2026 ASEE ANNUAL CONFERENCE June 21–24, 2026 | Charlotte Convention Center, NC

Host Sponsor UNC Charlotte

Paper ID #53416

Connecting Materials Science to Industry: A Project-Based Approach to Enhancing Student Engagement and Learning

Dr. Sharon K. Thorne, North Carolina State University

Dr. Thorne is a dedicated educator and experienced engineer who joined North Carolina State University less than two years ago as a faculty member in the Department of Materials Science and Engineering. Before transitioning to a university setting, Dr. Thorne taught at several community colleges, gaining valuable experience in accessible, student-centered education. Her professional background includes various roles across multiple engineering disciplines including a research engineer position working to enhance material properties in sensor technologies and using modeling software to analyze emergency scenarios at nuclear power plants. Currently, Dr. Thorne is focused on advancing effective teaching strategies for large classroom environments and promoting cross-disciplinary understanding of materials science.

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Abstract

Motivating students from other engineering disciplines to grasp the important concepts in materials science can be difficult, especially in a large classroom. This study examines the effect of implementing a semester-long poster project to aid students' understanding of basic concepts covered in lecture, including the students' understanding of the relationships among material structure on a microscopic scale, processing, and properties. The project was designed to engage undergraduate students through industry-specific, materials-focused research with applications related to various engineering disciplines. Analysis of the student reflections revealed that students enjoyed the freedom to select a material of their choosing and students were able to relate the material's microstructure, processing steps, and properties to the application. Results overall showed that students were more engaged in the classwork and they were able to connect concepts from lecture to real world applications. This report describes the design and implementation of the poster project as well as results of the student submissions and reflections.

Introduction

Teaching an introduction to Materials Science course to a large group of undergraduate students in various engineering disciplines can be difficult. The plethora of complex concepts and information that needs to be covered in a one semester course is overwhelming for students and challenging to teach, especially when there is large audience of diverse interests. Previous studies have analyzed traditional lectures (chalkboard), overhead projector notes, and online lectures vs PowerPoint presentations with mixed results [1]. Some have argued that college students are not gaining necessary skills such as critical thinking and complex reasoning [2]. Active learning was investigated as an alternative to traditional lecture-based learning in an introductory engineering statistics course. It was found that active learning can help to increase retention for students with average or below average scores, even 8 months after taking the course [3].

Keeping students in a large classroom captivated requires the use of engaging pedagogical tools [4]. Several papers have investigated the use of PowerPoint presentations as compared to traditional methods, such as notes on a chalkboard, whiteboard or transparency [5],[6],[7]. It has been shown that PowerPoint presentations may improve student attitudes toward the instructor and class presentation. However, there is no conclusive evidence that PowerPoint presentations improve short-term or long-term memory [5]. When compared to notes on transparencies, PowerPoint slides were noted as being preferred by students but the nature in which the information is given on the slides can impact the student's comprehension of the material [6]. Other studies show that traditional lecture methods surpass PowerPoint presentations in both material comprehension and overall teaching/learning effectiveness with results shown to be statistically significant [7].

Delivering notes to students is not enough for them to retain the information. Felder [8] has argued that engineering education is facing numerous deficiencies, including inadequate coverage of fundamental concepts and real-world applications. It is critical that engineering graduates gain skills in communication, teamwork, ethics and critical thinking. Traditional teaching methods may have changed the method in which they are delivered, but the technique still resembles that used in the 1960s. By incorporating problem-based learning methods, active learning techniques such as group exercises and discussions as well as short, interactive classroom activities, students will be more engaged, gain a better understanding of the material and improve retention of the material [8]. Active learning methods such as group projects and cooperative learning-based techniques have been shown to improve retention, even eight months after the course with students at average or below average grades [3]. A study comparing active learning techniques such as the Jigsaw method and H5P interactive videos showed active learning techniques should be integrated thoughtfully alongside traditional methods to support sustained learning outcomes [9]. It has been shown that creating a project that encourages students to be creative while still connecting concepts from class encourages self-regulated learning and critical thinking [10]. Furthermore, it has been shown that courses that utilize active cooperative learning which address diverse learning styles, outperform in terms of retention and graduation rates, when compared to students taught with traditional classroom techniques. [11].

Different types of problem-based and project-based learning techniques as well as their implantation in the classroom are explained by Kolmos [12]. Poster assignments are just one example of a problem-based approach and are a widely used pedagogical tool in STEM courses [13], [14]. Some advantages of creating student poster assignments include active learning, student engagement and conceptualization of difficult concepts. By creating a poster with information pertaining to the class, students are able to explain complex concepts to their classmates, which reinforces their understanding of the material and enhances their communication skills [15]. It has been shown that poster projects in STEM courses receive positive responses from students who reported that the project allowed them to explore scientific topics visually and creatively, therefore enhancing their learning experience. [16].

This paper gives details of an individual digital poster project assignment given in large-scale introductory materials science classes. Students were allowed to pick a material of their choice related to an industry in North Carolina. Knowledge learned in class regarding microstructure, processing, and properties were then reflected in the material chosen by the student and displayed on their poster. The project was divided into several parts which incorporated research skills, questions in which the students can reflect upon their work, a peer-review aspect and a final poster format that was easy to grade on a large scale.

The main goal of this assignment was for students to explore a product that uses a material of interest to them, apply classroom concepts to describe the material and to display their findings in a creative way. The second goal of this paper was to qualitatively assess the impact of student poster submissions as it relates to their understanding of basic concepts discussed in class. To evaluate the effectiveness of the poster assignment it is suitable to explore several questions, including:

- Will students in this course (especially non-materials science majors) understand the importance of studying the basic concepts of materials science?
- What aspects of materials science are most important to the students, as it relates to their engineering discipline of choice?
- Do students appreciate an assignment in which they have the freedom to choose their own topic?
- Will the poster assignment promote the learning of concepts discussed in class?
- Can students relate basic material science concepts discuss in class to real life examples?
- Can the students get enjoyment out of a poster project assignment?

Assignment Design

An Introduction to Materials Science course (MSE 200 and MSE 201) at North Carolina State University was used for this study. This course is one semester long with two meetings per week (each 1 hour 15 minutes long). Most of the students are from disciplines outside of the materials science major including, but not limited to, mechanical, civil, industrial, textile, aerospace, environmental, chemical, and electrical engineering. Three classes of students were evaluated, totaling 366 pupils in which 358 total projects and self-reflections were turned in by the end of the semester. With the approval of the university's Institutional Review Board (IRB), consent was obtained from the students at the start of the project to gather data from reflection questions toward the end of the project.

Students were given detailed instructions as well as a rubric for the project in the first few weeks of class. Throughout the semester, the project is scaffolded through a series of graded project parts that gradually build toward the creation of a final digital poster. It has been shown that multiple components with staggered due dates, including a peer review session to encourage feedback and revisions before final submission, allows students to make appropriate changes before turning in their final assignment [16]. The project was worth 9% of the student's overall grade.

These interim assignments ensure students develop their ideas with clarity and depth, receive formative feedback, and remain engaged with the course content. Peer review was incorporated into the process, encouraging constructive critique and iterative improvement. A reflection assignment concluded the project, prompting students to consider what they learned and how the project deepened their understanding of key concepts covered in class. The assignment was broken up into six parts as displayed in Table 1.

Table 1: Parts of the poster assignment that were submitted throughout the semester.

Project Part
Part 1: Industry, product and material selection
Part 2: Research microstructure, processing, properties and application
Part 3: Rough draft of poster
Part 4: Peer review two other posters
Part 5: Reflection questions
Part 6: Final poster submission

In the first assignment students were instructed to choose an industry in North Carolina, an object from that industry and a specific material used in the object that is of interest to the student. The material they chose would be the focus of their poster. Material categories chosen by students included pure metals, metal alloys, ceramics, polymers, and composites.

Part 2 of the project required students to investigate the material's microstructure— including microscopic images—along with the processing methods and resulting properties. The microstructure for a pure metal would be a particular crystal structure, such as face centered cubic or body centered cubic and either single crystal or polycrystalline. Metal alloy microstructures would be described from the different phases and how much of each phase one might find on a phase diagram for the main components of that alloy. These phases may also be altered by a processing step such as slow cooling, fast cooling or heating. The microstructure of ceramics would be the main single crystal structure such as rock salt, polycrystalline crystal structure type or completely amorphous with an emphasis on the elements in the ceramic. Polymer microstructure descriptions would be the layout of the elements in the polymer chains. For composite materials, the microstructure describes the two main types of material involved and how they are structured, including the matrix material, fiber or particle material and how the fiber or particles are arranged in the matrix. The processing steps would then describe how the material is made, including any heating, cooling or tensile/compressive forces that are applied to get the material into the particular shape in needs for the final product. The properties requested for the material include mechanical properties such as yield point and elastic modulus as well as any other properties that deemed important for the application, such as electrical conductivity, transparency or deflection. Moreover, students would analyze how these properties make the material ideal for its application in the selected product.

In Part 3, students put all of their information together in a pre-formatted draft poster. The draft poster was peer reviewed in Part 4 in which each student was assigned two posters to review and leave constructive comments. Reflection questions were answered in Part 5 and Part 6 was a final submission of their poster given consideration of comments from the instructor and their peers.

Results and Discussion

The study collected and analyzed data from three course offerings, with a total of 356 participants. Statistical methods were employed to evaluate trends in the industries, products, and materials selected by students, as well as to assess student responses to reflection questions regarding engagement and learning. Reflection questions included “rate your answer from 1 to 5”, multiple choice and open-ended responses. For questions in which the student had to rate their answers, “1” represents that the student does not agree with what was asked in the question, “2” means the student slightly agrees, “3” means the student was neutral, “4” means the student slightly agrees and “5” represents strongly agrees. Multiple choice questions gave the students possible answers with an option of “other” to fill in a response of their own liking. Open-ended questions were left as optional but required the student to answer in complete sentences.

Results: Aspect of Materials Science Important to the Students

Part 1 of the project required students to pick an industry in North Carolina and a product within that industry. Table 2 shows the broader industry categories chosen by students. One popular industry was motorsports with an emphasis on parts of the car including metal alloys as the frame, polymer/rubber tires and ceramics used in brake pads. Another popular industry was infrastructure including roads, buildings and bridges with examples of composite concrete roads and sidewalks, asphalt or concrete pavement, treated wood for pier piling, and steel beams used in high rise buildings and bridges. Other industries listed in Table 2 include food and beverage such as an aluminum beverage can body, furniture such as injection-molded chair components, biomedical such as pharmaceutical pill coating, and sports equipment such as polymer kayak bodies, just to name a few. The top industries chosen were infrastructure, aerospace, motorsports and biomedical, followed closely by construction equipment, and sporting equipment. These top industries correspond to the high number of mechanical and civil engineering students who enroll in the class.

Table 2: Breakdown of industries chosen by students.

Industry	Percent Chosen by Students
Infrastructure (roads, buildings, bridges)	20.9%
Aerospace	13.4%
Motorsports/automotive	13.4%
Biomedical/Biotechnology	10.4%
Equipment (construction and agriculture)	9.0%
Sporting Equipment	9.0%
Food and Beverage	6.0%
Power/Energy	6.0%
Miscellaneous (furniture, tourism, etc)	6.0%
Semiconductors	3.0%
Textiles	3.0%

The type of material chosen by students was specific to the object that they chose. For example, materials chosen for roads were usually asphalt or concrete and for buildings steel for beams was prevalent. While semiconductor materials chosen tended to be ceramics such as silicon wafers rather than metal contacts, materials chosen for the food and beverage industry varied from aluminum cans to glass jars. General categories for materials chosen by students were broken down into metal/metal alloy, ceramic, polymer and composite. As shown in Table 3, the overwhelming choice was metal or metal alloy. The variety of industries and materials chosen aims to show how diverse the interests were among the students.

Table 3: General materials chosen by students.

Material Category	Percent Chosen by Students
Metal or metal alloy	49%
Composite	24%
Polymer	18%
Ceramic	9%

Results: Freedom to Pick Topic of Project

Overall, students appreciated the freedom to pick a material of their choosing. When asked if given the freedom to pick a material, product and industry of their choice motivated them to complete the project, 59% of students gave an answer of 5 out of 5 (absolutely). Less than 3% answered with a 1 or 2. Freedom to pick their own topic lets the students explore their own interests and aided in relating their engineering discipline to materials science. Students were given the option to leave a comment based upon their answers. Most students remarked that they genuinely enjoyed exploring a topic of most interest to them and that this helped motivate them to complete the project.

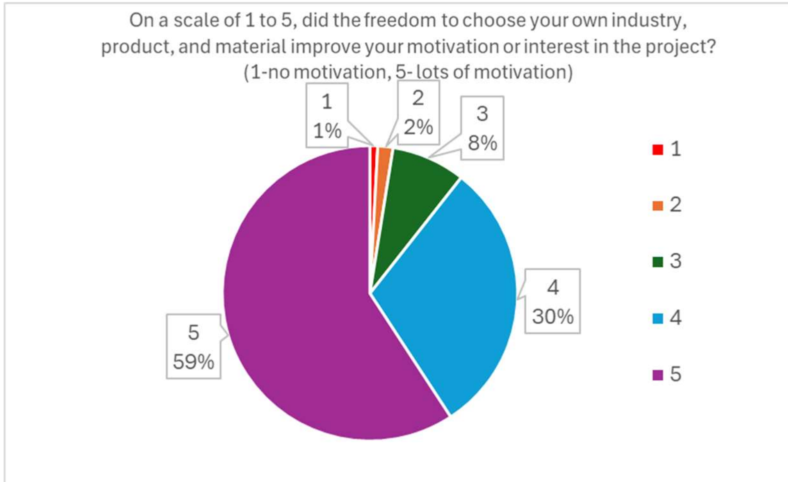

Figure 1: Responses from students when asked if freedom to pick the industry, product and material motivated or gave them more interest in the project.

Results: Understanding Concepts Discussed in Class

Part 2 of the project required the students to perform research on the microstructure, processing steps and properties of their chosen material. Overall, 51% of students found research to be more enjoyable than selecting the material or creating the poster. Students were asked if working on this project improved their understanding of microstructure, processing steps and resultant properties of materials. As show in Table 4 below, while there is some preference toward researching properties, there is no clear favorite. When given the opportunity to leave an optional explanation of their responses, some students noted that research was more enjoyable when it was a topic they were curious about. Due to the overwhelming amount of work to be completed in Part 2, some students were overwhelmed and had a difficult time completing all the individual sections. Also, in-class discussions of ceramics, polymers and composites did not occur until the end of the course, which made it even more difficult for students to research these topics earlier in the semester. Moreover, it is possible that research for the project took more time outside of class than the students expected. For these reasons, students showed a greater number of 4 responses, as noted in Table *4*.

Table 4: Student responses to research categories and whether it improved their understanding of the concepts.

Research aspect in Part 2	"1" (strongly disagree)	"2" (disagree)	"3" (neutral)	"4" (agree)	"5" (strongly agree)
Microstructure	0.6%	10.9%	27.4%	35.8%	24.9%
Process	0.6%	4.5%	20.4%	39.9%	34.6%
Properties	0.8%	4.5%	17.6%	42.5%	34.4%

Reflection questions revealed that a majority of students felt the poster project enabled them to connect concepts from class lectures to the project. Figure 2 shows that when asked if a connection was made between classroom lectures and the project, 80% of students answered with a 4 or 5 out of 5, with 5 meaning the student absolutely made many connections. Less than 5% of students answered with a 1 or 2, meaning little to no connection was made to the classroom lecture. For example, students commented that the classroom discussion of metal phase diagrams helped them with the research they needed for their project and that it helped them interpret microscopy images more clearly.

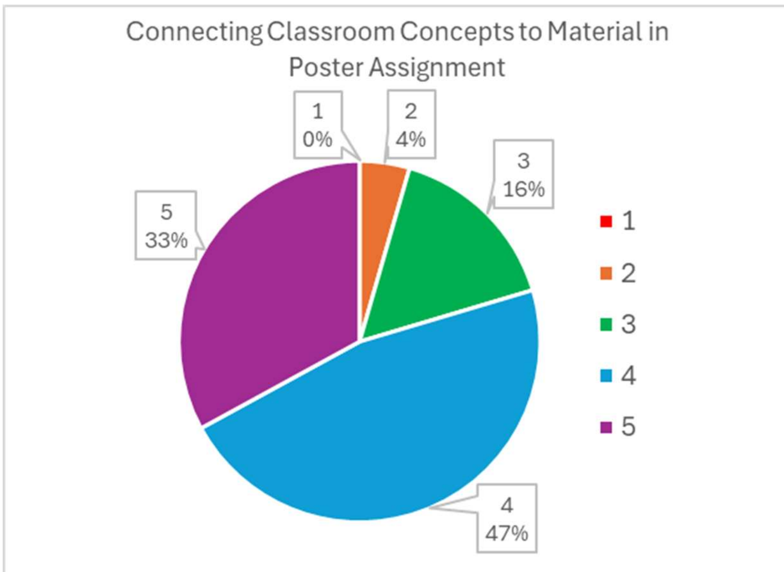

Figure 2: Student responses to connecting concepts from class to their poster project wherein 1 means not connecting information at all and 5 means absolutely connecting information.

Results: Importance of Materials Science

Students also expressed how much the poster project allowed them to see how materials science applies to their engineering discipline of choice. Remarks from students include statements in which they admit that they overlooked the importance of materials science in their major. Other students noted a project in which they had to choose specific material and halfway through the project they realized that they picked the wrong material. Moreover, some students remarked how they now understand the difference between various steels and why you would want to use one over the other. Yet another student grasped the importance of material science in terms of processing, realizing that due to the injection molding process of the material for a specific design, the resultant properties were drastically changed and not ideal for the application, requiring an additional processing step which increases time and money during production. By studying materials science through the poster project, most students now realize how important the science of materials is across different engineering disciplines and various applications.

Results: Real World Applications

When students were asked "Which part of the project are you most proud of?", 27% of the students responded with describing the application of the material to the product. By researching the microstructure and processing steps, students were able to relate these findings to the material properties. They were then able to explain, based upon the properties, why their material is ideal for that particular application. Students remarked how this was the easiest section to fill out. They were able to correlate the importance of the different material properties and why they are so important to keep in mind while creating a product. Moreover, students noted that they were able to take the properties listed on their poster and relate other concepts in class such as fatigue and creep to understand that in some applications it is undesirable to use a material in a situation such that it is close to its yield point since the application may involve a load that is applied over and over again or held for a constant period of time.

Results: Student Enjoyment of Project

Overall, students responded that they enjoyed doing this project, As shown in Figure 3 over 69% of students responded with a 4 (agree) or a 5 (strongly agree) while only 7% responded with a 2 (disagree) or a 1 (strongly disagree). Some students commented on how much they enjoyed researching a material of interest and how much they learned over the course of the project. Almost half of the students picked a metal, as shown in Table 3, which was discussed in the first part of the course and the classroom material made the research more familiar. This could contribute to the students' enjoyment of the project.

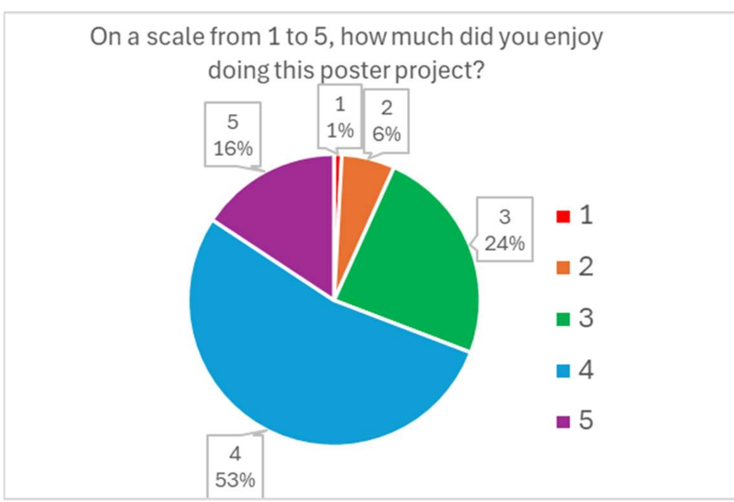

Figure 3: Student responses regarding how much they enjoyed or didn't enjoy the project.

Comments from students revealed why some students answered with a 4 rather than a 5. Some students found that filling out the worksheet in Part 2 and then pasting it onto a poster in Part 3 was just more work. Moreover, some students left comments that the steps of the project did not align with the timing of the content discussed in class. For example, composite materials are usually discussed in lectures toward the end of the semester. However, if a student picked a composite material for their project, they might have a more difficult time conducting research earlier in the semester. The uncertainty and being unfamiliar with the general concepts made it difficult to research a material that had not yet been discussed in class, which might account for some of the students who answered with a 1 or 2. Misaligned class material with certain aspects of the project, depending upon the material chosen, may have caused some students to answer with lower values. Other students commented that that while they liked the freedom to pick a material of their choice, the material they picked was difficult to research so they had to start over midway through the semester.

Conclusion

This paper describes the implementation of a semester long poster assignment and how this activity made the students more aware of how materials science applies to their engineering discipline. By using a material tied to a local industry and connected to their engineering discipline, it made the subject matter relatable to students and therefore more engaging. Results show that students take most interest in the infrastructure, aerospace and motorsports industries and that students appreciated a project where they had the freedom to pick a material of their choosing. Evaluations revealed that students were engaged enough to be able to relate concepts from class lectures to the project and how the students enjoyed different aspects of the activity.

To conclude a class project that lets students analyze a material of interest to them while tying in materials science concepts can make the classroom instruction more engaging for the students. Moreover, students can relate the knowledge of materials science to applications in their engineering discipline of choice. This pedagogical approach emphasizes student agency, real-world relevance, and interdisciplinary connections. By encouraging students to explore a material of personal or professional interest and communicate their findings through a digital poster, the project fosters deeper learning and highlights the integral role of materials science in diverse industries. Rubrics used throughout the course provide consistent assessment criteria and support student success. The study contributes to the body of research on project-based learning in STEM education and offers a scalable model for engaging large undergraduate cohorts in meaningful, applied scientific inquiry. Key metrics for a successful outcome include over 97% of students completing a high-quality digital poster and almost 70% reporting satisfaction with the project, indicating both enjoyment and perceived relevance to course content.

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