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A Visual Heat Transfer Exam Review Activity

Dr. Najmus Saqib, University of Indianapolis

Najmus Saqib is an Assistant Professor in the R.B. Annis School of Engineering at the University of Indianapolis (UIndy). Saqib received his Ph.D. in Mechanical Engineering from Colorado School of Mines (CSM), focusing on ”Optical Diagnostics of Lithium-Sulfur and Lithium-Ion Battery Electrolytes using Attenuated Total Reflection Infrared Spectroscopy”. He likes to use innovative pedagogical techniques to facilitate student learning.

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Abstract

Exams are intimidating. Students can feel overwhelmed by reviewing for exams. While students need to know subject matter content, reviewing concepts alone before exams is not always an effective exam preparation strategy. Although example problems may help, instructor-solved ones are often less effective in preparing students than student-solved problems.

In this engaging classroom activity, students in an undergraduate Heat Transfer course are given the opportunity to preview a figure from an upcoming exam as part of an exam review exercise. All exam questions are generally related to the heat transfer processes/geometries described in said figure. Students are asked to carefully scrutinize the figure to identify the probable mode(s) of heat transfer. During the review period, groups of students work together to come up with potential exam problems related to the covered content and then identify strategies, methodologies, and/or relevant equations to obtain solutions. The primary role of the instructor during these activities is to ensure that the discussions are relevant to the upcoming exam's content or focus. Review sessions are typically held the day before the exam, and the preview figures are provided in advance. The review activity is based on various studies supporting collaborative learning as study strategies that lead to enhanced academic performance. The majority of participating students are in the third year of their degree program.

This exam review activity has been used numerous times by the author. Students enjoy the experience, and it generally relieves exam anxiety. This paper will provide instructions on developing and running the activity, provide examples, and present qualitative and quantitative student feedback from three different offerings of the course.

Motivation

Review sessions for an upcoming exam are ubiquitous in undergraduate classrooms. Exam reviews are especially common in introductory engineering courses, where students are exposed to foundational concepts critical to their success in the remainder of their major curriculum. Exam reviews provide an opportunity for the instructor to help students focus on the material and concepts that directly support the course learning outcomes [1].

From the students' perspective, review sessions serve as an opportunity to learn about the exam format and get a general understanding of the types of questions they will be expected to answer or the types of problems they will be expected to solve. On the other side of the classroom, for an instructor, exam reviews may feel like a tedious and redundant exercise, where one is expected to regurgitate topics already covered in detail and to solve a series of example problems teasingly similar to what might appear on the exam.

Another approach to exam reviews is hosting a question-and-answer (Q&A) session with students without a set agenda. This approach usually leads to disastrously low classroom participation and classroom meetings ending awkwardly early. The author's experience with these is that students do not study prior to the review sessions, the instructor is not prepared with example problems, and both parties waste valuable class time. Such Q&A-based review sessions are usually ineffective because students do not know what questions to ask if they do not study prior to the exam review and they do not know in which concepts they need help.

Background

Visual learning is an important method for exploiting students' visual senses to enhance learning and engage their interest. Visual methods can open up new ways to solve engineering problems, provide alternative ways of thinking about engineering, and enhance the education and practice of engineering [2]. Interpreting and constructing figures and representations can lead to better understanding of concepts in science and engineering [3].

Studies have shown that active or collaborative methods produce both statistically significant and substantially greater gains in student learning than those associated with more traditional instructional methods [4]. Collaborative learning has been defined in a number of ways but is generally understood to refer to small group learning where the group members actively support the learning processes of one another [5,6].

If visual learning and collaborative learning can be effective in regular class meetings, it should also extend to exam review sessions. Based on these ideas, the author has adopted the exam review activity described herein for an undergraduate Heat Transfer course.

The Exam Review Activity

To prepare for the exam review, the author begins by selecting a physical process that includes one or more dominant modes of heat transfer and which can yield a variety of exam questions relevant to the course learning objectives. For instance, a jockey-box, which is an insulated

container containing ice and water, as well as a long coil of hollow tubing, used for cooling beverages being served at temporary locations, was selected as inspiration for an exam focused on convection heat transfer. A visual representation of the jockey-box was created by the instructor and shared with the students prior to the exam review. The "exam figure" can be seen in Figure 1. The entire exam was based on heat transfer processes described by this figure. The figure seen by the students during the exam review was identical to the figure they saw on the subsequent exam except any dimensional annotations were removed. Suitable exam graphics can also be sourced from trade magazines published by professional engineering organizations.

Review sessions are typically held the day before the exam, and the preview figures are provided in advance. The course typically meets for 50-minute classroom sessions on Mondays and Wednesdays and a 3-hour lab period on Tuesdays. Exams are usually given during selected lab periods; thus, the review takes place the day before the exam during the preceding classroom session. Although the review sessions are not mandatory, attendance is typically virtually 100%. Note that the course is taught at a primarily undergraduate institution with very small class sizes (< 20 students). Exam scores of students who attended the review session versus those who did not attend were not recorded for comparison.

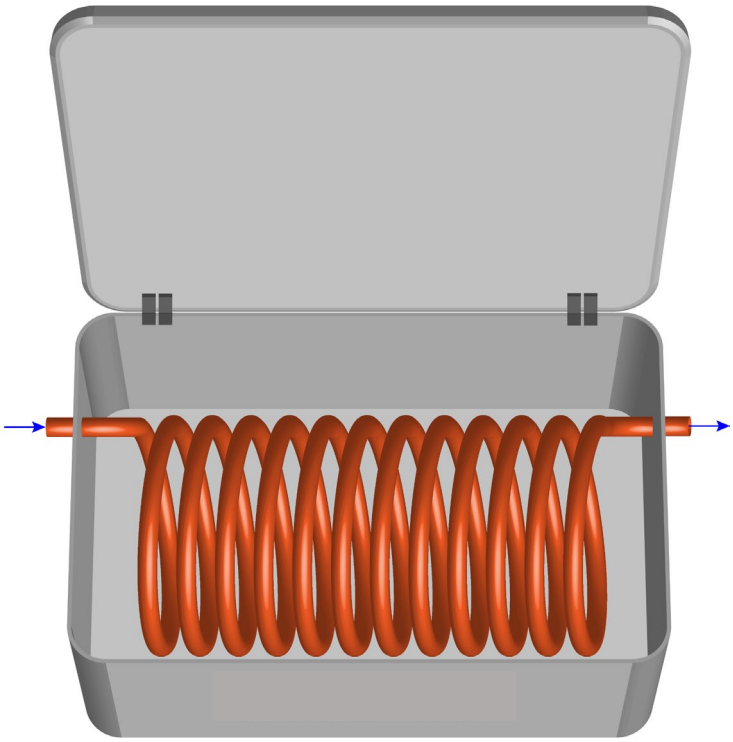

Figure 1: The exam figure shared with students before the exam review session. It illustrates a jockey-box for cooling drinking water.

At the exam review session, groups of 3-4 students work together to analyze the figure to identify the probable mode(s) of heat transfer. Student groups are self-selected. Student groups are then asked to come up with potential exam problems related to the course topics relevant for the upcoming exam and then identify strategies and/or relevant equations to obtain solutions. Beyond numerical problems, they are also encouraged to pose conceptual/design questions.

Students are also reminded that not all of the topics covered prior to the exam may be relevant to the figure and may not be included on the exam. The figure serves as a way for the students to identify and prioritize topics to review before the exam. Before the review session ends, the groups share their work with the rest of the classroom. The review sessions typically last for the duration of a 50-minute class period. For the specific exam review related to Figure 1, the student-led discussions led to potential exam questions such as:

- Find the Reynolds' number of the flow through the tube.
- Find the Prandtl number of the flow through the tube.
- Calculate the outlet temperature of the flow through the tube.
- Determine the Nusselt number and the convection coefficient of the internal flow through the coil.
- Determine the Nusselt number and the convection coefficient of the flow over the coil.
- Find the overall heat transfer coefficient from the ice-bath to the fluid in the coil.

The questions posed by the students were similar to those encountered in homework assignments or classroom examples. The questions asked by the instructor on the exam were:

1. Calculate the Prandtl number of the flow of the drinking water through the copper coil.
2. Determine whether the water flow in the coil is laminar or turbulent.
3. Neglecting thermal entrance length effects, calculate the average convection coefficient for the water flow in the copper coil.
4. Beginning with a carefully drawn and labeled differential control volume, derive the governing differential equation that can be solved for the mean water temperature in the coil.
5. Sketch the mean water temperature in the coil and the coil wall temperature vs. position along the coil.
6. Calculate the Prandtl number of the ice-water bath surrounding the cooper coil.
7. Calculate the natural convection coefficient for the coil submerged in the ice-water bath.
8. Calculate the overall heat transfer coefficient of the coil that includes both internal and external convection.
9. Determine the total length of coil required to cool the drinking water flowing in the coil from 32 °C to 18 °C.
10. Suggest a design modification to improve the convection coefficient from the ice-water bath to the copper coil.

The primary role of the instructor during these activities is to ensure that the discussions are relevant to the upcoming exam's content or focus. The instructor must also take an active role before a lot of time is wasted on one problem or students going off in various tangential directions.

Exam figures shared with students, like the one shown above, are very general. Dimensions, properties, assumptions, etc. are not provided before the exam. The figures alone are unlikely to lead students to specific answers for the exam. All exams were closed-book with students allowed to bring one sheet of hand-written notes/equations to the exam.

Qualitative and Quantitative Student Feedback

While the author has been going through the exam review activity in the classroom for several years, prior to the writing of this paper, there was little documented qualitative and quantitative feedback from students. In order to gather data on the exam review activity, a survey with short-answer and Likert scale questions to be administered following an exam in the course, beginning with the Winter 2022 semester, was developed. The anonymous student survey was distributed through Qualtrics. The questions were adapted from Battistini [1]. The author also solicited feedback from 13 students who had participated in similar exam review activities in the Winter 2021 offering of the heat transfer course using the same survey. The survey results are summarized below. Note that the Winter 2021 students completed the survey in the academic year following the completion of the course, whereas, at the time of writing this paper, the Winter 2023 students have completed one survey after their first exam.

Likert Scale Survey Questions

Select your level of agreement with the following statements:
(1 - Strongly Disagree, 2 - Disagree, 3 - Neutral, 4 - Agree, 5 - Strongly Agree, DNR - Do Not Remember)

A) Participation in the exam review activity improved my performance on the exam.
B) The questions discussed and/or solved as part of the exam review activity were representative of the difficulty of the exam questions.
C) The exam review activity was a group effort.
D) The exam review activity improved my learning experience in the course.
E) The exam review activity improved my preparation for the exam versus traditional exam review activities in other classes.
F) The exam review activity helped relieve my exam anxiety.

Table 1: Average Results of Likert Scale Survey Questions.

Semester	**Sample Size**	**Likert Scale Question Average**					
		A	**B**	**C**	**D**	**E**	**F**
Winter 2021	13	4.31	4.00	4.69	4.31	4.46	4.00
Winter 2022	18	4.50	3.78	4.44	4.00	4.56	3.83
Winter 2023	7	4.57	3.86	4.57	4.43	4.71	4.14
Total	**38**	**4.45**	**3.87**	**4.55**	**4.19**	**4.55**	**3.96**

Short Answer Survey Questions

Please write 1-2 sentences summarizing your opinion (positive/neutral/negative) of the exam review activity and provide any feedback for the professor.

- "Positive" – 12 students noted that the exam review was a positive experience.
- "Like" – 5 students noted that they liked the exam review.
- "Fun" – 3 students described the exam review activity as being fun.
- None of the students noted any negative opinions of the exam review activity.

Please write 1-2 sentences summarizing how your group worked together to come up with potential exam problems related to the course content. Were you able to identify strategies, methodologies, and/or relevant equations to solve the problems?

- "Yes" – 12 students said they were able to identify strategies, methodologies, and/or relevant equations to solve potential exam problems.
- "Lecture notes" – 10 students noted that reviewing lecture notes helped them identify ways to solve potential exam questions.
- "Homework" – 8 students noted that they reviewed homework problems to identify potential exam questions.
- "Critically think" – 6 students noted that the activity made them think critically about the subject matter.

From the results of the Likert scale survey questions reported in Table 1, it is clear that most students agree or strongly agree that the exam review activity is an improvement over traditional review sessions (Question E) and that participation in the activity was a group effort (Question C). Most students also agree or strongly agree that the review activity described above generally improved exam performance (Question A) and the course learning experience (Question D). The respondents also agreed that questions discussed by students in the exam review were representative of the difficulty of the exam questions (Question B) and that the exam review activity helped relieve exam anxiety. Other highlights from the survey were:

- "Seeing the figure was a better way to study for the test."
- "I thought the exam review was very beneficial and different from typical reviews. I thought it was positive but wish I would have put a little more thought into it"
- "The exam prep provided me with a clear idea of what topics I needed to be studying and the type of questions that I could expect to see on the exam."

It should be noted there is no control data from students who did not participate in the review activity.

Conclusions

Sharing the exam figure with students makes for a unique and engaging exam review activity with encouraging student feedback. It is an active learning strategy that employs visual and collaborative learning in the classroom. On the instructor's part, the activity requires writing a set of exam questions that can be translated into a schematic that can be shared with students. While currently only being used in an undergraduate Heat Transfer course, it is adaptable to any exam that involves solving multiple problems relating to an engineering system.

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