Northeastern
Center for Advancing Teaching and Learning Through Research

# The Scholarship of Teaching and Learning

## Essays by the 2023-24 Teaching and Learning Scholars

# GAIL MATTHEWS-DENATALE
CATLR

## What is the Scholarship of Teaching and Learning?

As educators, we are invested in a generative process of building knowledge and sharing insights. In our own work this involves delving deeply into the disciplinary and interdisciplinary puzzles that intrigue us most: unpacking the nuances of a given text, creating evocative art, solving an engineering conundrum, connecting lessons of the past with current unresolved concerns, making sense of patterns in population data, and so much more.

The Scholarship of Teaching and Learning provides us with an opportunity to invest just as deeply in understanding and improving the learning of our students.  SoTL is located at the intersection between the passion we feel for our area of study and the aspirations we have for our students. What SoTL looks like in practice depends on the context (e.g., discipline, year, location, modality, instructor approach, student profiles and perspectives). However, some goals are overarching, such as increasing student engagement, curiosity, capacity for critical thought, and ability of students to use what they learn beyond a given course.

### Cultivating Interdisciplinarity, Preparedness, and Curiosity

The Teaching and Learning Scholars program provides Northeastern educators with an opportunity to engage in the SoTL in a way that benefits the entire university. In this booklet, you will see the results of three recent studies that are grounded in the real-world concerns of Northeastern educators, each of which addresses an essential challenge in teaching and learning. Their investigations are both thorough and important. Needa Brown's work, carried out in the context of a recently launched interdisciplinary program in Nanomedicine, focuses on meeting the needs of students with diverse prior experience and life goals. Marguerite Matherne's work recognizes the importance of preparation, engaging students in work prior to class, and drawing on the results of that work so that class time can be personalized to meet the needs of a specific group. Ayce Yesilaltay considers the question of student agency, helping learners transcend hesitance to ask questions, collaborate with classmates on finding answers, and build confidence in their capacity to analyze difficult material.

We hope you enjoy the work of the 2023-24 Scholars, and perhaps that their work will spark ideas for studies you might want to pursue related to improving the learning of your students! For more information about the Teaching and Learning Scholars program, contact catlr@northeastern.edu.


# NEEDA BROWN
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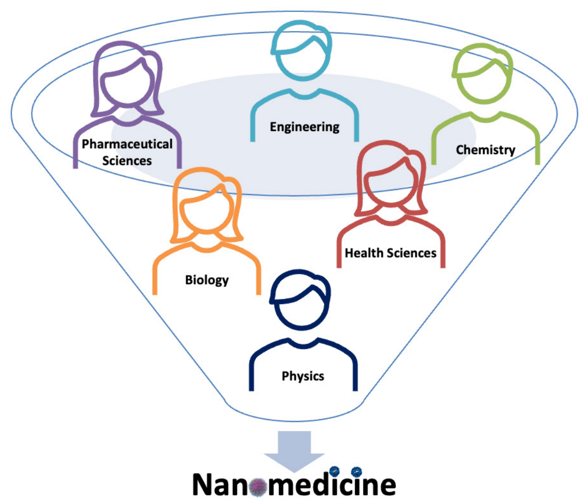
## Impact of prior knowledge on a student’s experienced curriculum

### Introduction & Literature

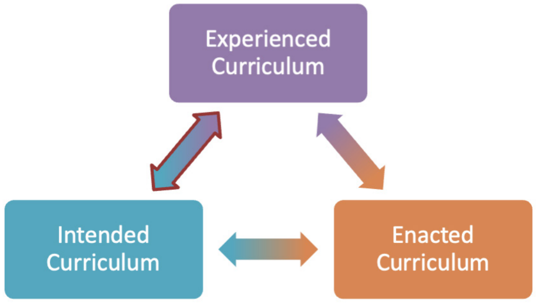
Given the largely interdisciplinary nature of the field of Nanomedicine, there is no model for teaching or standard textbook for reference. Nanomedicine brings in students from assorted educational, cultural, and experiential backgrounds. Although these diverse backgrounds add a richness and depth of discussion to the classroom, they also impact how each student experiences the curriculum. In a traditional discipline, a student needs to meet certain prerequisite requirements to enroll, thus justifying the assumption that these students have similar prior knowledge.

Unlike traditional disciplines, nanomedicine brings in students from a large pool that includes physics, engineering, biology, biotechnology, and more. Due to the diverse backgrounds of these students, the conventional assumption of similar prior knowledge may fail. *The risk of making basic assumptions about prior knowledge drives my curiosity.*




As the Program Director of a Master’s in Nanomedicine degree, my job is to anticipate industry demand and prepare an educational structure that will allow all my students to meet these demands. Given the range of backgrounds entering this discipline within a single cohort, my objective as an educator is to ensure that my students are graduating with the same level of knowledge regardless of what prior knowledge they bring into the classroom. Although the focus of this work has been on a Nanomedicine course, it is highly relevant to a broader audience. This idea of an interdisciplinary education has been gaining rapid momentum over the last couple decades as industry leaders emphasize the need for an incoming workforce with a versatile skillset, an ability to adapt, and the proficiency to apply classroom knowledge to a broad range of real-world problems. The knowledge gained in this study can be applied to a broader scope of interdisciplinary programs to understand differences in student learning as a tool to tailor curriculum development.

Conventionally a curriculum is described as a planned sequence of instructions that imparts knowledge of a particular field to a student. As we expand our lens, we see that a curriculum is really a living, breathing concept that is shaped by the perspective of the observer. Viewed as a process, curriculum occurs in three simultaneous dimensions: 1) intended curriculum, 2) enacted curriculum, and 3) experienced curriculum [1-3].




The ***intended curriculum*** is the planned sequence of instructions that are outlined in the syllabus. Each time these instructions are presented to students, that curriculum transforms based on how the content is delivered, what examples are provided, and how different ideas are connected together. This further reshapes this intended curriculum into an ***enacted curriculum*** that is built around the interaction of the instructor and the student. The intended and enacted curricula are viewed from the lens of the instructor, however on the other end of every delivery is a recipient, which in this case is our student. How our students understand this delivered curricula is the ***experienced curriculum*** [1-3]. The careful balance and interaction between these three curricula drives the impactful transfer of knowledge from instructor to student.

There are several factors that influence a student's experienced curriculum. One factor is frequency of interaction with the curriculum. As an instructor I am constantly and continuously interacting with my curriculum, while my students only interact with it one time when it is being delivered [4]. Another factor is the inherent discrepancy between the novice and the expert organization of knowledge which influences what connections are formed between different ideas [5]. As an expert in the field, I am able to make deeper connections with very little information, yet my students still need to build this foundational knowledge to develop a richer understanding of the field. This is an important consideration as my intended curriculum may make assumptions  that leave gaps in knowledge for my students, thus changing how they experience the curriculum. A final critical factor is the prior knowledge that my students bring with them into the classroom, whether it is discipline specific knowledge or life events or cultural interactions which all shape how they experience this curriculum.

Prior knowledge can be viewed within the lens of a friend or a foe. At times, prior knowledge can help a student expand on ideas and build deeper connections, while other times it can limit how a student perceives and understands new concepts [5]. There are four types of prior knowledge: 1) accurate and appropriate, 2) accurate but insufficient, 3) inappropriate, or 4) inaccurate. Which bin a student's prior knowledge fits into will impact how they experience the intended curriculum. Our students come into a classroom with a wealth of prior knowledge, but not all that knowledge is necessarily correct or relevant to the intended content being taught.


Activating inaccurate and/or inappropriate prior knowledge such as an invalid assumption, especially at the fundamental level, can hinder a student's understanding of stemming concepts. Part of bridging the gap between the intended and experienced curriculum is to activate and leverage "accurate and appropriate" prior knowledge. So, how can I determine what prior knowledge my students are bringing into a classroom? Additionally, from the wealth of knowledge they bring in, how can I ensure I am activating the accurate and appropriate prior knowledge?

Determining what prior knowledge a student brings with them into the program is a nontrivial task. Prior knowledge can encompass course work, professional opportunities, self-study, personal experiences, and more. Some of this knowledge may be directly related while some may be indirect or completely unconnected. Some of it might be consciously known to a student and some might be unconscious.

Teasing out these different lived experiences requires a systematic methodology that needs to include multiple points of data entry. Previous literature has included techniques such as student and/or faculty brainstorming discussions, questionnaires, or concept maps that can be collected at a single, stagnant timepoint or continuously over time [2, 4-6]. Selection of a data collection methodology is highly dependent on the disciple of study. In my case, I was specifically interested in collecting data on the holistic understanding of my students' general prior knowledge and their specific nanomedicine prior knowledge. To achieve this, I collected various types of data through pre and post surveys and a series of iterative concept maps. A critical question for my scholarship was to tease out the impact of prior knowledge on my student's experienced curriculum with the ultimate goal of bridging the gap between my intended curriculum and my student's experienced curriculum to ensure satisfactory development of knowledge, as depicted in Figure 1.

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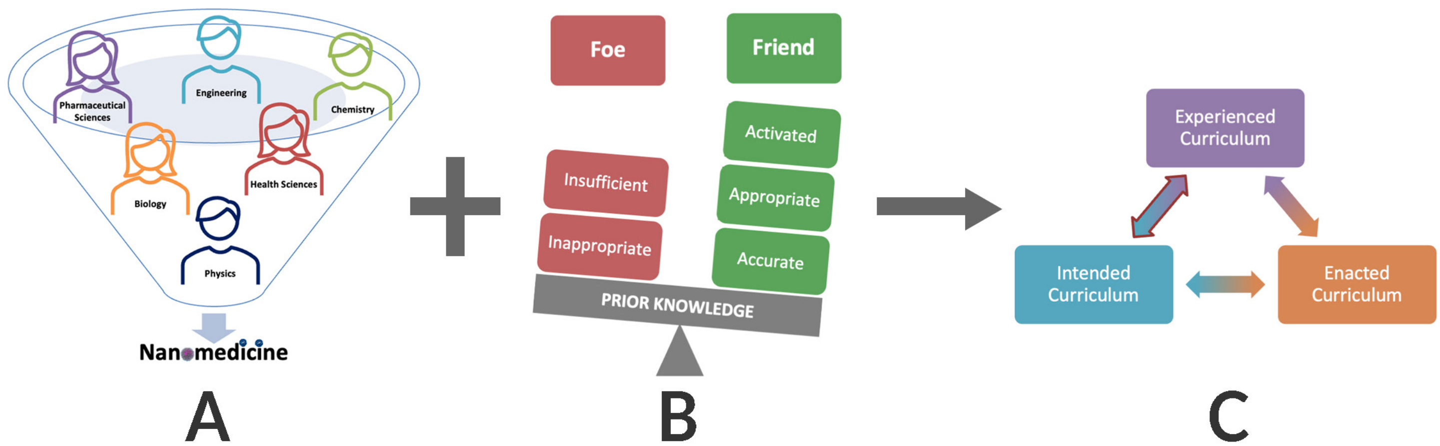


Figure 1. **A)** Given the interdisciplinary nature of nanomedicine, students entering a nanomedicine course come from various educational backgrounds with different levels of exposure to nanomedicine. **B)** Each student brings with them specific prior knowledge that stems from their previous courses or lived experiences. This prior knowledge can be a foe if it is inappropriate or insufficient, while it can also be a friend if we are able to active the appropriate and accurate knowledge. **C)** This prior knowledge impacts how students understand and experience the curriculum presented to them, creating a unique interaction between the experienced and intended curricula for each student.

### My Question

My question grew out of a surprising interaction I had with a student in a previous course. She was in a M.D. program, taking my course on Nano/Bio Commercialization. The focus of our conversation was on developing AI algorithms that might help identify best drug combinations for patients with depression using a patient-derived training set. I asked my student whether patients who were depressed had the right mindset to appropriately consent to giving their private data for research. Her response was simple, "consent is consent" - this took me by surprise! As a researcher, theoretically getting consent from a patient is a complicated process but from her *lived experience* in a hospital it was not a big hurdle. This difference in perspective sparked my Scholarship of Teaching and Learning (SoTL) journey.

Wearing my "Program Director" hat I first started by looking at my courses from a holistic view and was interested in whether my intended curriculum was transferring the necessary and appropriate knowledge to my students, training them to meet industry demand. However, after examining the literature and studying the development of similar STEM programs [2, 4, 6], I quickly realized that a curriculum is a living concept that is impacted by the deliverer and the receiver. To address this, my initial SoTL question was: How do my intended and enacted course curriculum align with student mastery of course learning outcomes?

Taking a closer look into the interaction with the M.D. student, it wasn't the content that I presented or how I presented it that impacted her response, it was her lived experience that she was bringing into the classroom. To know if my students were really gaining the necessary and appropriate knowledge, I first needed to assess what factors were influencing my students understanding of curriculum material. This led me to revise my SoTL question, arriving at: "How is my students' prior knowledge about nanomedicine impacting their understanding of course material as framed within the course objectives?"

## Teaching Context

Nanomedicine is a nontraditional disciple in which the fundamentals of the field are still being discovered. With the recent success of the SARS-CoV-2 vaccine and the Nobel Prize in Chemistry for quantum dots, interest in nanomedicine has grown exponentially, drawing in students from versatile backgrounds including but not limited to engineers, physicists, chemist, physicians, biologists and more. Additionally, these students range from extreme novices who have heard the term "nanomedicine" either in a course or on the news to budding experts working in the field and developing novel formulations.

The subjects of this study were students enrolled in an introductory "Foundations in Nanomedicine: Nanotherapeutics" course which provides an interdisciplinary introduction to nanotechnology-based treatments. There were 49 students enrolled, most of whom were first or second year Master's degree students with one B.S. and one PhD candidate. There was a higher proportion of international students within the course compared to domestic. This is an important confounding variable as each culture and country has different standards and formats of teaching that can further influence the prior knowledge and perspective on learning that students bring into the classroom.

The course was taught in a hybrid format with three sections, on-ground, online - synchronous, and online – asynchronous, with 32, 15, and 2 students respectively. All students watched 1 hour of online lecture content to build background knowledge about a particular topic and then had a 1.5 hour live or pre-recorded case-study lecture focused on applying their knowledge. The course content builds from lower-order concepts such as foundations of nanoparticle synthesis and characterization to higher-order concepts of nanomaterial-biological interactions and translation. Each week students blog about enabling innovations within the nanomedicine field related to a disease of their choice, that work culminates in a final term paper.

Regardless of background, each student is entering the same classroom and will be taught the same curriculum, but each student will not walk out with the same experience or understanding of the material. Therein lies the crux of my SoTL study.

## The Project

### *Data collection*

To collect data on my students' prior knowledge about the field of nanomedicine I use two different techniques: 1) survey and 2) concept map. All students were asked to complete an optional "pre-survey" during the first week of class and a "post-survey" during the last week of class. The survey included questions to elicit information about the general educational background of the student such as education level, discipline of study, and prior degrees as well as more nanomedicine specific background such as experience in industry, prior nanomedicine coursework, or to establish no prior knowledge. I also translated course objectives into Likert scale-based questions to gather individual student perceptions of their nanomedicine related knowledge prior to taking the course.

The Likert scale questions were designed to assess students' confidence of nanomedicine knowledge over each of the cognitive domains of Bloom's Taxonomy from lower-order memory and understanding knowledge to high-order application-based knowledge of nanomedicine. Additionally, I included a subset of general knowledge and professional skills-based questions that I believe are fundamental concepts my students needed to succeed within the course. The breakdown of the Likert-scale questions and their respective Bloom's Taxonomy hierarchical classification can be seen in Figure 2 [7]. The questions were stated as "Select the option that best represents the degree to which you agree with each statement about yourself…I am confident in my understanding of each of these concepts related to nanomedicine:" with 0-1 being 'Strongly Disagree' and 9-10 being 'Strongly Agree'. This Likert scale-based assessment was repeated at the end of the semester to gauge individual student perspectives of their understanding of course content after their experience of the curriculum. The data from this questionnaire provided me with information about the nanomedicine prior knowledge my students consciously had before to entering my classroom and what knowledge they believe they had at the conclusion of their classroom experience.

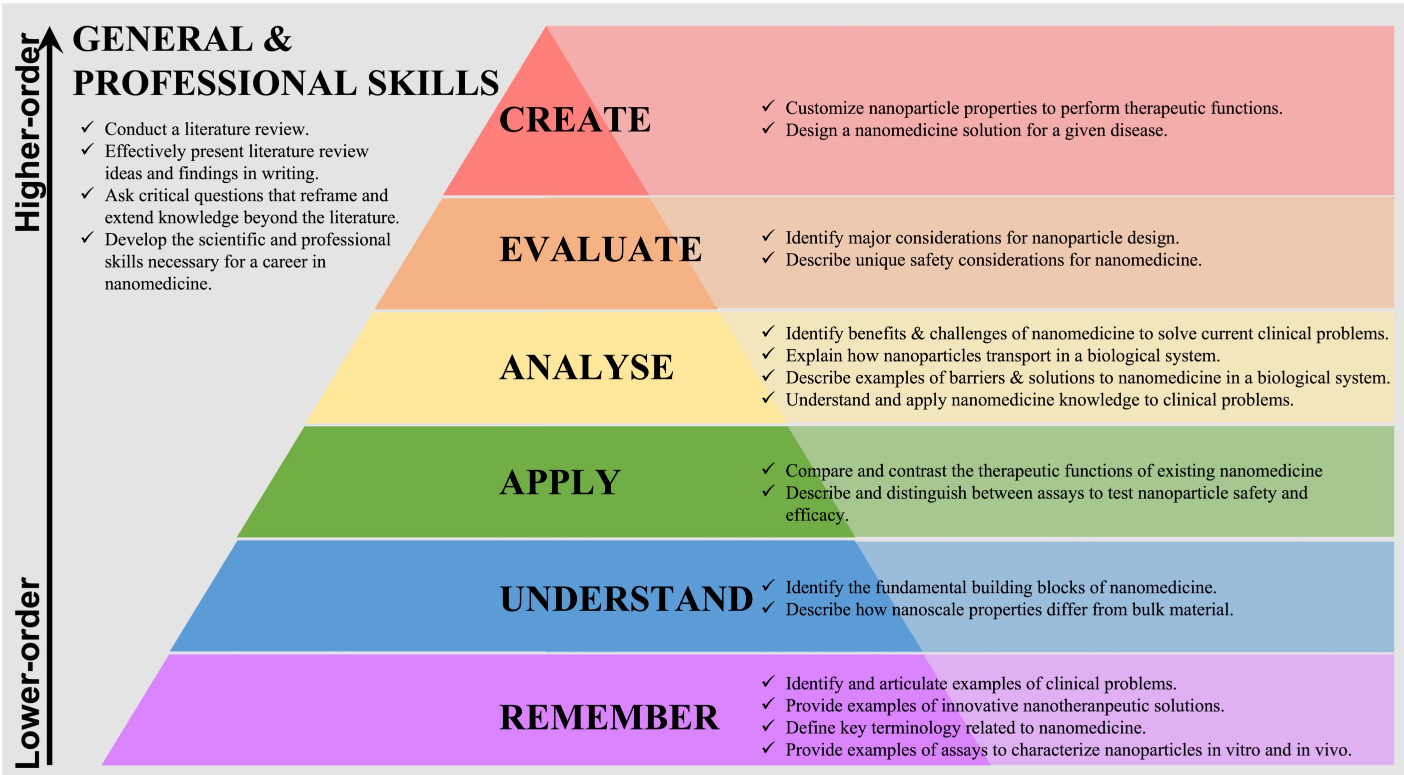


**Figure 2.** Breakdown of Likert-scale questions in the pre-survey and post-survey based on their hierarchal ranking in the Bloom's Taxonomy cognitive domain. The survey was given to assess student confidence of their nanomedicine specific knowledge and gain additional general information about their background and experience in nanomedicine. Each Likert-scale question was prefaced by: "Select the option that best represents the degree to which you agree with each statement about yourself…I am confident in my understanding of each of these concepts related to nanomedicine:" with 0-1 being 'Strongly Disagree' and 9-10 being 'Strongly Agree'. For the post-survey, the second statement was changed to: "AFTER completing Foundations in Nanomedicine: Nanotherapeutics, I am confident in my understanding of these concepts related to nanomedicine:" Figure adapted from Vanderbilt University Center for Teaching, CC BY 2.0, via Wikimedia Commons [7].

In parallel, I had my students complete three concept maps throughout the course as a conceptual visualization of their nanomedicine prior knowledge and progression of knowledge. Only the on-ground section students were asked to complete a concept map in class during the first, seventh, and thirteenth week of class as initial, mid-semester, and final timepoints.

The first concept map provided me with visual evidence about what specific nanomedicine knowledge my students brought with them into the classroom. These initial concept maps ranged from very simple topics such as how nanomedicine can be used for therapy and diagnosis to more complex maps such as different types of nanomedicines and their functions.

As the course progressed, I had the students complete a concept map at the mid-semester and end-of-the-semester timepoints to visually see the growth of their knowledge as well as to gain data about how my intended and enacted curriculum were translating to student knowledge. An example of a student's concept map progression throughout the semester is presented in Figure 3.

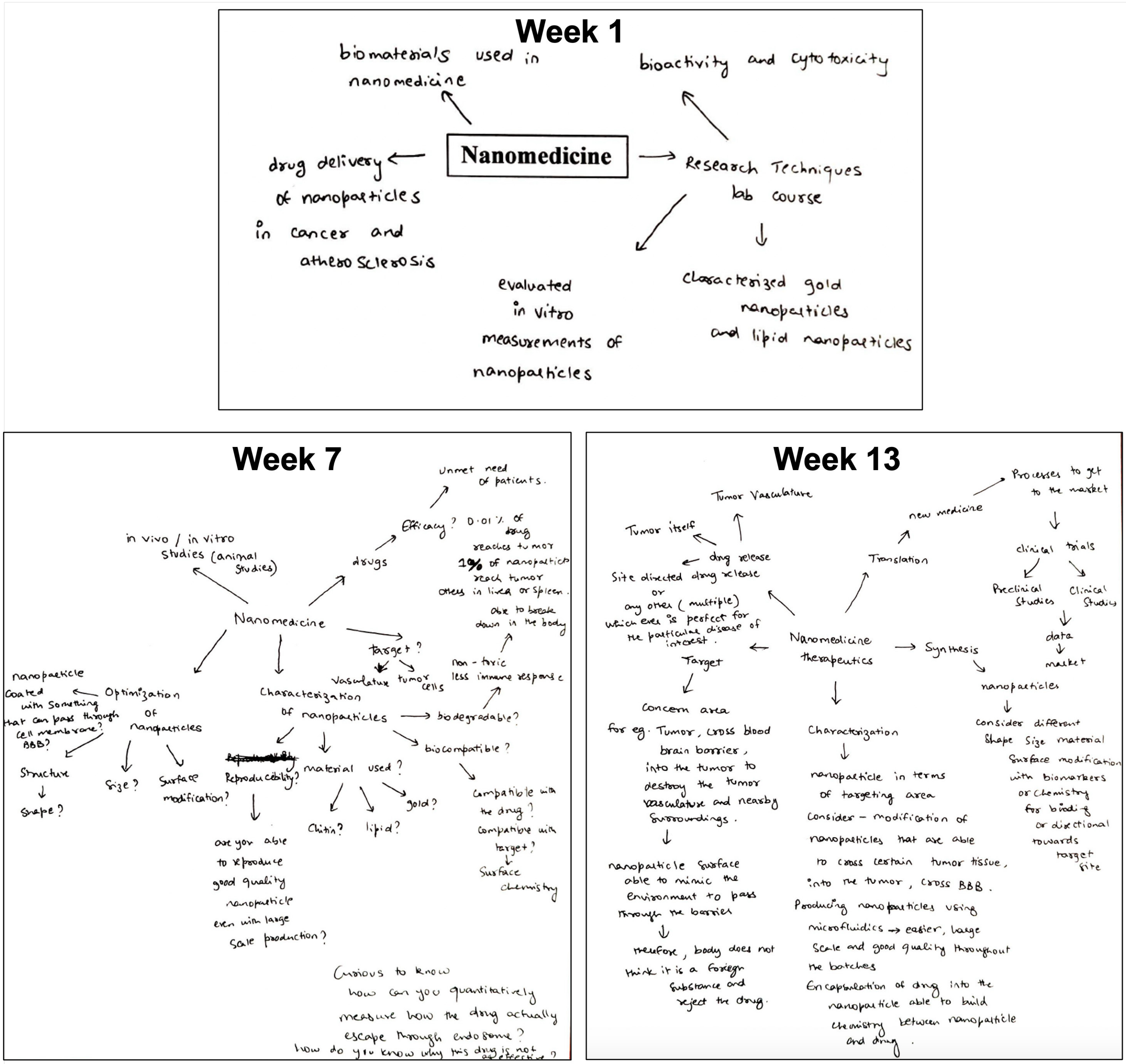


Figure 3. Representative examples of the same student's concept maps at week 1, week 7, and week 13.

### Data pre-processing

Of the 49 students, only 47 submissions were recorded for the pre-survey and 30 submissions were recorded for the post-survey. After removal of either blank or incomplete submissions, there were only 41 pre-survey and 27 post-survey submissions for further assessment.

Furthermore, not all students' submissions were able to be matched between pre-survey and post-survey either due to lack of a submission or mismatch of identification. Final sample size for matched submissions was 23 paired surveys for evaluation.

### Data classification

To assess variances in incoming student prior knowledge, students were first binned according to their incoming major (Figure 4A) based on their pre-survey response. Over 60% of students entering the course were in a M.S. in Biotechnology program followed by 10% from Biomedical Sciences and Pharmaceutical Sciences each, and the remaining 20% of students were a mix between Pharmacology, Nanomedicine, Bioengineering, Chemical Engineering and Medicinal Chemistry.

Given the high propensity of Biotechnology students, an alternative binning was conducted based on student's response to the pre-survey question, "What experience have you had in the field of nanomedicine?" to better distinguish students nanomedicine specific prior knowledge (Figure 4B). Students had to pick from a multi-selection answer key. Students who responded with "I have no experience in the field of nanomedicine" were classified as *No experience*. Students who responded with either "I have taken a course in nanomedicine" or "I have taken a course that included some nanomedicine education" were classified as *Course work only*. Students who responded with either "I am currently or have done research in the field of nanomedicine" or "I am currently or have worked in the field of nanomedicine" or "My current or previous job involved some aspect of nanomedicine" were classified as *Work experience only*. Lastly, students who had a combination of statements related to courses and work experience were classified as *Course + Work experience*.

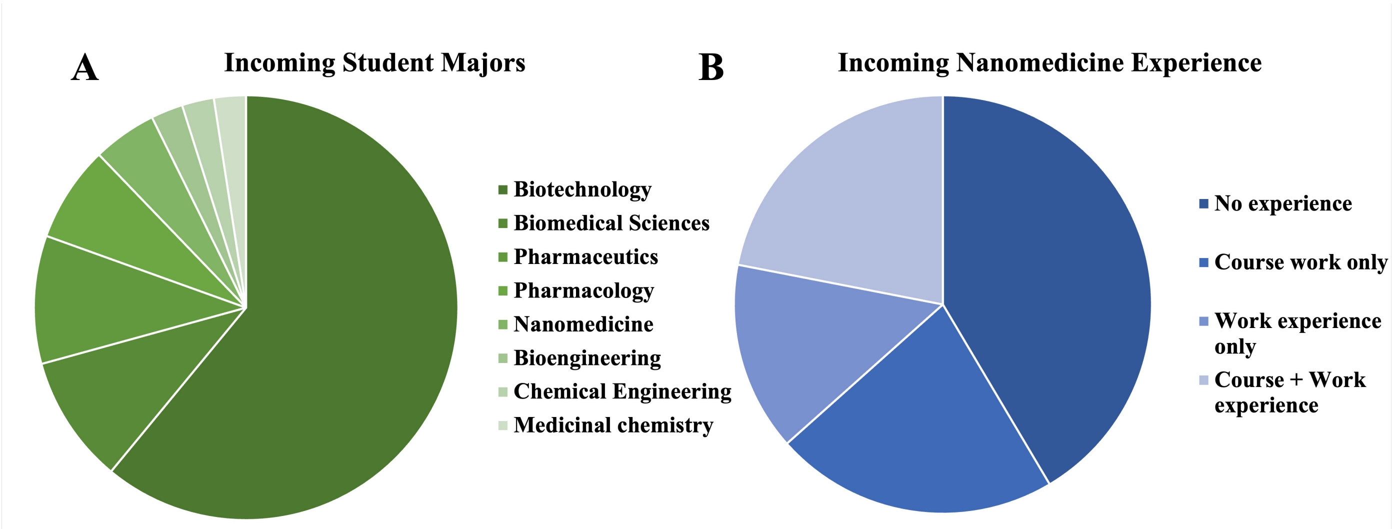


**Figure 4. A)** Classification of students based on their incoming majors. **B)** Classification of students based on their answer to the question "What experience have you had in the field of nanomedicine?" into four groups: 1) no experience in the field, 2) taken a course or part of a course where nanomedicine concepts were presented, 3) current or past work/research experience in the field of nanomedicine, and 4) a combination of course and work/research experience.

### Data analysis

Of the 23 students with matched pre-survey and post-survey data, analysis of the Likert-scale questions was conducted by grouping the questions based on which cognitive domain of Bloom's Taxonomy they address: 1) Remember = 4 questions, 2) Understand = 2 questions, 3) Apply = 2 questions, 4) Analyze = 4 questions, 5) Evaluate = 2 questions, and 6) Create = 2 questions. There were an additional 4 questions grouped together and categorized as 'General & Professional Skills'. The average of the grouped questions was compared across the different groups: No experience, Course work only, Work experience only, and Course + Work experience. It is worth noting the small sample sizes within these groups (No experience = 8, Course work only = 6, Work experience only = 3, Course + Work experience = 6) limited any statistical analysis, however trends were present.

In the post-survey an additional question was included to assess students' familiarity with concepts and modules taught in the course: "What percent of the module content was new for you?". This data was further evaluated based on prior knowledge grouping and modules were classified based where they fit in the cognitive domain of Bloom's Taxonomy.

For the concept maps, qualitative assessment of a representative student from each group was assessed to track emergence of new concepts that have been added to the map as well as building of new and/or stronger relationships between key concepts. It is worth noting that only a limited analysis of the concept maps has been conducted and further detailed evaluation is necessary to support any observations made in this very limited dataset.

## Findings

*Prior knowledge did impact student curriculum experience in lower-order cognitive concepts.*
Each week in the course is dedicated to a specific concept or a module. The course begins with lower-order fundamental concepts such as nanoparticle synthesis and characterization. As the semester progresses each module builds on the previous such as considerations of material-biological interactions in nanomedicine design and finally to higher-order concepts such as clinical translation of nanoparticles and real-world applications.

To study how my student's prior knowledge impacted their understanding of concepts presented throughout the semester as well as over the different levels of complexities, in the post-survey, students were asked how much content presented within a particular module was new to them. A subset of modules was selected for evaluation based on which cognitive domain of the Bloom's Taxonomy they best addressed to see if the complexity of the concept correlated with student prior knowledge.

As you see in Figure 5, for lower-order, less complex concepts students with no experience found 70% of the content new while students with course + work experience found only 45% of the content new. For both Modules 3 and 4 the same trend is present – as the level of experience or prior knowledge within the field of nanomedicine increases so does familiarity with presented content. The difference in familiarity between groups is lost as we move into more complex modules such as Module 5 – 10 which require the use of more higher-order cognitive thought of application, analysis, evaluation, and creating. The classification of whole modules into one category of Bloom's Taxonomy is a very simplistic approach to view the impact of prior knowledge through a holistic, macroscale lens. A more in-depth analysis of critical concepts within each module is necessary to make any conclusive statements.

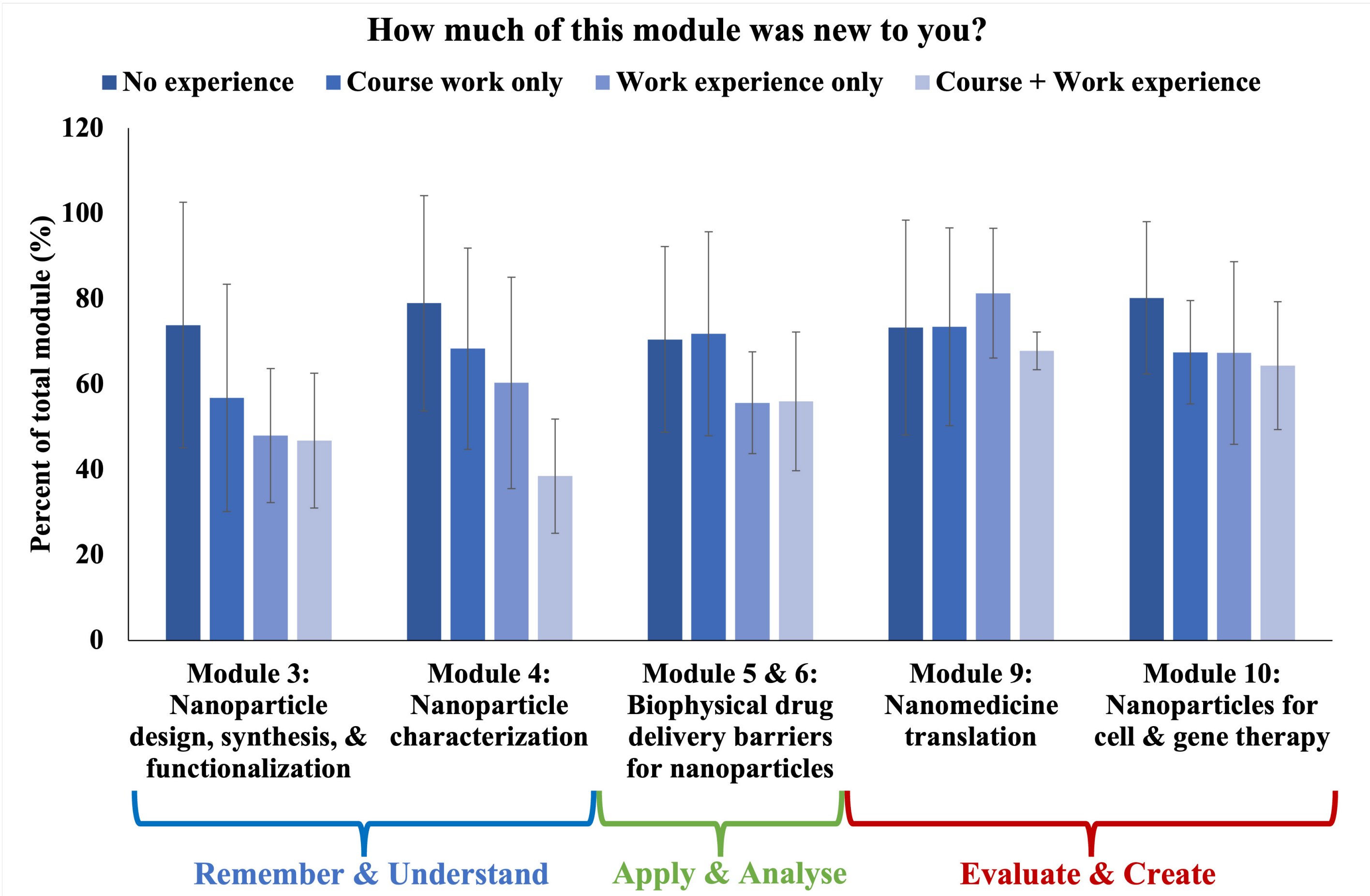


**Figure 5.** Responses of students to the question "How much of this module was new to you?" to assess if their prior knowledge impacted how they experienced the content presented to them. The modules were chosen to holistically represent a range of lower-order to higher-order Bloom's Taxonomy cognitive domains. The data are presented as mean +/- standard deviation (n = 3 – 8).

*Difference in initial prior knowledge of nanomedicine did not impact end-of-term knowledge.*
I was interested in seeing if difference in content recognition translated to difference in end-of-term understanding of course content (Figure 6A). Overall, students coming in with no experience had lower confidence in their understanding of nanomedicine concepts regardless of the cognitive domain of Bloom's Taxonomy classification. Students with either work experience only or a combination of course and work experience seemed to have similar levels of confidence in their knowledge of nanomedicine, which correlates well with the previous data of new content recognition.

It is worth noting that the highest-level of Bloom's taxonomy "Create" questions had the lowest confidence rating in all groups regardless of experience classification, suggesting that even for more experienced students higher-order cognitive thoughts are still difficult.

When we look at the post-survey responses, no difference in nanomedicine knowledge is present regardless of experience classification (Figure 6B). This suggests that either prior knowledge does not impact student understanding of course material as framed within the context of course objectives or that course content was presented in a manner that bridged the gap between my intended curriculum and my student's experienced curriculum to ensure satisfactory development of knowledge regardless of prior knowledge. Within this very small sample size, no conclusive statements can be made. Given the potential dependence of student understanding may vary by specific modules or concepts, it might be necessary to further scale the analysis to more sublevels to tease out the impact of prior knowledge. A very important clarification is that this data is based on the student's confidence in their understanding of the course concepts rather than an independent evaluation of their actual understanding. Independent assessment of objective data sources such as the mid-term and term paper may impact the result outcome.

Taking a step away from nanomedicine specific prior knowledge and evaluating more general and professional skills we see that the difference between groups is still present (Figure 6C). Surprisingly students with no experience and course work only still have a lower confidence in their general skills such as literature review, oral and written skills, and critical thinking skills. This may suggest that students with less experience may inherently have a lower confidence that needs to be considered during future evaluations. It is worth noting that the average difference in general and professional skills confidence between the no experience and course + work experience groups was 1.5 points while the average difference for nanomedicine specific knowledge ranged from 2.75 – 3.33 in the pre-survey responses. Similar to the other post-survey responses, no difference in general and professional skill confidence was identified.

*Initial concept map analysis pointed to a discrepancy between student self-assessed nanomedicine experience level and concept map data.* Initial assessment of concept maps comparing students' self-assessment of nanomedicine experience level and their first concept map identified a discrepancy on what students considered nanomedicine experience and what unconscious knowledge they actually had about the field. As evident in Figure 7, a student who claimed to have no nanomedicine experience made more in-depth concept-node connections than a student who said they had course work only or work experience only knowledge. Regardless of which subgroup a student was categorized into, all students showed general improvement in concept map visualization with each iteration.

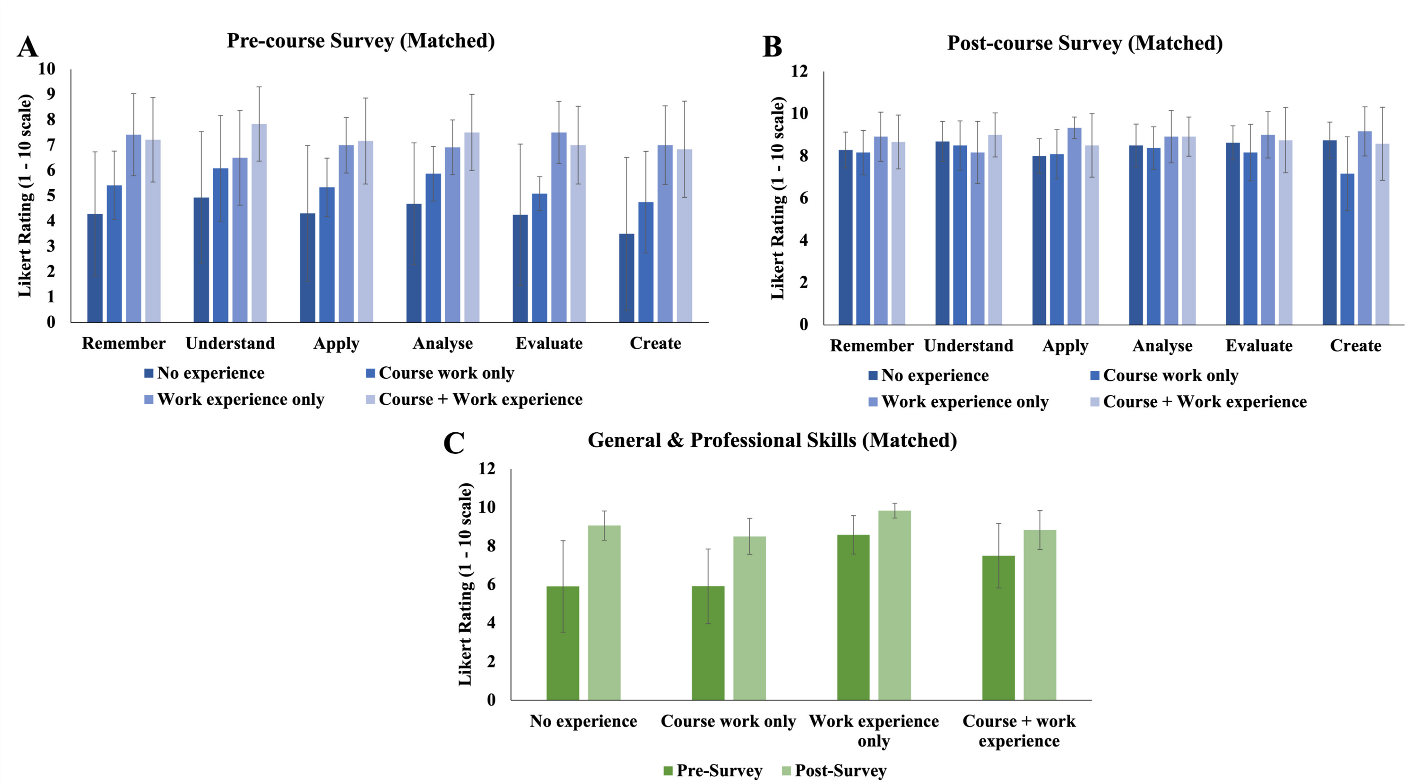


**Figure 6.** Responses of students to the nanomedicine knowledge specific Likert-scale question in the **A)** pre-survey and **B)** post-survey categorized based on based on their hierarchal ranking in the Bloom's Taxonomy cognitive domain. **C)** Responses of students to the general and professional skills Likert-scale question in the pre-survey and post-survey. The data are presented as mean +/- standard deviation (n = 3 – 8).

This may be a confounding factor due to students gaining more experience with making concept maps and may not necessarily be related to gaining more knowledge related to nanomedicine. Additionally, we see that the concept map depth of the student coming in with no nanomedicine experience grew significantly in nodes and depth compared to a student with some course or work-related experience.

It is worth noting that this trend was unique for this representative student selection, however other concept maps of students from the same group did not show as much improvement. Initial examination of the concept maps points to the need for a multi-level analysis approach. For example, although some concept maps did not necessarily growth in size, the depth of information presented grew with each iteration. There are two parts to a concept map, the actual concepts and the relationships between the concepts. Future analysis will need to incorporate this additional level of complexity to compare the association of prior knowledge and course learning objectives within the concept maps.

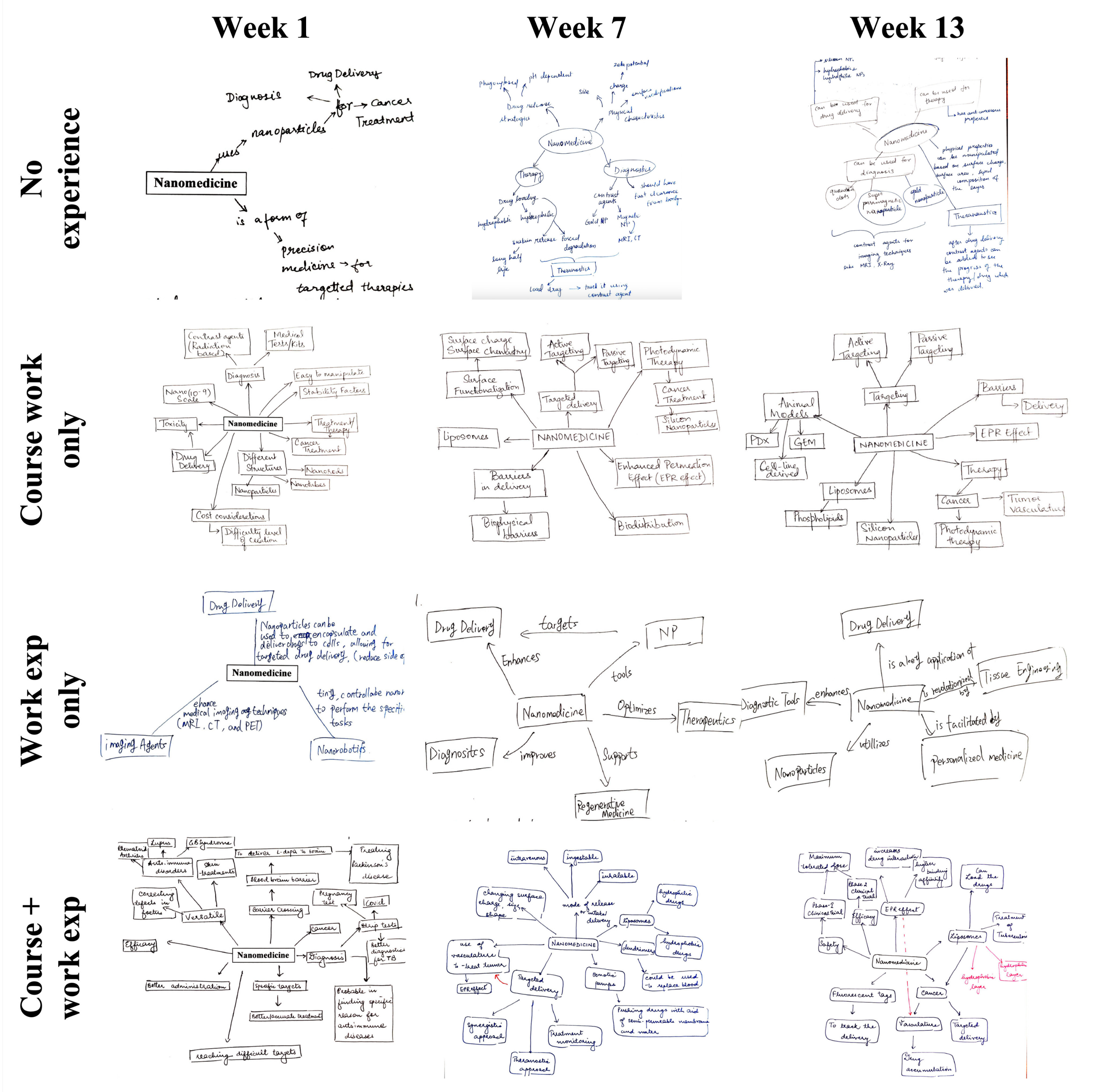


Figure 7. Representative concept maps from one student in each experience classification. Concept maps were created by students on week 1 to assess their initial nanomedicine specific knowledge and then at the mid-semester point (week 7) and end-of-semester point (week 13) to see how their understanding on nanomedicine knowledge evolved.

## Conclusion

Although further in-depth analysis and a larger sample size are necessary to make any conclusive statements, several key lessons were learned throughout the process. Dissemination of these lessons/recommendations is provided with the goal to improve study and data collection practice in the area as well as broaden the scope of the work to other interdisciplinary fields assessing how a student's prior knowledge shapes their understanding of course material to better improve transfer of knowledge from instructor to student.

1. Binning students based on only their self-assessed prior knowledge is insufficient and a more in-depth, modular and multi-leveled approach is necessary. One example is a student who claimed to have "no prior knowledge or experience in nanomedicine" on the questionnaire but actually produced a more comprehensive concept map in week 1 compared to a student who has had multiple courses in nanomedicine. Additionally, among students grouped within the same experience levels, concept maps varied highly in depth of nodes and connections between concepts.
2. Students were asked to self-assess their confidence of their knowledge in nanomedicine, which introduces well-known limitations of over self-estimation in novices and under-estimation in experts. This phenomenon is referred to the as the Dunning-Kruger effect which suggests that low-skilled individuals tend to overestimate their own ability [8, 9]. More objective data collection techniques may provide a better assessment of students' actual prior knowledge about the field and overall understanding of course material.
3. Comparison of the pre-survey confidence rating and initial concept map revealed a major disconnect between a student's unconscious and conscious knowledge that warrants further investigation to ensure we identify and activate the right prior knowledge.
4. Although I presented a brief introduction to a concept map in the course, its advantages, and an example on a topic students should have learned in high school, this was not sufficient to overcome bias in data collection between students who had experience making concept maps and those who had not. Throughout the semester most students developed stronger concept maps, however this could have been a confounding factor of gaining experience and practice making maps rather than knowledge gained.

   An option to overcome this bias would be to have an independent activity to introduce students to concept maps and assess their understanding prior to data collection. Alternatively, given time limitations within a course, we could consider adding a simple question "Do you have experience making concept maps?" which may help in further subgrouping students and account for difference in concept maps.

5. In my initial pre-survey, I asked students to anonymize/de-identify their responses by providing a 4-digit code where "The first 2 digits should be the last 2 numbers of your Northeastern University student number. The last 2 digits should be the first 2 letters of your mother's maiden name." This sparked a lot of confusion as "mother's maiden name" is a U.S. based term; given the large proportion of international students within the classroom there were several misinterpretations. Additionally, even students that understood the language may simply be unaware of their mother's maiden name or name of their mother. When asked to replicate this code during their week 7 concept map, only a handful of students were able to successfully reproduce their code. A key lesson was to simplify the anonymization key to ensure repeatability and consider cultural differences when selecting language presented to a diverse group.

My SoTL question stemmed from inquiring about how students from various educational and cultural backgrounds bring in different prior knowledge to a course or program and how that prior knowledge impacts their understanding of the curriculum. The multi-faceted nature of the data collected allows for further in-depth analysis which may reveal exciting correlations and expand the understanding of how different types of prior knowledge impact student learning and curriculum experience. Given the growing demand for interdisciplinary education, the study conducted and the results obtained can be applied broadly to other disciplines for better curriculum development and alignment.

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# MARGUERITE MATHERNE

College of Engineering


## Effectiveness of Just-In-Time Teaching on helping students achieve lower order learning goals in a Mechanics of Materials class

### Introduction and Literature

Over the course of my 2.5 years teaching, I have noticed that students do not read the textbook even though I assign sections to read from it for every class meeting. One student comment from an early course feedback survey from the Spring 2023 semester says it all: "I find the outside readings less helpful because everything is explained easily and well in class." While it is encouraging that students are learning from their in-class experience, I would prefer if they came to class with some background knowledge. If they did, I would be able to dedicate more class time to higher order cognitive processes, on Bloom's Taxonomy beyond remembering and understanding (see Figure 1). I can't do this if students haven't at least attempted to achieve lower order content mastery prior to class by engaging with the readings.

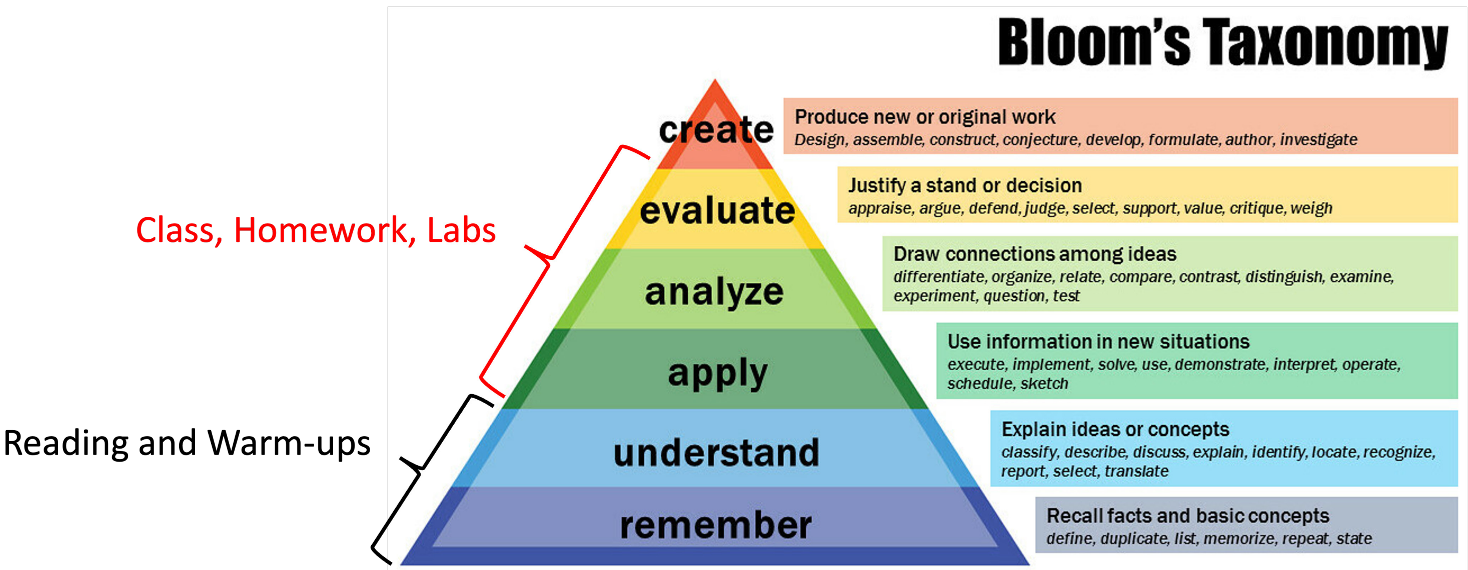


Figure 1. Readings and warm-up assignments are intended to help students achieve the lower order learning goals prior to class. Class time, problem-solving homework, and labs are meant to achieve higher order thinking skills. This diagram is shared with students on the first day of class as a springboard for discussion about the purpose of readings and warm-up assignments in their course learning. Image from Vanderbilt Center for Teaching, CC BY 2.0, via Wikimedia Commons

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I have been striving to make more space for active learning in my classes, yet it takes time to do this well. I was curious if perhaps I could free up more time for active learning if I could get students to read the textbook prior to class to familiarize themselves with key foundational concepts beforehand. Specifically, I wanted students to dedicate attention to content acquisition, the remembering and understanding aspects of Bloom's taxonomy, so that together we could devote most of our class time to applying course concepts and analyzing the results of those applications. I wondered if I might be able to use Canvas, our learning management system, to increase student preparedness.

Over the summer of 2023 I began searching the literature to learn more about how others have accomplished the same or similar goals to increase student preparation prior to class. At first, I focused on literature about flipped classrooms because I was focused on the use of technology to deliver asynchronous material, but I quickly discovered that this wasn't exactly what I wanted to do with my course. Flipped classrooms and blended or hybrid classrooms involve replacing some or all class time with asynchronous material delivered online [2]. I was not looking to replace my classroom time with asynchronous material, but rather to supplement it by supporting student learning before and between face-to-face class time.

Eventually, the literature led me to Just-In-Time-Teaching (JiTT), a pedagogy that aims to help students effectively prepare for class and develop good study habits [3]. It was first developed in the late 1990s with the advent of the internet at Indiana University Purdue University Indiana and the U.S. Air Force Academy to help non-traditional students in STEM courses effectively prepare for class and improve their learning [4].

JiTT involves assigning students a reading and an online assignment, called a "warm-up," associated with that reading. The warm-up assignment is made available to students well in advance of the due date, which is a few hours before class time. The just-in-time aspect comes from the instructor reviewing the student responses in those few hours before class and gauging what learning goals the students did or did not attain. The instructor then adjusts their lesson plan according to the level of knowledge that students will have coming into the class. I wondered if the JiTT approach might also help my students see the benefit of their pre-work because I would be able to identify areas where they were struggling and be more responsive to their homework experience in class.

JiTT has been shown to provide a scalable method for creating a regular feedback loop between student and instructor [4] and to increase student learning relative to classes that do not use this method [5]. In addition, warm-up assignments promote good study habits by requiring frequent, short spurts of studying throughout the course rather than cramming right before major exams [4]. Warm-ups also promote motivation, if used effectively. Effective use of JiTT includes explaining the learning benefits of the warm-up exercises on the first day of class, making the assignments low-stakes in terms of grades, using open-ended questions, and creating a supportive environment where mistakes are seen as part of the learning process [4].

### My Question

My original question was "How can Just-In-Time Teaching be implemented in a Mechanics of Materials class?" This question focused on how to implement JiTT within my specific teaching context. While that is useful information, it has been detailed before for very similar contexts, including in an undergraduate Mechanics of Materials course at another institution [6].

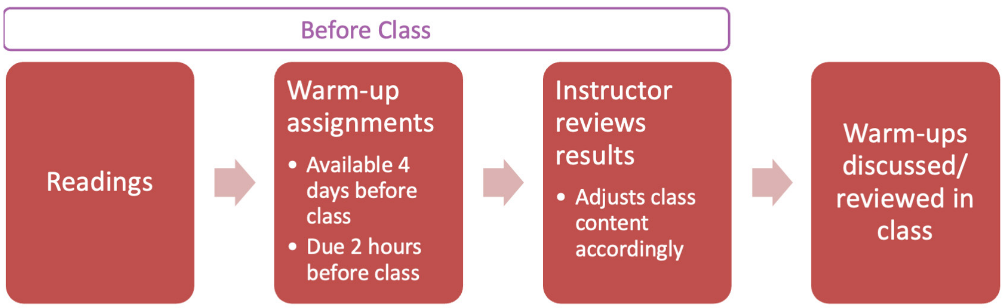
A more useful focus is how using JiTT influences student learning. This especially became apparent as the semester progressed and I read student responses to the warm-up assignments. Open-ended questions revealed student thought processes that made misconceptions apparent. I realized I could get a lot more from this data than just ideas for how to implement instruction, which led to my revised SoTL question of "What is the impact of Just-in-Time Teaching on student mastery of lower level (on Bloom's Taxonomy) learning goals prior to class?"

### Teaching Context

I began to probe my curiosity about student pre-class preparation in the Fall 2023 semester, in two sections of ME 2355 Mechanics of Materials. This is an intermediate level, lecture-based Mechanical Engineering course that teaches the fundamentals of solid mechanics. It is a lecture-based class with a separate lab corequisite. Most students are either sophomores or juniors. Each section meets three times a week for 65 minutes, one at 9:15 am and the other at 1:35 pm. In Fall 2023 the 9:15 class had 51 students enrolled and the 1:35 class had 49 students enrolled, for a total of 100 students.

The summative assessments largely focus on problem-solving. The final course grade is based on weekly homework problem sets (10%), weekly 15-minute quizzes (35%), one midterm exam (20%), and one final exam (35%). Formative assessment is largely performed through active learning in class, such as think-pair-share, polls, and small group work.

Warm-up assignments were part of the homework grade. There were two warm-ups per week, due every Monday and Thursday at 7:00 am. Each warm-up was worth 5 points, half of one problem on the weekly problem sets, making the warm-ups collectively worth 1.5% of the final course grade. The warm-ups were graded for completion, not accuracy, to discourage cheating and encourage participation. Each week's assignments and warm-ups  were released no later than noon the preceding Friday to ensure students had ample time to complete them, as depicted in the flow diagram below.




## The Project

### Designing Warm-up assignments

I designed the warm-ups by first examining the learning goals for each chapter and identifying which ones were lower on Bloom's taxonomy – these were the learning objectives I wanted to target with the warm-up assignments. I then drafted ideas for questions targeting the specific learning goals on paper.

The details for each question were fleshed out when I created the actual questions in Canvas quizzes. An example of the instructions and questions for one reading are shown in Figure 2. A variety of question types were used, including multiple choice, choose from a dropdown, fill in the blank, calculation, and short answer, which are all easily created in Canvas quizzes. In addition, every warm-up assignment ended with the question, "After reading the textbook and completing this assignment, what are you still confused about? If nothing is confusing, what part of this reading/assignment did you find the most interesting?" [4]. This is often called a "muddiest point" question, with the purpose of understanding student's current level of understanding [7].

**Preparing students for warm-ups**

Instructors using JiTT have noted the importance of preparing students for the assignments and motivating them to complete them [4]. Many warm-up questions ask for short explanations and reasoning, so there was an additional concern that students would use ChatGPT or other large language models (LLMs) to produce answers which they could copy and paste into their submissions. Although the warm-ups were not graded for accuracy, this would defeat the entire purpose of the exercise. To preempt this, I explained  he objective of the warm-up assignments to students on the first day of class with the image in Figure 1. Specifically, they were told the goal of the warm-ups was to help them achieve the lower order goals before class so class time could be spent on the higher order goals.

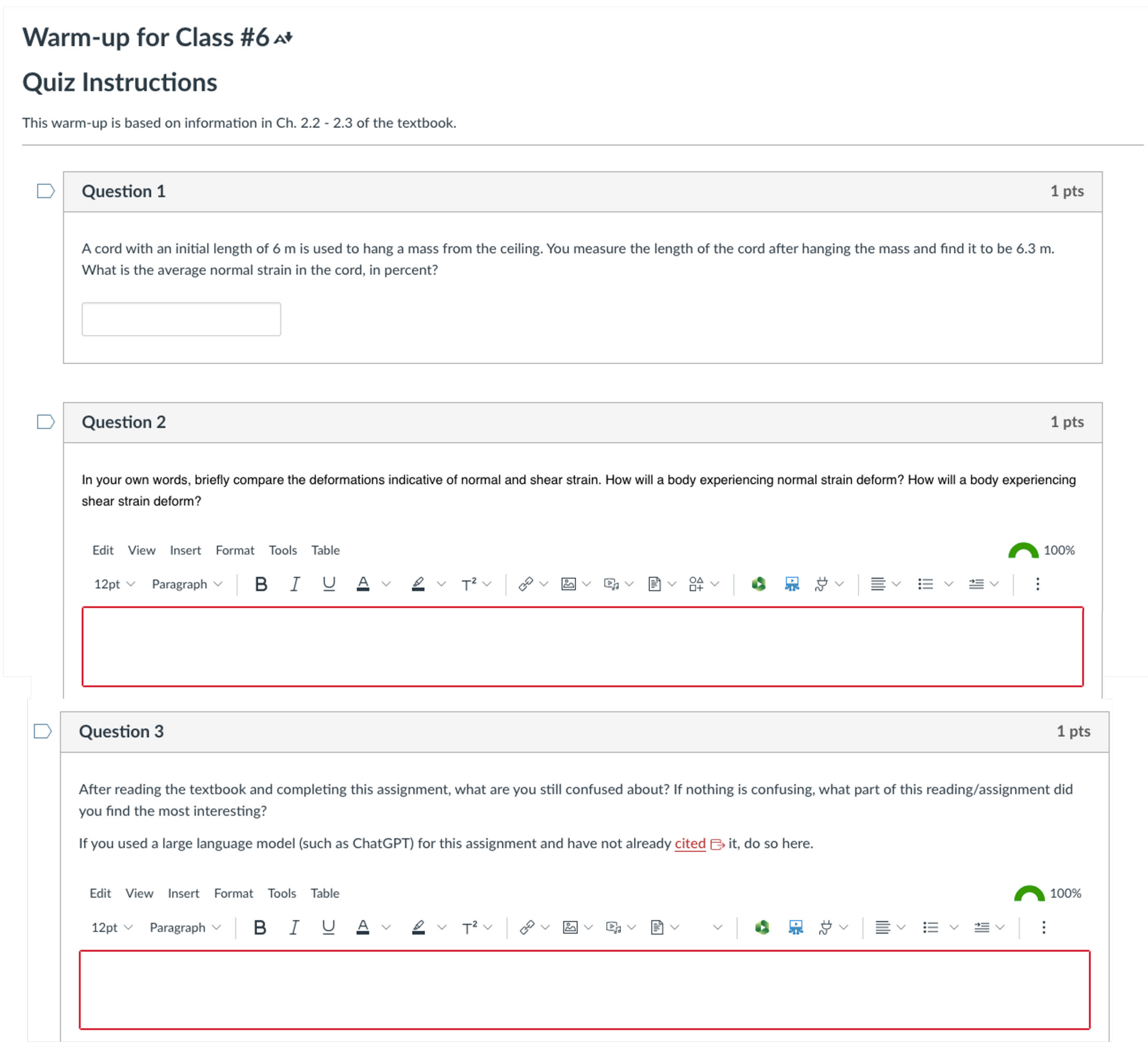



**Figure 2.** An example of a warm-up assignment created in Canvas quizzes. Question 1 is a calculation question, question 2 is a short answer question, and question 3 is the "muddiest" point and AI citation question.

**Synthesis of student responses to the Warm-up**

Analyzing 100 student responses in the two hours prior to class was a daunting task. After a few weeks of doing this, I was able to review the responses and prepare for class on my 40-minute train commute in to campus. Multiple choice or fill in the blank questions were quickly reviewed in Canvas, but the responses to the open-ended and muddiest point questions were more challenging to quickly and thoroughly synthesize. I downloaded these from Canvas into an Excel sheet for review, either by reading the responses or using ChatGPT to summarize the responses.

ChatGPT proved to be an effective tool to summarize student responses to the muddiest point question. I copied and pasted the responses to this question from the Excel sheet into ChatGPT with the prompt:

> *I asked students what they found most confusing or interesting about an assigned reading. Their responses are below. Summarize them according to what was interesting and what was confusing.*

Thankfully, the responses did not need to be formatted or edited for ChatGPT to distill rows and rows of text into a short, concise list. The first few times this method was employed, I verified the efficacy of ChatGPT's summary by doing my own thematic review of the student responses. When I compared my analysis with the output from ChatGPT, I determined that it was both an exhaustive and accurate reflection of what the students said.

ChatGPT was less effective at analyzing student responses to the short answer questions. Initially, I prompted ChatGPT to analyze responses for inaccuracies, misconceptions, etc. After reviewing ChatGPT's analysis and doing a manual analysis, it was clear that what ChatGPT produced was inaccurate and did not reflect the student's actual responses.

ChatGPT proved useful in analyzing one specific type of short answer question: those that asked students to explain a concept or term in their own words. For the most part, responses that included certain keywords demonstrated full understanding of that concept. While ChatGPT could not determine the accuracy of student responses, it could list responses that included a set of key words that would be part of any adequate explanation.

For example, I used ChatGPT to analyze student responses to the question "In your own words, explain what stress is." In Excel I concatenated a number at the beginning of each response and then copied and pasted the column into ChatGPT with the following prompt:

> *A set of student responses are below. Categorize the responses that include the following key words*
>
> *Group 1 – "internal force" and "area"*
> *Group 2 – "intensity"*
> *Group 3 – "internal force" only*

ChatGPT then generated a list of numbers corresponding to the response for each group.

**Using Warm-ups in class**

The last part of the synthesis I did during my commute was to summarize the responses to all warm-up questions on slides, starting with the muddiest point responses, which I shared at the beginning of class. For open-ended questions, I shared one or two anonymous student responses on the slides [4]. The class would then discuss the strong points of the explanation and anything that was missing or incorrect.

A peer-instruction model was used for multiple choice and dropdown questions [4]. If more than 70% of the class got the question correct on the warm-up, I spent a few minutes in class explaining the correct answer, and perhaps more importantly, why the other options were incorrect. If less than 70% of the class got the answer correct, I reviewed the relevant material and asked students to revisit the question with their neighbors in the classroom. After a few minutes of discussion, students would re-vote and/or a volunteer would explain their thinking.

For calculation questions, students were provided with the worked-out answer [8], both electronically through Canvas and as a print-out given in class. I briefly walked them through the steps and answered questions. Students were then tasked with solving a different, slightly more advanced problem with their neighbor, which I then reviewed in class after they had time to work on it on their own.

## Findings

### Student perception of warm-ups

A midcourse survey was administered to students in either week 4 or 5 of the 15-week semester and asked, among other things, to what extent the warm-up assignments were helpful to their learning. The same question and a few others about the warm-up assignments were posed again in an end of semester survey (separate from the university administered student evaluation of teaching survey). Results from both surveys as well as the mid-semester survey from Spring 2023, in which JiTT was not used, are shown in Figure 3. Student perception is overwhelmingly positive.

One of the most notable takeaways is that before using JiTT, students for the most part were not reading the textbook at all. In Spring 2023, when JiTT was not used, 42% of respondents chose N/A in answer to the question “To what extent have the before class readings been helpful to your learning?” in a mid-semester survey. One student comment says it all: “I find the outside readings less helpful because everything is explained easily and well in class.” In the Fall 2023, when JiTT was implemented, 79% of students said the readings were either somewhat helpful or very helpful in the mid-semester survey. One student quote from the mid semester survey emphasizing this is “The warm ups and readings are actually helpful to understanding concepts before they are developed in class.”

Likewise, 72% of students said the warm-ups were either somewhat or very helpful in the mid-semester survey, and 73% said the same in the end-of-semester survey. A quote from those surveys that emphasize this is: “I enjoy the warm-ups. Completing a warm-up familiarizes me with the material and helps guide me towards key concepts. I often get lost while reading engineering textbooks, so the warm-up questions help center my attention and allow me to focus on relevant/important information.”

Not everyone was thrilled with the warm-up assignments, though they were in the minority. 6% of students in both the mid- and end-of-semester surveys said the warm-ups were not at all helpful to their learning. One student wrote, “The warm ups do so much more harm than good. I often spend valuable lecture time trying to unlearn the concepts I tried to teach myself so I could complete the warm up….” This quote is particularly interesting from an instructor’s point of view, as this student’s experience is indicative of the work and frustrations that are part of the learning process. Whether or not this “unlearning” would need to happen with or without the warm-ups is an interesting question.

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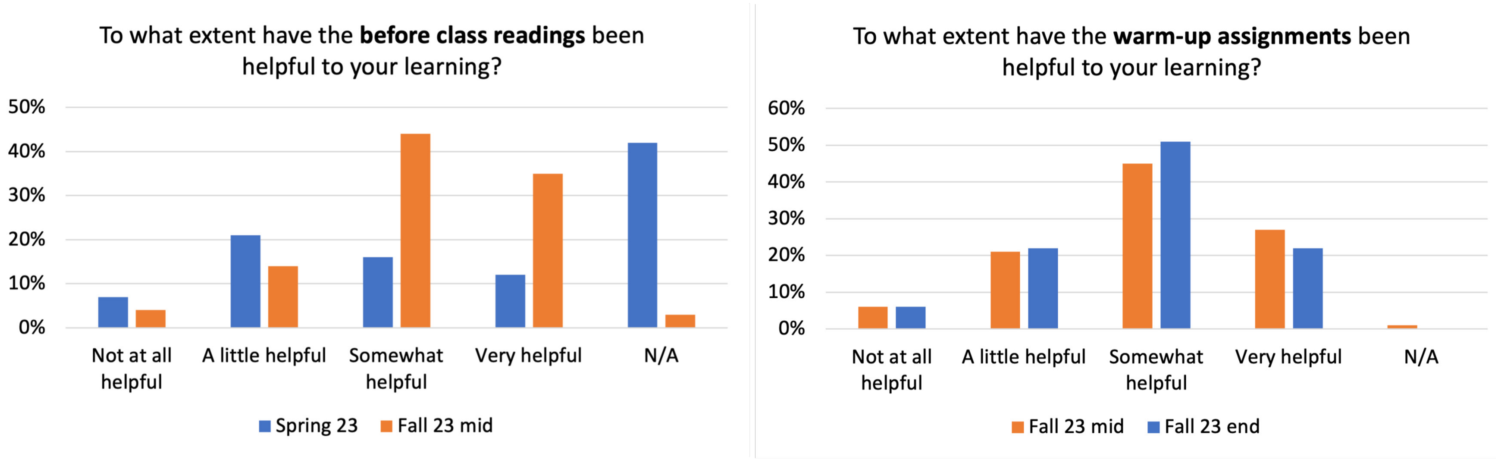


Figure 3. Student responses to feedback surveys. The Spring 23 and Fall 23 mid surveys were sent in either weeks 4 or 5 of the 14 week semester. In Spring 2023, there were no warm-up assignments. The Fall 23 end survey was sent out in the last week of the semester.

### Effectiveness of warm ups on student mastery of lower order skills

Each question in the warm-up assignments targeted a specific learning goal for the course, concentrating on the levels of cognitive process represented in Bloom's taxonomy. Table 1 shows the number and types of questions used for each level in the taxonomy. Most questions targeted either the "understand" or "analyze" level. Understand learning goals were most frequently assessed using a short answer question type, and multiple choice was most frequently used for analyze learning goals. Because these two taxonomy levels and question type pairs had the most data, they were analyzed to determine how effective they were at helping students meet the learning goals.

| | **Understand** | **Apply** | **Analyze** |
|---|---|---|---|
| **Calculation** | 0 | 3 | 1 |
| **Dropdown** | 1 | 0 | 4 |
| **Fill in the blank** | 0 | 0 | 6 |
| **Multiple choice** | 2 | 0 | 14 |
| **Short answer** | 12 | 3 | 4 |
| **Short answer/MC** | 1 | 0 | 0 |

Table 1. The types of questions used to target a level of mastery on Bloom's taxonomy.

Student responses to short answer questions were classified either individually by the instructor or with assistance from ChatGPT, as detailed previously, as wither having met the learning goal (LG), almost met the LG, or not met the LG. The results are shown in Figure 4 for a subset of these questions. For these questions, an average of 60% ± 28% of students met the learning goal, 22% ± 18% of students almost met the learning goal, and 17% ± 14% did not meet the learning goal, where the ± is a standard deviation. While the average of meeting the learning goal is high, it is also relatively variable. It is worthwhile to note that students did not meet the learning goal on only one of these questions.

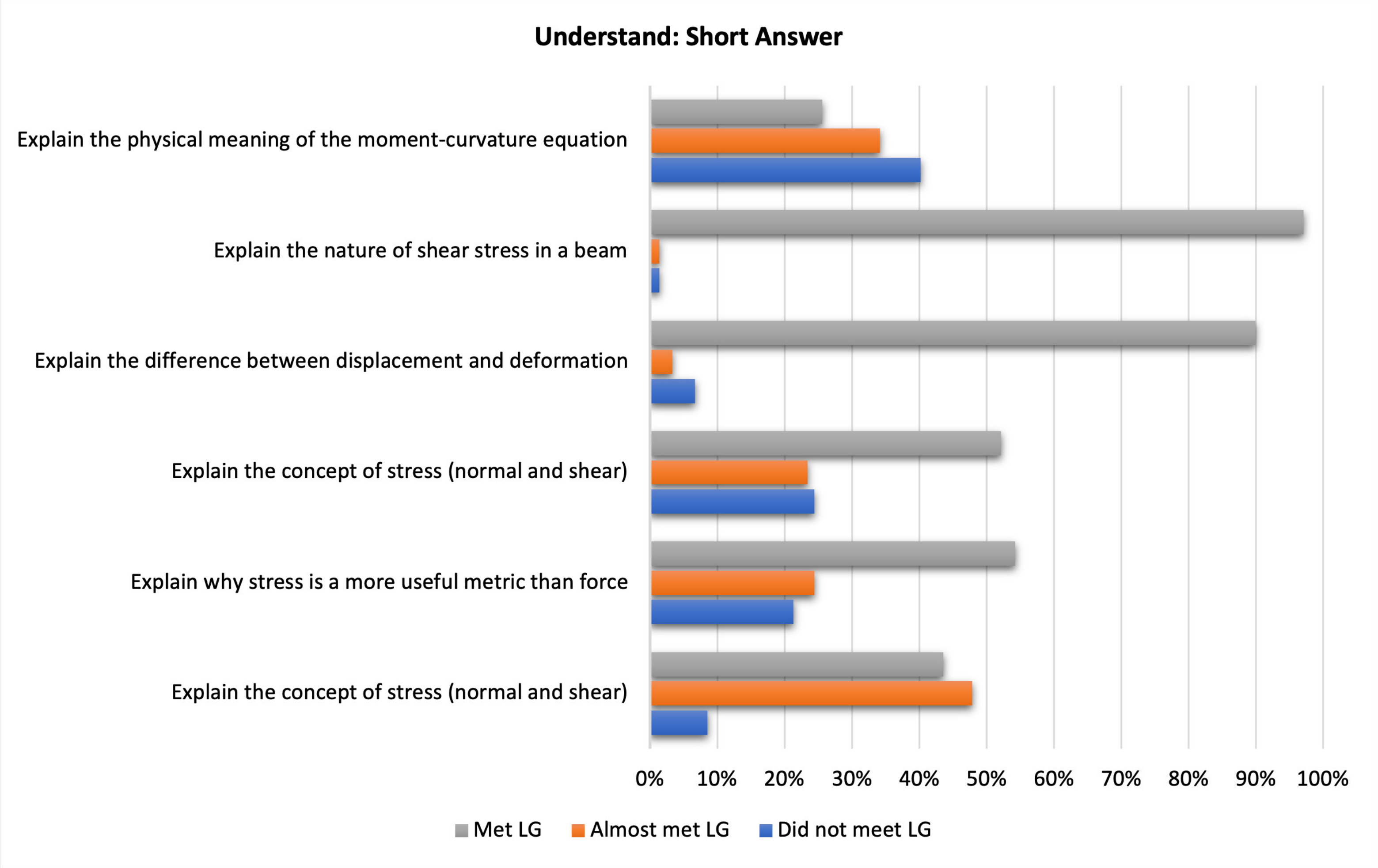


Figure 4. Percentages of responses that indicated the student had met, almost met, or not met the learning goal of understand using short answer questions. Specific goals of each question are listed.

Student responses to multiple choice questions were analyzed using the survey statistics feature in Canvas (see results in Figure 5). Some questions only had the possibilities of either meeting the learning goal or not, while others had options that indicated the learning goal was almost met. For these questions, an average of 62% ± 23% of students met the learning goal, 16% ± 24% of students almost met the learning goal, and 22% ± 12% did not meet the learning goal, where the ± is a standard deviation. Again, the greater proportion of students met the learning goal on these questions. The proportion that almost met the learning goal was small because some questions did not have an option for almost meeting the goal.

## Conclusion

Below I list some recommendations for anyone wanting to implement this Just in Time Teaching in their own class.

### Warm-up design

It is worthwhile to learn the best way to use your LMS before starting to create the warm-up assignments. For instance, creating questions in the question bank of Canvas quizzes allows for organization of questions by chapter, as well as providing a master copy of the questions that then can be imported into individual assignments.

With 100 students, I would not recommend including more than two short answer questions on one warm-up assignment. The time required to analyze those responses, especially if ChatGPT cannot be used, is prohibitive. It is possible that ChatGPT, or another LLM, could be better leveraged to analyze student responses accurately and speed up this analysis. Because this is such a new tool this author and many others are still learning how to use it.

That being said, there is a strong argument for including as many short answer questions as possible. The nature of the response type allows a richer picture of how students understand (or don't understand) the concepts being assessed than would be possible through a multiple choice, dropdown, or calculation type question. The latter question types do not yield insight to the student's thought process; they simply tell you whether they got the question right or wrong. Having the students write out their thoughts helps draw out misconceptions and gaps in knowledge.

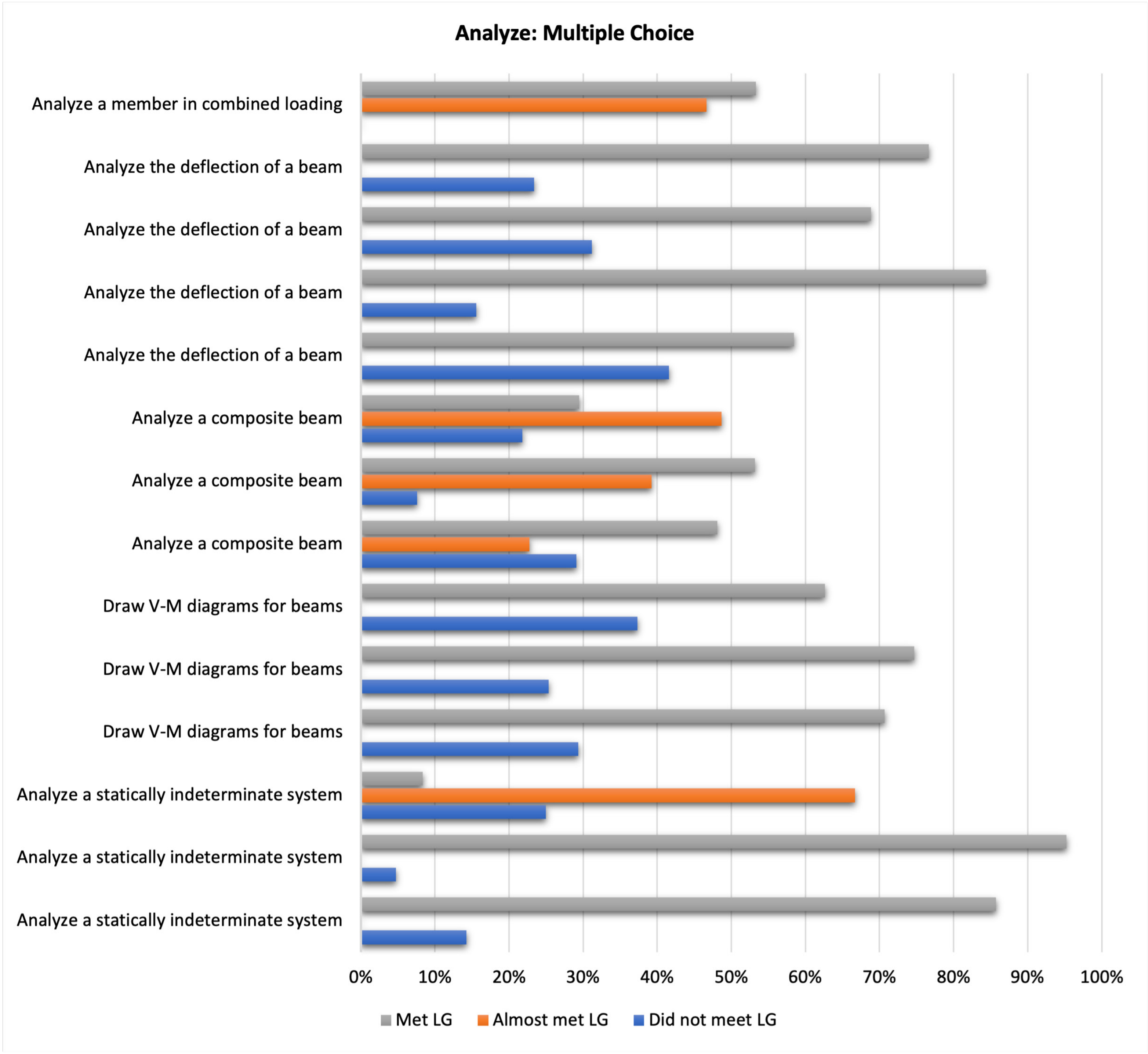


Figure 5. Percentages of responses that indicated the student had met, almost met, or not met the learning goal of analyze using multiple choice questions. Specific goals of each question are listed.

For example, one of the warm-up questions assessing understand level learning goals was "In your own words, explain what makes shear stress different from normal stress." Most students were able to identify that shear stress acts parallel and normal stress acts perpendicular. But an important misconception was identified through their responses – many of them said that the stress acts parallel or perpendicular to the force, rather than to an area. This reveals that students did not understand the connection between stress and force. If this had been a multiple choice question with options of parallel and perpendicular, it is likely a vast majority of students would have gotten it correct and this misconception would not have been revealed. This is one example of many similar misconceptions drawn out in the short answer questions.

**Using ChatGPT**

Using ChatGPT effectively took a lot of trial and error. Being as explicit as possible in prompts and not giving it room to make any judgement calls yielded the most accurate results. It is important to use prompts with clear criteria and indicate the exact word or phrase must be present. Otherwise, it made inaccurate interpretations of student responses. Prompting with these stringent instructions resulted in many responses that indicated the learning goal was either met or almost met not being identified as such, but it also did not result in any false positives. Even with a stringent prompt, it is important to review what ChatGPT provides for accuracy. With some practice, it can be used quickly and reliably to categorize student responses where key words or phrases can be identified.

**Using warm-ups in class**

Using JiTT requires a change in how instructors think about teaching and about class time [4]. Implementing this pedagogy made me realize that I was assuming students were not coming to class prepared. I detailed every definition, concept, and application as if the students were being introduced to it for the first time. During the design phase of the warm-ups, it became clear that if I expected students to use the warm-ups effectively, I needed to hold them accountable by not reviewing every concept in class as if they had never seen it before.

But there is also a risk in not spending time on concepts that students could use more support and practice with, even if they did read about it in the textbook. The feedback loop constructed by the warm-ups closed this gap. The level of student understanding was apparent in their responses, so I knew exactly what needed to be reviewed and practiced in class.

Ending every warm-up with the "muddiest" point question was also invaluable. Many times students answered a question correctly, but indicated they were not confident in their answer in the muddiest point question. This lent further insight into what needed to be touched on in class to best support their learning. Another interesting insight derived from the muddiest point question responses was that often the aspect of a reading that one set of students found the most *confusing* was found by another set to be the most *interesting*.

When most students demonstrated they had met a learning goal, the class content previously used to introduce a topic was replaced with the students' own responses to the warm-up. Examples include "Why do you think an engineer cares about stress?" or "What benefit do you think having a beam made of more than one material provides? Can you think of any examples of beams made of two or more materials?" Their responses led to a richer discussion in class.

Implementing JiTT certainly benefitted the students in this project. It helped them stay on top of the material, come to class prepared to learn, and helped them see how useful their textbooks are. It also acted as a catalyst for creatively thinking about how an instructor should use class time. Students asked deeper questions in class and showed a lot of interest on why engineers should care about these concepts. Their perception of the assignments was overwhelmingly positive. Short answer and multiple-choice type questions were moderately successful at helping students demonstrate mastery of low-level learning goals. The most important take-away from each assignment was that I knew exactly where the students' level of knowledge was, and class time could be tailored to what the students needed.

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AYCE YESILALTAY
College of Science

# Student-led questioning within peer feedback groups as a means for increasing student confidence in analyzing scientific literature

## Introduction and Literature

My pilot study examined the effect of peer feedback on students' confidence when implemented within a collaborative learning environment guided by student-generated questions. Participants in this study were first-year college students enrolled in *Inquiries in Biological Sciences*, a discussion-based course focused on reading, analyzing, and communicating primary scientific literature in biomedical sciences.

When I first started teaching this course, I was most puzzled by class dynamics around participation and asking questions.  Students would speak freely on subjects such as study strategies, presentation techniques, self-check, and wellness, but grew more cautious when discussing science and answering questions.  Student participation in science courses can be impeded by their fear of negative peer evaluation [1]. They do not want to make mistakes in front of classmates and are therefore reluctant to take intellectual risks. Fear of negative evaluation by peers also affects students' willingness to ask questions. I have been searching for strategies that might help circumvent student hesitation around asking questions, participating, and taking intellectual risks.  I wanted to have students to participate in discussions more freely and to normalize the asking of questions.  I speculated that mechanisms for lowering anxiety and increasing confidence needed to be built into the learning experience design, through both pre-class assignments and in-class collaborative work.

Collaborative learning techniques can have a positive impact on student self-regulation and improve retention of information [2]. A plethora of studies indicate that involving students in small group activities prompts them to participate more readily in the classroom.  I was intrigued by a technique called "holding discussions without speech" that I discovered in The *Discussion Book: 50 Great Ways to Get People Talking* [3]. The authors propose that fruitful discussions can be held without anyone needing to raise their hand. Ideas can be contributed via smaller group discussions, by text, or by writing on a shared poster board. This was an eye-opening concept for me as an educator because it postulated that in-class participation, while a marker of student understanding, does not always have to take place verbally in front of the entire class.

I wondered if small group discussion might prompt my students to ask more questions. A study grounded in the classroom observation protocol COPUS (Classroom Observation Protocol for Undergraduate STEM) found that undergraduate students who engaged in small group discussions before answering questions spent more time asking and answering questions during subsequent lectures [4]. It was interesting to note that simply giving students clicker questions did not automatically make the classroom an "active learning" environment. Students who were asked to engage in discussion prior to answering clicker questions asked more questions during the lecture.

I also noted the value of using individual work (e.g., problem solving, reflection) in conjunction with group engagement. In one chemistry recitation class, students were given sample chemistry problems relevant to the coursework that they were asked to answer in a cooperative group setting [5]. Then students were given some problems to solve on their own before the next class. When students came to the next session, their answers were assessed by the TAs and, after receiving feedback, students discussed their answers within a group-based cooperative discussion format. After the group discussion, students were allowed to change their answers and improve their grades, then worked again in groups on another set of questions.

This group-individual-group (GiG) format was compared with another group (control group) where students attended recitations in a traditional format. Students who engaged GiG format recitation sessions performed better on all exams throughout the course and reported increased satisfaction in evaluations about the course and recitation sections. When designing small group learning experiences, this research helped me recognize the importance of beginning with individual work, followed by immediate feedback and an opportunity for students to improve their work in a cooperative setting, in promoting student learning. It was also reassuring to me to see that the GiG format increased both student academic performance *and* satisfaction.

Small group learning has benefits for students at all levels, promoting deeper learning, longer knowledge retention, improved self-confidence, and enhanced self-motivation [6, 7]. For deep learning to be attained, students need to develop self-awareness of their own questions on a given topic, learn how to ask questions, and have the ability to receive feedback.

Peer feedback in a small group setting where students work together creates an atmosphere of positive interdependence in which students develop these important deep learning skills. I speculated that small group learning, grounded in student-generated questions and peer feedback, could provide my students with an opportunity to practice their scientific communication skills and deepen their learning in a safer environment without the fear of feeling judged.

In addition to my background reading about the value of small groups on active engagement, I also considered what kind of student-produced artifacts might help me understand the impact of the question-posing, peer feedback strategy I planned to implement in my study. A major goal in my course is to improve student capacity to read, analyze, and explain scientific literature. Concept mapping is a widely used educational strategy for helping students recognize patterns and hierarchical relations between topics and display their knowledge of connections in a meaningful schematic. In the book *Thinking ,Fast and Slow*, Daniel Kahneman conjectures two systems of thinking that operate contemporaneously in our minds [8]. "System one," our fast and intuitive thinking system, is fast yet prone to making errors. "System two" is our deeper, more analytical system of thinking that is less likely to make errors, but operates more slowly. Concept maps were used to prime students to think more deeply about the paper on their own before discussing with peers. Indeed, the process of analyzing scientific articles lends itself to schematic organization of background, experiments, figures, graphs, and experiments, and therefore concept maps could provide me with insight into how students were interpreting what they were reading [9], and how that capacity for interpretation developed during the course. Zimmerman's theory of metacognition promotes the benefit of initial, individual preparatory activities phase that require planning [10]. Building on that idea, I incorporated a pre-class component into the study in which students read scientific literature, generated concept maps, and through that mapping process identified questions about aspects of the literature that they found confusing. I tracked the development of student concept maps across their engagement in the course.

### My Question

The goal of this study was to help students gauge their sense of increasing proficiency, normalize help-seeking behavior, and leverage self-reported gains in confidence to increase student engagement in class. I decided to focus my study on collaborative learning techniques because that broad category of teaching strategies has been demonstrated to help students self-regulate their learning, fostering both "positive interdependence and individual accountability" [11]. Small group work was the collaborative learning strategy, but my curiosity revolved around increasing student comfort with asking questions for which they did not have answers, thereby improving confidence in relation to reading and analyzing scientific literature. The question I posed was "**What is the effect of peer feedback, grounded in student questions, on student confidence in a collaborative learning environment?"**

## The Project

My review of the literature helped me recognize the importance of proper scaffolding, monitoring, and instructor support when engaging students in small group work – that design and implementation of the learning experience was important. The learning experience I created unfolded in three phases: preparatory, executive, and closing.

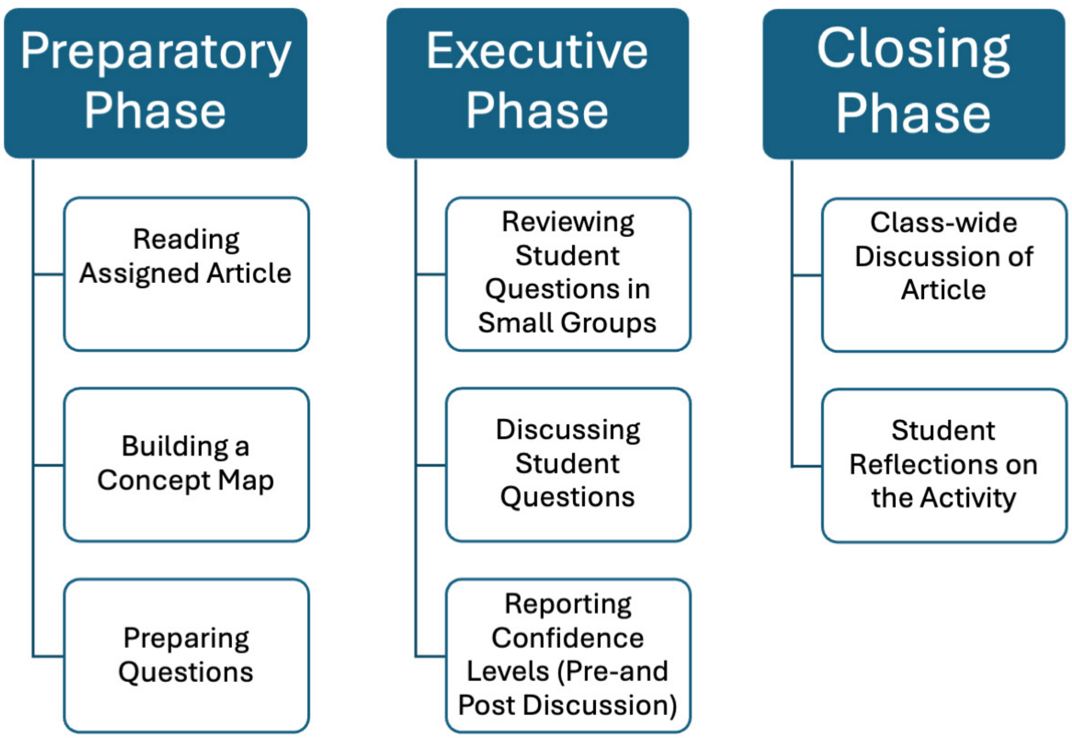


Figure 1: Three phases of the learning experience.

This carefully constructed sequence began with pre-class work to promote individual analysis and question identification, followed by in-class small group work to provide peer feedback on student questions. This guided students through a process of both generating their own questions and attempting to answer questions posed by other students.

The activity was repeated four times with small changes in each iteration. The changes included having students analyze different parts of the paper to be analyzed that week (e.g., abstract, introduction, figures). Each student created an alias for the exercise and used the same alias throughout the semester instead of their real names. This allowed me to track individual work while maintaining student anonymity. Students reported on their level of confidence following each cycle of question and answering generation so that both they and I could gauge their perception of self-development. I compiled and did a thematic analysis of these reports. For the purpose of this study, one of the four cycles was not usable because some students neglected to report their confidence levels at the end.

**I. Preparatory Phase**

In the preparatory phase, students read part of a scientific article, created a concept map of that part, and articulated two questions about any aspect of the article that was unclear or confusing to them. Prior to the mapping exercise students received instructions on how to create a concept map. They were also provided with online resources and examples of concept maps prepared by students from prior semesters. My goal in doing this was to scaffold the development of student understanding of concept mapping as a process so that both they and I could focus our attention on their analysis of scientific literature.

Students were prompted to upload all their work a few hours prior to class. All student questions were compiled and printed on paper to distribute in class.

**II. Executive Phase**

The executive phase took place in class when students were divided into small groups consisting of three or four people. Each student was supplied with a printout of all student questions about the abstract of the paper to be analyzed (not just the questions posed by those in their group). Students were then asked to review the questions on their own and to report how confident they were about being able to answer each question on a Likert scale (1 not confident at all, 4 moderately confident, 7 extremely confident) on the paper. Students were then prompted to discuss the questions and possible answers to the questions amongst themselves for 20 minutes. During the discussion they were also asked to share their concept maps and show each other where they thought each question belonged on their concept maps. Students had an opportunity to review their concept maps, see how everyone prepared theirs, and better visualize their questions in relation to the article's content and concepts. At the end of the 20 minutes, students were asked to rate their confidence on being able to answer the same questions once again post-discussion.

**III. Closing Phase**

Students were asked to write and submit reflections on the activity after it had concluded. Class discussion of the paper after the peer feedback activity allowed answering any remaining student questions and addressing any student misconceptions.

## Findings and Lessons Learned

**Preparatory Phase Insights:** A careful review of student concept maps provided me with insight into how student analysis of scientific literature evolved throughout the semester. Some students' concept maps became progressively more complex with each iteration. For example, the work of Student #1 is represented in Figure 2, A-C. Map A is the student's first concept map prepared in a pre-class assignment. Maps B and C show the student's increasingly complex representations created for their second- and third-pre-class assignments. In contrast, the maps of other students did not increase noticeably in complexity, but rather became better organized. For example, the first concept map D created by Student #2 below reveals a grouping ideas and arrows that indicate perceived relationships, but subsequent maps by the same student (E, F) demonstrate increasingly schematized representation of the analyzed article.

By the fourth cycle of analysis, both students created maps that resembled their third (complex or organized). It is possible that by the third iteration, students had developed an analytical process that made sense to them.

**Executive Phase Insights:** Analysis of student confidence levels indicated that their confidence increased in each exercise when averaged per question (total of six questions were evaluated per exercise in groups of three students (Fig. 3). Each student prepared two questions per article. The exercise was repeated four times throughout the semester. The change in student confidence seemed similar across the three exercise regimens. The average level of student confidence expressed in Likert scale (mean value of confidence levels expressed for six questions per nine students for three separate exercises out of 7 ± standard deviation) for answering each other's questions pre-discussion was 2.29 ± 0.18. After discussion, the average confidence levels increased to 3.48 ± 0.28 ($p<0.01$ in Student's t-test).

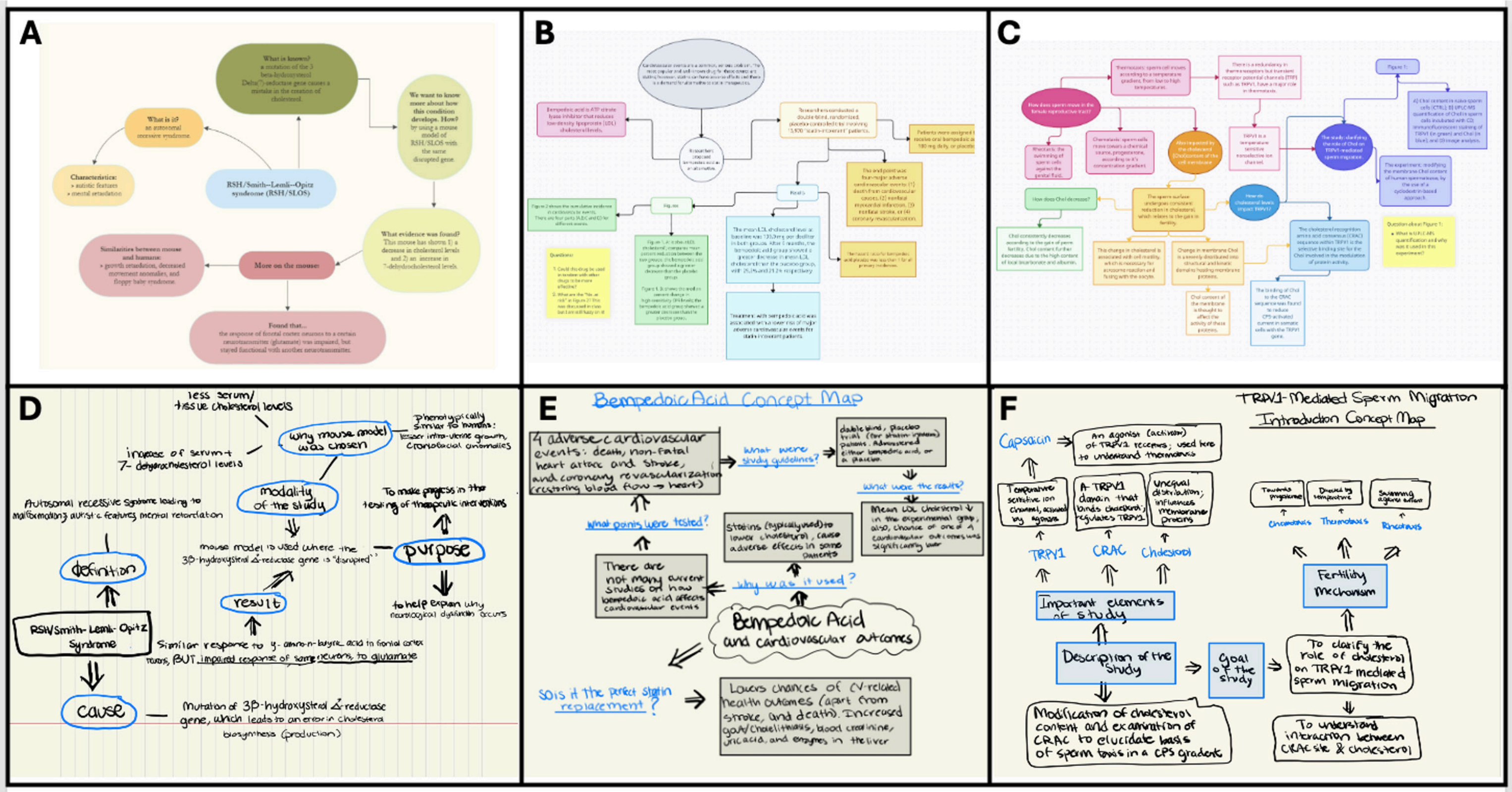

**Figure 2:** Examples of student work showing how concept maps evolved throughout the semester in complexity (Student #1 panels A–C) or organization (Student #2 panels D–F)

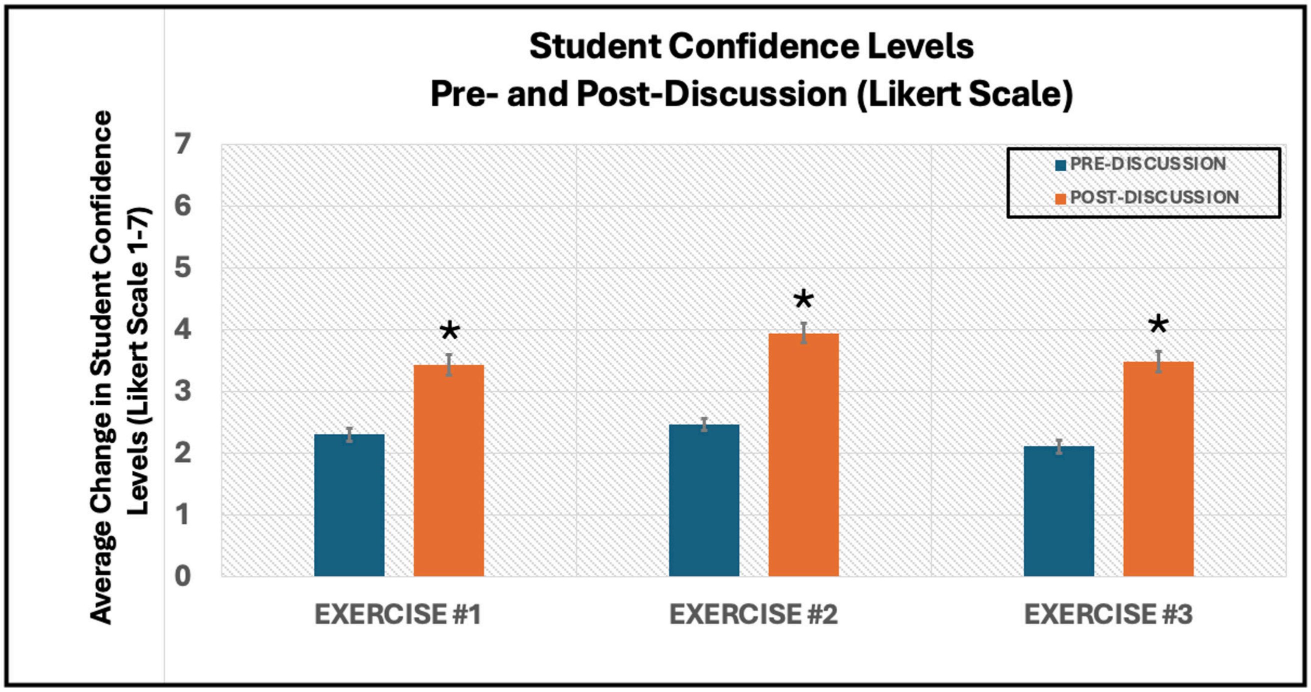


**Figure 3:** Average changes in student confidence levels per question are shown in Likert scale (1-7) for pre-discussion (blue bars) and post-discussion (orange bars) confidence levels in three separate exercises in the semester. Asterisks indicate p value < 0.01 in a two-tailed paired Student's t-test. Error bars indicate standard error of the mean.

**Closing Phase Insights:** Initial student reactions were extremely positive. Students reported that they enjoyed discussing the paper with their peers, as evidenced by the following comments:

> "I do like the idea of trying to figure out the article and ask questions before going through the slides because it allows me to try and make my own inferences before hearing the correct answers."

> "I found it surprising how some of us had very similar questions to each other, which made me feel a lot more comfortable about the fact that I had some doubts. It helped me relate to my classmates and allowed me to truly realize that others can struggle too."

> "I was surprised at how quickly I had my questions answered by my group members and how quickly I was able to answer some of their questions."

> "...since I didn't really process the paper in-depth as an individual, I didn't know how much I knew before working with my peers. Afterwards, I realized I knew more about some of the nitty-gritty details than I would have thought. ...I thought this experience may have been more challenging than it was. Since we all have different strengths, collaborating together and combining those different strengths made analyzing the paper much easier than expected."

> I was surprised by how much we were able to clarify as a group by sharing our understanding. However, it was different because it felt more streamlined; also, we had to share out our answers to the class after. It was consistent though, because everyone had gaps in their knowledge but slowly we helped to fill them. I really like this sort of activity because we get to do it individually, talk it out in a group, and then discuss as a class."

Students reported that they enjoyed reading each other's questions and were pleasantly surprised to see that they all had similar questions and that they all had similar struggles. This indicates that the goal for normalizing questions had been attained. Students were also surprised at how they were able to make progress on understanding the article when they worked on it together, indicating that the group component of the project helped increase confidence in the quality of their answers to questions.

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