# Peer Presentations as a Student-centered Learning Approach in the Nanotechnology Class

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**Abstract**:

*Background*
Active learning techniques have proven effective at engaging students in course content and fostering deeper learning, as compared with traditional lecture techniques. Additionally, research has shown that one of the best ways to teach professional skills such as communication is within disciplinary courses; this strategy makes the material more relevant to students' career goals. This paper will explore the first phase of a multi-year study on the use of an active learning approach called *student-centered learning* to build communication skills in a graduate-level nanotechnology course offered in a department of mechanical engineering. In the course, students develop presentations as a means of understanding current trends, emerging research topics, relevant applications, and fundamental science and technology concepts related to nanotechnology.

*Motivation*
The aim of this research is to determine the efficacy of peer presentations in a graduate-level engineering course as a means to more effectively engage students with course concepts while providing opportunities to practice critical thinking and presentation skills

*Methodology*
Using thematic analysis, we analyzed student responses to five open-ended questions as part of a seven-question survey given twice at the end of the spring 2019 and fall 2019 semesters.

*Results*
Peer presentations can guide students in developing and articulating their own, novel interpretation of the learning materials. Guided reflection further engages students with the material by "forcing" them to pay close attention to the presenter to answer the questions.

*Conclusions*
The results of this research thus far point to student-centered learning as an effective means of teaching critical reading and presentation skills. However, the variation in perceptions between predominantly undergraduate and predominantly graduate course enrollment indicates a need for deeper inquiry into the ways academic maturity affects those participants.


## Introduction

Active learning techniques have proven effective at engaging students in the course content and leading to deeper learning, as compared to traditional lecture-style course engagement. Further, research has shown that one of the best ways to teach professional skills, such as communication, is within disciplinary courses, which makes the material more relevant to students' career goals [1-2]. This paper will explore the use of an active-learning approach called *student-centered learning* in a graduate-level nanotechnology course offered by the Department of Mechanical Engineering-Engineering Mechanics at Michigan Technological University. In the course, students develop presentations as a means of understanding current trends, emerging research topics, relevant applications, and fundamental science and technology concepts in the field of nanotechnology. The students use materials developed by the instructor as a starting point, find a related journal paper, and then present a synopsis of that paper to the class as a lesson.

This paper describes how peer (student) presentations and guided reflection were implemented as an active-learning tool, placing students at the helm of the learning process, and most importantly, helping students to develop critical reading skills and an awareness of their capability for self- and group-learning. Students were asked to expand their knowledge by exploring journal papers and multimedia (e.g., use of PowerPoint, YouTube videos) related to course content; subsequently, students presented their findings to the full class. This method of student-peer presentation also implements active listening and reduces attention span durations by breaking class sessions into two parts: ~25-30 minutes of presentation-based teaching and two peer presentations of 10 minutes each. A portion of each class was allocated to questions and answers based on a reflection activity and notes from student presenters and the audience (other members of the class). Using a seven-question, open-ended survey, analysis of the responses showed that peer presentations could guide students in developing and articulating their own novel interpretation of the learning materials by encouraging critical reading and improving students' presentation skills via observation and practice.

## Background

*Defining active learning and establishing efficacy*

Active learning is rooted in constructivist learning theory, which posits that students are more likely to retain and build new knowledge long-term if they can learn concepts in a way that is meaningful to them [3], e.g., applying friction coefficients to the design of cross country skis. Such learning is more likely to happen when an individual is actively engaged with a concept, as opposed to simply listening to a lecture or watching a demonstration. The concept of active learning gained prominence in the 1980s as both faculty and government researchers explored ways to more fully engage college students with their coursework [4]. Prince argued that although one all-encompassing definition of active learning had not been agreed upon at the time of his work in 2004, he presented a broad definition of active learning "... as any instructional method that engages students in the learning process" [5]. Bonwell and Eison more narrowly defined active learning as students engaging in such higher-order tasks as analysis, synthesis, and evaluation, i.e. "instructional activities involving students in doing things and thinking about what they are doing" [4]. Such techniques include a range of activities from the simple - minute papers or pausing periodically to have students work a problem or reflect on the material with a partner - to complex - concept mapping or peer instruction in which students present course materials by "teaching" their peers how to solve a problem or relate the material to their interests [6].

In a meta-analysis of 225 scholarly papers, Freeman et al. found that student performance in STEM courses improved by nearly half a standard deviation, or half a course grade, when active learning techniques were incorporated into a course, compared with lecture-only courses [7]. The techniques presented in the papers included a wide variety of options ranging from specific in-class activities such as think-pair-share to entire workshops designed with active learning techniques at their foundation. The improved performance results held regardless of the course content or class size.

Despite this study and others supporting the use of active learning techniques [8-10], faculty and students sometimes resist such instruction. In their study of ten STEM departments across two colleges at Boise State University, Shadle et al. found that time constraints and instructional challenges, such as assessment issues or inadequate space, were barriers to faculty implementing evidence-based instructional practices such as active learning techniques [11]. Students tended to be more open to and eager to participate in active learning when the instructor had clearly explained the exercise and its intent and when the instructor actively engaged with students during the activity [12].

*Genre Analysis and Modeling*

Genre analysis and modeling are at the foundation of the series of assignments presented in this paper. Swales championed the use of genre analysis as a method of helping students develop an understanding of the structure and use of language in peer-reviewed research articles [13]. He describes a genre as a collection of communicative events with a "shared set of communicative purposes" [13]. Bazerman traced the textual development of the research article genre in terms of five characteristics: article length, references, syntactic and lexical features, non-verbal material, i.e. graphics and equations, and organization [14]. Genre analysis has long been used as a pedagogical strategy. A recent example is a study by Rappa and Tang in which four secondary school science instructors used genre analysis to teach disciplinary literacy via deconstruction of research articles according to the premise of the study, reasoning behind the study, and outcome of the study [15]. The study revealed that by incorporating genre analysis into their teaching, "they were able to model to their students some of the thinking and writing practices within the discipline of science education."

Modeling has proven to be an effective method of imparting knowledge on novice learners, with learners retaining that knowledge years later [16, 17]. Cognitive modeling occurs when instructors verbalize their thought process as they perform a task [18]. Schunk argues that "Modeling informs and motivates. Models provide information about what sequence of actions will lead to success and which actions have undesirable consequences. Models can raise efficacy among observers who are apt to believe that they, too, will be successful if they follow the same behavioral sequence" [19]. Schunk found that modeling strategies for understanding a text led to improved reading and writing [20]. While graduate students are likely to be strong readers, those who are new to research may be unfamiliar with the genre of scholarly research communication and thus may need guidance in how to approach reading scientific papers that use unfamiliar terminology [21]. By observing the thought process used by an experienced researcher in determining the purpose and value of a particular article, the task of reading and comprehending technical papers is made less taxing [22].

*Reflection as a Learning Tool*

Baxter-Magolda studied the learning practices of college students over five years and developed a model of four stages of knowledge acquisition [23]:

- Absolutist, in which knowledge is thought to require certainty, with easily discernible right and wrong answers;
- Transitional, in which the learner begins to comprehend uncertainty within a field of study;
- Independent learning, in which the learner is able to discern different ways of solving problems and obtaining different results; and
- Contextual, in which the learner is not only able to discern different ways of solving problems and obtaining results but is able to weigh the pros and cons of each approach within the context of the problem.

Incorporating practices that promote reflection (i.e., the processing of information in a way that is meaningful for the individual) into a course has proven to be an effective tool for improving metacognition by enabling the student to move through those stages gradually [24]. For example, such practices have been used in engineering in the form of reflective essays that focus on specific aspects learned from an activity or course [25], or broader aspects such as one's progression through the degree program [26] or approaches to ethical issues [27], as well as using problem-solving activities as means of reflection [28].

**Motivation**

The motivation behind this project, applying *student-centered learning* in a Nanotechnology class, was four-fold:

1) To help students engage more critically with the course material by selecting articles related to nanotechnology and building connections between the core concepts presented by the instructor and the latest research in the field.
2) To build the reading and comprehension skills of students in the field of nanotechnology by modeling how scientists approach the process of reading and evaluating technical papers and then having students practice the technique on their own.
3) To develop presentation and peer-review skills by having the students present their chosen paper to the class using the assertion-evidence method and then asking peers to assess the quality of those presentations by their peers [29].
4) To practice reflecting on what they learned from the experience to improve their performance on presentations and reviews in the future.

Our purpose in this study is to explore whether the incorporation of a multi-phase, active-learning assignment would improve student engagement with the material in terms of their interest in seeking additional knowledge about nanotechnology applications outside of class and improve student engagement with the material in class by forcing them to think more deeply about the content of peer presentations.

**Methodology**

This paper explores the effects of this series of activities using a qualitative, open-ended seven-question survey given in the spring and fall 2019 semesters. Qualitative research methodology is useful in analyzing texts such as extensive survey responses because it goes beyond a simple counting of types of responses. Weisse notes that qualitative methods work best when researchers want to capture in-depth information to achieve a fuller understanding of the respondent's position [30]. The responses were evaluated using Boyatzis' thematic analysis method [31]. Boyatzis describes thematic analysis as "a process for encoding qualitative information. The encoding requires an explicit 'code.' This code may be a list of themes; a complex model with themes, indicators, and qualifications that are causally related; or something in between these two forms." Themes are patterns to be discerned from the data that provide context to the information. This method reflects the three-stage analytic cycle described by Bendassolli [32], which includes careful examination of the student responses, creation of a codebook based on themes and patterns that emerge, and finally the categorization and conceptualization of those themes and patterns in comparison to relevant theories and findings in the literature. In a codebook, each theme includes the following:

- label
- definition of the theme
- description of how to recognize the theme
- description of qualifiers or exclusions in determining whether a piece of data fits the theme
- examples of positive and negative responses that would fit the theme.

The process of determining whether a response fits into a particular theme requires interpretation on the part of the researcher, an admittedly subjective process. Each co-author analyzed the survey responses independently for common themes, such as the frequent appearance of certain words or phrases in student responses, e.g., presentation skills and audience. Then the authors compared their results, determining agreement/disagreement in the list of frequent themes and the number of times those themes appeared in the students' survey responses. Perhaps because of the clarity and concision of student responses, both reviewers found no disagreement in their interpretations.

*Course Overview and Goal*
Nanotechnology is a graduate-level course offered in the Department of Mechanical Engineering-Engineering Mechanics at Michigan Technological University, which introduces nanoscience, nanotechnology, and the impact of the $4^{th}$ industrial revolution on the field. It provides perspectives and tools related to nanoscience, as well as properties and characteristics of physics, chemistry, and biology at the nanoscale. Nanoscience allows us to expand our understanding of nanotechnology, which includes medical nanotechnology, biomimetics, thin films, fibers, nanocomposites, nanotubes, and related concepts. In addition, this course instructs students in how to give professional presentations, choose/read academic journals, and write a proposal and manuscript via a series of assignments.

*Assignment Description*
Early in the course, students practice four aspects of the research communication process using genre analysis [13]:

1. Reading a technical journal paper and learning the function of each portion (abstract, introduction, methodology, observations, analysis, conclusions, citations, etc.),
2. Defining the key components of effective research communication,
3. Preparing a professional presentation, and
4. Identifying the process of writing a journal paper.

Students then review the syllabus to determine what topic is scheduled on a specific day and select the day that interests them the most, while ensuring that a maximum of two students present each day. They then find a corresponding journal paper, analyze it, and prepare a presentation describing the work. Student presenters also lead a discussion related to the paper following their presentation. The paper is shared with non-presenting students prior to class to help them better understand the topic, evaluate the presenter's interpretation, and ask appropriate questions. The non-presenting students also complete a guided reflection questionnaire in which they reflect on the presenter's performance and what they would change if they were presenting. The objectives of the assignment, outcomes, and expectations are outlined in Table 1.

Table 1 Assignment Objectives, Outcomes, and Expectations

| Objectives | Outcomes: Peer-presentation based active learning enables students to do the following: | Observations (expectations) |
|---|---|---|
| Enhancement of students' active involvement | Apply professional presentation and communication skills | Students' behavior changes as students shift away from a sole source of knowledge (i.e., a teacher-to-students pedagogy) |
| Strengthening self-confidence in learning | Analyze their capability for self- and group-learning | Students improve their presentation and communication skills |
| Creation of inclusive and cooperative class environments | Comprehend and exercise self-regulated learning | Giving students a chance to select a topic (a paper) and to creatively design their presentations enables them to be accountable for their own learning, which results in enhanced their confidence and more active learning. |
| Growing students' accountability | Become an independent/ active learner as both a presenter and a listener | Peer presentations can teach students how to listen and learn from peers: an accountable presenter will try to prepare and present a paper in a succinct, informative, and convincing manner; a responsible audience will listen carefully and speak with attention and critical comments. |
| | Evaluate their confidence to speak and participate in class | |

**Results**

At the end of the spring 2019 and fall 2019 semesters (phase 1 of this multi-year study), students completed a survey of seven open-ended questions to obtain their views on the effects and efficacy of the peer presentation assignments. The survey results differed between the spring 2019 and fall 2019 semesters due to two main factors. First, the spring course enrollment was composed of 10 graduate students and 13 senior undergraduate students. In contrast, nearly all students in the fall course were senior-level undergraduate students (18 UG students and 1 graduate student). These differences in academic maturity resulted in distinct perspectives in their responses to questions one and two. Second, two of the questions (four and five) were changed in the fall to elicit more detailed responses, rather than simple "yes" or "no" answers. Finally, the number of responses for the spring course was 22, while the number for the fall course was 17. The questions were as follows:

1. Can you summarize the key points of this topic or subject matter, considering the peer presentations and reflections?
2. Which part of the class do you find more thought-provoking, the teacher presentation or the student presentations?
3. Did the student presentations motivate you to participate and explore other related topics?
4. Does the Q&A based on your reflection induce you to participate in the presentation? (Question changed in F' 19 to "How and why does the Q&A based on your Reflection induce you to participate in the presentation?")
5. Please write your three most valuable takeaways from your peers' presentations.
6. Do you think breaking a class into two parts (professor's lectures and the peer presentations) helps you prepare for the class and stay focused? (Question changed in F' 19 to "Why does breaking the class into two parts (professor's lectures and the peer presentations) help you stay focused and prevent you from being bored?")
7. What challenges do you foresee in preparing for peer presentations? If you had any resistance in the beginning, please share your concerns, e.g., public speaking and presentation skills?

Although the survey contained seven questions, this paper focuses on student responses to five questions (#1-4 and 6). Most students responded to each question with a short phrase or one sentence. However, responses in the spring semester tended to be longer, with some students writing several sentences for one response. What follows is an analysis of student responses to each of those five questions.

**Question 1:** *Can you summarize the key points of this topic or subject matter, considering the peer presentations and reflections?*

This question asks students to reflect on their perceptions of the point of each peer presentation within the context of nanotechnology. The motivation for this question was to figure out which one, among knowledge or skills, the students consider more important for their learning. The majority of responses in the spring class cited improved knowledge about nanotechnology applications and/or stated the point of the assignments was to make the class more interesting, increase participation, and increase engagement or provide a different perspective than the instructor on a concept. One student expressed the latter sentiment this way, "Peer presentations allow us to learn the course content from the peer perspective. I believe we learn better from our peers because we often do not have the technical background and are able to present in a way to understand the important content."

Conversely, just two students in the fall cohort cited improved knowledge of applications as the key point and were more likely to talk about the peer presentations and reflections as an aid to learning the material. We hypothesize that such a discrepancy could be related to the spring cohort being more academically mature and better able to pull meaningful information from the technical student presentations.

**Question 2:** *Which part of the class do you find more thought-provoking, the teacher presentation or the student presentations?*

Responses to question 2 also varied by semester, with the majority of the spring cohort indicating the student presentations were more thought-provoking, while the fall cohort found the teacher lectures more effective. One reason for this difference may, again, be related to students' level of scientific knowledge coming into the course, which resulted in more or less effective presentations based on the speaker's skill as a presenter and the listener's ability to comprehend new technical information. One student in the fall stated, "Some of the student-led presentations are a little difficult to follow given the technical nature of the material." However, one of the spring cohort students felt the opposite, stating, "The student portion of the class, by virtue of having less of a filter and clear end goal, generally has a more thought-provoking discussion." However, both groups were both comfortable with the presentations and enjoyed learning from from their peers because peer presentations gave students' perspectives.

**Question 3:** *Did the student presentations motivate you to participate and explore other related topics?*

Responses to question 3 did not vary significantly by cohort; a similar majority of students in each class indicated that the student presentations led them to participate more fully in the discussions via increased attention and/or asking questions. However, students in the spring cohort were more likely to indicate they did seek out additional information on the presented topic after class.

**Question 4:** *Does the Q&A based on your reflection induce you to participate in the presentation? (Question changed in F' 19 to "How and why does the Q&A based on your Reflection induce you to participate in the presentation?")*

As noted above, this question changed from requiring a yes/no response in the spring to requiring a more nuanced response in the fall. Twelve of the twenty-two students in the spring indicated that the reflection questions induced them to participate in the presentations; many students cited taking notes while reading the papers to develop questions to ask following the presentations and being more attentive during the presentations because the reflections had forced them to think more deeply about the papers and the topics presented. The revised fall question assumes the reflection activity induces more participation than would otherwise occur, and it seeks students' input on how and why as it relates directly to the "Q&A" portion of the class. As with the spring cohort, the fall students tended to say that the reflections forced them to be more attentive during the presentations. However, one student cited a flaw with the activity, saying, "It requires me to pay attention to not only the content of the presentation, but the performance of the presenter as well. Personally, this split in attention tends to come at the cost of attention to the content of the presentation, but the teacher presented portion at the beginning tends to help offset this." Two students felt the reflection had no effect on their participation in the Q&A portion, with one stating that the quality of the presentation had the most effect: "The Q and A is more about the content/quality of the presentation, not about thought-provoking concepts to ask the presenter." Two students also indicated that knowing there would be questions asked following their presentation motivated them to put more effort into their talks: "I tried to present well because I know my peers were basically grading me. I wanted to make sure they understood everything."

**Question 6:** *Do you think breaking a class into two parts (professor's lectures and the peer presentations) helps you prepare for the class and stay focused? [This question changed in fall 19 to "Why does breaking the class into two parts (professor's lectures and the peer presentations) help you stay focused and prevent you from being bored?"]*

As with question 4, question 6 was changed in the fall semester to elicit more detailed responses, (rather than a simple "yes" or "no") and makes the assumption that the course structure improves focus but asks for the students' perspectives on why it does so. However, one student of the seventeen in the fall pushed back against this assumption, stating, "This question assumes that the change itself keeps me from getting bored. Normally, it's the reflection writing that re-engages me during the peer presentations. I keep finding myself zoning out every 3-5 minutes otherwise." Generally, students expressed that breaking a class into two parts does make it easier for them to stay focused. Other students cited the switch to a different activity and speaker as providing a "break" in tone and style as the class moves from the instructor's lecture to student presentations. A few students in the spring found the switch distracting and felt it detracted from learning the material, with one student stating, "I feel like it breaks the rhythm of the lecture and I lose focus," while another stated, "... I feel that if we were presented more content, we would focus more. I feel the class is moving very slow."

## Discussion

These results confirm that the multi-phase assignment incorporating student article reviews and presentations with question-and-answer sessions and reflection increased students' sense of self-efficacy in reading, interpreting, and presenting complex technical information. Their responses also indicated students had a better understanding of the components of an effective presentation with regard to the audience and use of technical jargon. Finally, the results revealed some interesting differences in perceptions of the assignment and its effect, depending on the academic level of the students enrolled. The survey results presented above were anonymous; thus, we are not able to attribute responses to specific students. However, we can make some generalizations based on an analysis of the wording of the responses.

The first is that a student's familiarity with the concepts underlying the field of nanotechnology likely changes their perception of the value of the student presentations, when compared with the instructor's lectures. The fall course, whose enrollment was majority undergraduate, had a higher percentage of students citing the traditional lecture component as more thought-provoking than the student presentations. The main reason cited was that the instructor demonstrated more depth of knowledge on any given topic and, through experience, was better adept at highlighting the most relevant points. Conversely, the spring course consisted of more graduate students than the fall course did; this spring group appreciated getting practice in reading scholarly articles, presenting the research, and engaging with their peers in scholarly discussions. The implication is that, in semesters when the enrollment is majority undergraduate, the class as a whole may need a glossary of key terms for reference and student presenters may need more guidance in what to highlight during presentations to make the content more coherent and meaningful for their peers. (Alternatively, given a class with more undergraduate students, the pedagogy can be bent toward traditional lecture at the start of the course so that the instructor can show the students what is expected of them during presentations and reflections)

A second generalization is that, by giving students the opportunity to present on topics of interest to them rather than assigning them specific articles or stretching the traditional lecture to fill the entire class period, the students were more likely to pay attention to the presentation and develop follow-up questions. Some possible explanations for this increased engagement, as stated by the students, include hearing about a topic they would never have researched themselves and seeing how the presenter interpreted the work. One student said the fact that peers were presenting on more state-of-art applications as opposed to "broad, conceptual topics" made them more thought-provoking. This generalization confirms the work of Felder and Brent in which they argued that "providing some choice in the assignments helps minimize the frequency at which students are forced to work at levels too high or too low for their current level of development" [33]. We would add that working within their current field of interest aids learning as well.

Finally, the responses indicate the students are able to achieve the third learning stage in Baxter-Magolda's framework, independent learning [23]. Students indicated they were able to guide their own learning by self-selecting topics, finding further information when desired, and differentiating between effective and ineffective presentation techniques.

**Future Work**

To further improve the proposed *student-centered learning approach* we are researching, we plan to add practice quizzes to future courses. Prior to each class session (a minimum of one day before), students will need to complete a self-test on the paper and lecture that will be discussed in the next class. Students will have to earn 100% on this practice quiz (no trial limit and no time limit) to move to the next step. This is designed to enable students to prepare for the following class adequately. Online discussion on Canvas will be offered by asking each student to post one thing that they did not know and/or are not sure about the topics (or materials) seen in the practice quiz. Also, students will need to respond at least twice to other classmates' posts, which will contribute to student engagements. These formative assessments, practice quizzes, and discussion posts in the learning management system will be mandatory. These will be preceded by a lecture video, which must be viewed prior to the class. (Alternatively, a transcript of the lecture video can be read prior to the class.) In that case we will have two presentations (10 minutes each) by students per day, followed by a 15-20 minute discussion led by the presenters. A lecturer will participate in this discussion session as a facilitator. All students will make two presentations during the semester: one individual and one group presentation. For the group presentation, the 4th industrial revolution was selected as a subject, which will include ten emerging technologies, including Artificial Intelligence (AI) for Molecular Design; Quantum Computers; Augmented Reality; AI with social robots; Plasmonic Materials; Gene drive; Personalized Medicine; Implantable Drug-making cells; Lab-grown Meat; and Eletroceuticals.

It is hoped that this proposed future work vis-a-vis student-centered learning will address the issues observed in the spring and fall 2019 Nanotechnology courses. Students will evaluate these methods through a survey, which may lead to more improvements.

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