Implementation

Students were informed in advance that the epic finale was a design challenge in which they would be asked to solve to an authentic problem. They were asked to confirm that their personal computers were properly working and that they had installed the different software used throughout the semester. A remote meeting link was shared to offer technical assistance during the epic finale.

Three hours were allotted to complete the design challenge during the final exam week. The epic finale was conducted remotely and synchronously. Students were expected to work on the tasks individually and had uninterrupted access to all the course materials. During the activity, the instructor offered support when unexpected issues related to the use of software or the learning management system arose. Students submitted scans or pictures of their hand calculations and results through the learning management system. After the deadline, the instructor confirmed that the submission files were received, and provided written feedback in a timely manner.

Outcomes

The epic finale assignment scores did not significantly boost or lower overall course scores. As shown in Table D.1, the average epic finale assignment score was slightly higher than the average score of all the previous exams combined. However, the standard deviation of the epic finale assignment scores was relatively small compare than that of most tests.

Table D.1 Test average scores and standard deviations

Test	Average Score	Standard Deviation
Exam 1	77.8	±8.2
Exam 2	71.4	±10.8
Exam 3	80.0	±7.5
Exam 4	88.9	±5.5
Exam 5	86.2	±2.5
Exams 1-5	80.9	±9.7
Epic Finale	82.6	±4.5

Appendix E – A representative selection of student comments

Building engineering professional identity

This team was assigned randomly, and I have never worked with, so it was great to see us all get to work right away and come together to produce high quality work. I also believe this final method is a better real-world preparation than other finals. I can see a boss coming up to a team and asking for a report on a topic the company is interested in producing by the end of the day rather than handout a test where you cannot use resources or notes. Overall, this not so stressful environment taught me more lifelong skills of research, teamwork, and reporting in three hours than most classes do in a semester.

Engineers are problem solvers and what we did today is engineering in a true sense- looking into the world and seeing how we can help.

I think these are the types of things we will be doing out in the workforce, so to do it in a classroom setting as a wrap up and being able to apply the skills we learned, really teaches us about what we know and how to function effectively in a group to meet a common goal with a deadline

I prefer this much more to a normal final. It is much less stressful and much more realistic to what we would be asked to do at an actual job.

Although I do not have much experience in the real world of engineering, I believe this Epic Finale format more accurately reflects the experience of being an engineer.

It also helps to prepare us for jobs in the future because we are given a problem and are tasked with using our resources to solve it.

I think that this format for a final works very well to demonstrate a student's understanding of the theory and fundamentals behind the content of the course. The student needs to be able to take their new skills and knowledge and be able to apply it to something where they have no prior experience. This helps to prepare them for life after college in the workplace.

Real-world application

I think it is important that engineering students see where the things they learn get applied.

I like to look at real life examples of how engineering directly affects our lives and make the connection between coursework and those examples.

I feel that this was a great way to realistically utilize our skills learned in class and apply them to the real world today.

I love practicing real world applications, and in this sense, it was a good way to conclude our time together before we go into professional careers.

In my mind, it makes sense that the final exam should be a real world application of the material studied throughout the semester. The exams during the semester, after each unit, should test our knowledge of the topic, whereas the final should test the application and show connections to daily life. I think this reinforces the importance of the material and is a nice conclusion that summarizes the course.

I think this is a really nice way to end a class and I wish more classes did this too. I feel like we are able to show what we've learned by taking the other exams during the semester and having a final that covers every topic can be

too much and overwhelming. We were still able to show what we learned in this class throughout the semester, but it was more to apply our gained knowledge of the course to a real-world situation – which I liked a lot.

This format also better shows how all of the topics we studied interact with one another.

The type of learning wasn't so much of an 'what can you remember for a 3-hour exam' but more of 'how can you apply what you've learned over the semester.

Today's activity was great, I love doing problems that are meaningful and have real life practicality. The parts that my group worked on all dealt with the rivers and water treatment. The problems were difficult but it is always beneficial to be able to bounce ideas off other people.

Learning during the exam

In the standard final exams, there is not much learning happening, it instead focuses on what you have already learned.

We were still able to actually learn in the finale, instead of going over old notes that we already took a test on. I didn't know anything really about ventilators or the mechanics behind it, but now I do.

I usually don't learn at all during a final exam, I usually just show what I already learned throughout the semester. With the epic finale, I felt like I learned real application and engineering skills. This is the first time I actually learned some skills and gained knowledge DURING a final. It was also really cool to see how much all of us learned and how it can apply in real-life.

Typically, for a traditional final exam, students cram and work to memorize every possible detail about the class they can. I think this results in a certain overflow of information; things that can be remembered for the short term and quickly forgotten after the exam. While I believe it is important to be able to demonstrate knowledge about a particular subject, I do not know how useful it is for the long-term.

Most of our information that we have learned has already been presented to us in testing format. It felt nice to apply learning to a wider scenario and move toward a more final project rather than another big exam that puts pressure back on the student.

I love epic finales compared to a traditional final because it gives us a chance to actually apply what we've learned and build upon it instead of just testing to determine what we learned and retained. We get to take the topics we discussed in class (in this case, pumps and valves, among others) and learn how they are used in various devices.

I think that this epic finale is much less of a stress on my brain and is also an effective learning tool. The use of teams to research and learn about a multidisciplinary topic that both apply to the class and our current world, I feel, is an invaluable process that has taught me a lot. Before this exercise, I had no idea how a ventilator worked other than that it provides a way to aide in breathing, but I now feel much more confident about the topic as well as being able to explain it to others.

I think the Epic Finale is a better ending to the semester compared to a typical cumulative exam. The Epic Finale allowed me to research a current topic that I normally wouldn't have known much about, while incorporating thermodynamics and other engineering background into the discussion of the scenario at hand.

This final was not only an assessment of our skills, but also an opportunity to apply them and learn more about how materials break in the real world.

I really liked the Celebration of Learning as a replacement for a traditional final exam because I enjoyed seeing how what I learned from the course all connects to each other.

The Celebration of Learning scenario helped me to understand that air and water pollution impacts are all connected, and people usually face multiple types of pollution in their community. I also learned that there are different ways to manage pollution, but they also depend on the situation. For example, there are many different types of air pollution control devices, but you want to use one that's effective for pollutants in the air in your community. My group and I worked on a problem involving stormwater runoff in an industrial setting, and I learned that the one perfect solution doesn't exist. We instead had to propose several different solutions including green roofs on all the buildings, bioswales along the rivers, multiple bioretention cells in the area, and nonpermeable pavement. All of this shows the incredibly amount of research, design, and planning that encompasses environmental engineering solutions to pollution.

Research, creativity, and critical thinking

I also think that researching advanced and specific topics is valuable exercise because it teaches you to obtain knowledge on your own and gives you a better understanding of the world that you live in. It also teaches you to think critically and evaluate the information that you are receiving very quickly.

it really gave us a chance to use our research skills and relate our findings to previous classes such as thermodynamics, controls, fluids, and physics.

rather than seeing if we can just run through a bunch of equations and problems, we were tasked with something interesting to really show what our minds can put together in a short period of time. It was much more enjoyable to show what ideas and thoughts I have in regards to our class rather than trying to show if I can do some super specific evaluation in a thermo problem. I felt that I could show my creativity and what my mind can do which in college I do not believe there is enough freedom to express oneself in the classroom.

My memory is a little rough, but T.H. White said something like "The purpose of an education is to prepare you to use your knowledge later in life" in The Once and Future King. I fully agree with this statement, and I feel that this model of final puts that statement to practice. Instead of relying on the brute memorization of facts and figures, it encourages critical thinking about a topic and how to apply gathered knowledge from this class, as well as many others in the engineering curriculum.

While for other classes I end the semester studying to forget, the finale method allows me to recollect information that I learned throughout the semester.

Teamwork

It also displayed not just out thermodynamics abilities, but our skills to be leaders and work in a team, which are essential to be a great engineer. I think out project came out very well and I'm proud of how much we accomplished and learned in just 3 hours

Also, the group setting allows for a variety of ideas and backgrounds to come together in a unique way. The benefit of this is then used to solve a real-world problem and lets you think about how else your engineering background can be used to make changes in the world.

I also like the collaborative aspect of it. Since in an actual job we'll be working collectively in teams to solve a problem, epic finales are a more realistic way to approach the topics learned in class.

a major component of engineering is working on a team. I really appreciate the ability to work with others for this exam format. In my experience, engineering a solution to a problem is usually more effective when all of the ideas of a group of people are brought out into the open to be reflected upon and adjusted.

I liked the fast pace research style and the participation of all group members. We came together to create a professional document or at least gather enough information to talk about the subject to some extent technically and informally.

This final exam was eye opening in some areas and was a great group exercise with many people helping out on all fronts. It was fantastic to see people volunteering and taking lead on certain areas of the project and having people move around the breakout rooms to look over calculations, help out on a design, or edit the google doc.

Memorable and positive feelings about the subject

As cliché as it wounds it was a happy experience to end out the year rather than a test and goodbye. Working as a class was fun and it was interesting to see how much we analyzed in about an hour and a half. I feel more confident about what I learned coming out of this final.

I feel it certainly helps my respect for Thermo when it doesn't leave a bad taste in my mouth. In my exhale of relief after this assignment, there will be a mix of triumph and excitement

I learned a lot this year and this was a great way to close out the semester.

This final was much more memorable than any other class and lets us leave with a good feeling rather than fear of doing poorly on a high-weighted final exam.

an epic finale is memorable, applicable, and useful. While the event of traditional final exams is quickly forgotten, an epic finale is something that enriches a student's life and gives them the information they can carry forward into the world.

Additionally, the Epic Finale allows for a more stress-free environment and positive feelings about Thermodynamics, especially as we battle through the isolation and anxiety we may feel from COVID-19.

Having this experience has certainly made me feel more positive towards the subject matter, and realize retaining and using what you learned can be really fun. Simply taking a [traditional] written exam would not have been nearly as rewarding. It simply would have caused a lot of stress, anxiety, and negative feelings causing me to want to forget all of the things I just forced myself to learn.

Lower stress

The big thing for me is the reduction of stress with this format.

This epic finale took a lot of stress out of the finals process.

One of the benefits of having the final in this way is that it massively reduces the stress of finals week.

I am not a gifted test or exam taker as it is, and that is especially true for final exams.

Finals week is usually one of the most stressful weeks every semester of every year of college. I would say that this epic finale was way more fun any final ive ever taken. People usually overly stress out and physically hurt themselves trying to prepare and get a good final score, which I think is ridiculous.

Overall, I really enjoyed this over a final, less stress, and I greatly enjoyed this class even with all the challenges we have faced.

Cons

The cons of taking an exam this way would be the potential for a student to re-master a topic they originally did poorly on,

I guess the cons would be that you can ensure one last time that a student really understood the material.

The only negative outcome from this style of final is that it would be very difficult to find a single situation that encapsulates all the topics covered throughout the semester.

This type of final exam does not reinforce all the material we have learned over the course of the semester and it does not show that we have mastered the calculations we have been studying, like the standard final format.

Another negative is more for courses where there is additional content learning after the last mid-semester exam. In this case, there isn't a way to specifically test students on that additional content.

I think this model of final increases the amount of gained knowledge and demonstrates the purpose of education extremely well, but at the cost of self-reliance and reiterating critical material from the course. The main idea, much like all of engineering, is the balance of the two. Do the costs of this model outweigh the benefits gained, or the opposite? I think that we gained much more in this case than was lost, particularly with the COVID situation. But perhaps a different topic would require a different balance.

One negative of it, is it sometimes allows people to go through the final without applying themselves. In my group, I don't think that happened at all, though.

The only con that I found to the epic finale was the uncertainty before it began.

I think today's activity was one of the best finals I have taken at Etown. However, I don't like the thought that some of my grade will be up to people that I completely did not get to communicate with during the test. They were put into different breakout rooms and with the sheer amount of work my group had to complete we never got a chance to really see their work. I think that has more to do with us being over zoom than anything else. If we were in the classroom I would feel a lot better about submitting everything because I could see them doing the work and overhear certain things to maybe help other groups.

The one change that could be made is to allow more movement of individuals between groups to help check other areas of the project. It did get a bit hectic at some points with people explaining problems that I did not work on, so I was lost for a good ten minutes until they were done explaining the process that was conducted. I think another modification would be to allow the breakout rooms to breakout again to make even smaller groups to organize the people who worked on the same problems. This would help alleviate the overtalking and confusion that occurred.