2026 ASEE ANNUAL CONFERENCE June 21–24, 2026 | Charlotte Convention Center, NC
Host Sponsor UNC Charlotte
Paper ID #53930

Chocolate in the classroom: engineering, scientific, and sustainability principles

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Work in Progress: Chocolate in the Classroom: Engineering, Scientific, and Sustainability Principles

Introduction:

This work in progress study evaluates the impact of chocolate as a teaching medium for introducing scientific and engineering principles to non-STEM majors. A new course centered around the chocolate making process, going from bean-to-bar, has been developed to broaden students' exposure and increase interest in science and engineering. Chocolate production incorporates concepts such as heat transfer, fermentation, reaction chemistry, plant biology, and sustainability. As a familiar, sensory-rich material, chocolate provides an engaging, hands-on platform for making abstract engineering ideas more concrete and approachable.

Food in the classroom is not a revolutionary idea. For years, instructors have used food as a vehicle for teaching engineering concepts, including at universities such as MIT [1] and UC Davis [2]. Engaging students with familiar, tangible topics that they can connect with is crucial for building intrinsic motivation. Intrinsic motivation plays a key role in academic success. Students with greater levels of intrinsic motivation demonstrate strong conceptual learning, improved memory, and high overall achievement in school [3], [4], [5]. Identifying strategies that build intrinsic motivation is important to create more impactful teaching and foster better student learning outcomes.

Science, technology, engineering, and mathematics (STEM) education is critical to prepare students for the modern workforce [6]. However, STEM can provoke anxiety or fear, which can lead to some students avoiding these topics and disengaging in learning [7], [8]. By using chocolate as an accessible and delicious medium to engage students and introduce scientific and engineering principles, this study aims to reduce the avoidance of STEM topics and encourage non-STEM majors to engage more with STEM topics. Relatable context has been shown to be particularly impactful in STEM education [9], [10]. Contextual learning has been around for a while and is widely regarded as important for engineering education [11], [12]. According to NCA, 95% of households purchase chocolate treats each year and chocolate represents $21.5 billion in sales in 2024 [13], making chocolate an available item is in most households, hence it is a relatable topic for many students and can be used as a medium to contextualize scientific and engineering principles.

Chocolate is composed of three primary ingredients: cocoa beans, cocoa butter, and sugar. Both cocoa beans and cocoa butter originate from the fruit of the cacao tree, and transforming these raw materials into finished chocolate requires a series of carefully controlled steps, including

harvesting, fermentation, drying, roasting, grinding, tempering, and distribution. Scientific and engineering principles play a critical role at each stage of this process. For example, during fermentation, complex chemical and biological reactions occur as microorganisms break down the pulp surrounding the cocoa beans. Understanding these biochemical reactions enables engineers to design specialized equipment and develop processes that guide fermentation in the desired direction, optimizing flavor development, consistency, and overall efficiency. The chocolate-making process offers numerous opportunities to contextualize core chemical engineering principles in a tangible and engaging way.

The guiding research questions for this study are:

1. Does using chocolate as a teaching medium make engineering concepts more approachable for non-STEM majors?

2. Does chocolate-based instruction increase student motivation and engagement in STEM learning?

Institutional Context

Colorado State University is a land-grant R1 public institution with a student population of approximately 34,000 students. The College of Engineering has around 3,200 students enrolled, representing just under 10% of the total student population. With an acceptance rate of 88.5% and an average incoming GPA of 3.69, the institution maintains broad accessibility while supporting strong academic preparation. As part of its land-grant mission, the university emphasizes practical and accessible education in agriculture and engineering. *The Chocolate Class* aligns with this mission by integrating agricultural content (cacao cultivation) with engineering principles in a general-education course designed to reach a wide and diverse student audience.

Course Context

The Chocolate Class is a 100-level, semester-long course that fulfills a general physical science requirement. Developed within the School of Biomedical and Chemical Engineering, the course introduces chemical engineering concepts to a broad audience and is intentionally designed to attract non-STEM majors. Its primary goals are to cultivate critical thinking skills, broaden the scientific and engineering knowledge of students, and increase interest in chemical engineering and STEM more broadly. STEM majors are defined as degree programs that have to Science,

Technology, Engineering, and/or Mathematics as their primary disciplinary foundation. Non-STEM majors include the humanities, business, social sciences, and arts. The course has no prerequisites, which attracts a diverse set of students from across campus. Course objectives include applying the scientific method and engineering principles, describing the chemical, physical, and biological processes involved in cacao cultivation and chocolate production, communicating scientific information across written and graphical formats; and evaluating the sustainability impacts of chocolate production using energy, water, and carbon metrics.

The Chocolate Class is a 3-credit-hour lecture course with 150 minutes of weekly contact time. Instruction incorporates discussions, hands-on activities, chocolate tastings, and guest speakers from local and international chocolate-related industries. Students explore the entire chocolate-making process from farming practices to the final bar production. Engineering connections are made at each stage of the process and include heat transfer, conservation of energy, scale-up, and mass balances. Class time is divided between foundational scientific and engineering principles and their applications within the chocolate process. A complementary laboratory course is under development but is not part of this study.

Methods

To evaluate the impact of *The Chocolate Class* on non-STEM majors, this study employed a pre- and post-course survey. Students completed surveys at the beginning and end of the semester. The goal of the survey is to measure changes in students' attitudes toward STEM, their motivation and engagement, and their conceptual understanding of scientific and engineering principles. Using the same survey structure at both time points allows for direct comparison of student perceptions and knowledge before and after participating in the course. Pre- and post-course surveys responses will be matched for comparison.

Participation in the survey was limited to students who are enrolled in the course and is voluntary. The study was approved by the Institutional Review Board (IRB) and designed to minimize risks associated with participation. Participants are allowed to leave the research study at any point.

The survey began with a set of demographic questions designed to contextualize student responses and support subgroup analyses. Students report their year in higher education, declared major, and prior exposure to college-level science and/or engineering courses. These demographic

variables enable comparisons across groups such as STEM versus non-STEM majors, underclassman versus upper classmen, and students with or without prior scientific/engineering coursework. Subgroup analyses are important for determining different impacts on students with varying academic backgrounds and levels of STEM preparedness.

Following the demographic section, students complete a series of Likert-scale items rated on a five-point scale (1=strongly disagree, 5=strongly agree). The statements are designed to measure several constructs relevant to the study's research questions which include, STEM anxiety, perceived approachability of engineering, intrinsic motivation, and engagement in academic settings. The pre-course survey established baseline attitudes in these areas, while the post-course survey assessed shifts in perception after completing the course. The post-course survey also includes additional items specifically targeting students' experiences within *The Chocolate Class* such as engagement in this course compared to others and the extent to which chocolate enhanced their understanding of scientific and engineering concepts. Example statements include "I am anxious about science, technology, engineering, and/or mathematics" and "I feel confident having discussions regarding scientific topics." These items directly support the study's aim of understanding how chocolate-based instruction influences motivation and approachability of STEM.

The surveys also include a knowledge-based quiz designed to assess students' conceptual understanding of scientific and engineering principles. The quiz consists of 11 multiple-choice and true/false questions covering topics such as the scientific method, sustainability, and engineering design. The pre-quiz serves as a baseline measure of students' prior knowledge while the post quiz evaluated learning gains and retention of course materials. The quiz was intentionally brief to minimize survey fatigue while still capturing essential concepts aligned with course objectives. An example quiz questions is "Which of the following is the best example of a hypothesis?"

Altogether the course surveys provide a comprehensive dataset for evaluating the effectiveness of *The Chocolate Class*. This mixed-methods survey design enables the study to capture both objective and subjective dimensions of learning, offering a holistic view of how chocolate-based instruction influences non-STEM students' engagement with scientific and engineering principles.

Proposed Data Analysis

The survey data will be analyzed using a combination of quantitative and qualitative methods to evaluate changes in students' attitudes, motivation, and conceptual understanding over the duration of the course. The first stage of analysis will involve organizing responses into relevant subgroups, including STEM versus non-STEM majors, underclassmen versus upperclassmen, and students with or without prior STEM coursework. These subgroup comparisons will help determine whether the course has differential effects on students with varying academic backgrounds.

To assess changes in attitudes and perceptions, paired t-tests will be conducted on pre- and post-survey Likert-scale items. This approach allows for the detection of statistically significant shifts in constructs such as STEM anxiety, confidence when discussing scientific topics, and perceived approachability of engineering. For example, comparing pre- and post-responses to items such as "I am anxious about science, technology, engineering, and/or mathematics" will reveal whether the course reduces STEM-related anxiety. If there are significant outliers or non-normality is present, non-parametric alternatives such as the Wilcoxon signed-rank test may be considered.

To assess the internal consistency of the Likert-scale constructs, a reliability analysis using Cronbach's alpha will be performed. Several items are designed to measure related constructs such as motivation, confidence, and STEM anxiety; Cronbach's alpha will help determine whether these items function cohesively and whether any items require revision in future iterations.

Multiple regression analyses will be used to explore which student attributes predict changes in attitudes or knowledge. Predictor variables may include prior STEM coursework, year in school, major classification, and baseline motivation levels. These models will help identify which factors most strongly influence learning outcomes and whether certain student populations benefit more from contextualized, chocolate-based instruction.

Altogether, these analytical approaches will provide a comprehensive understanding of how *The Chocolate Class* influences students' motivation, engagement, and STEM learning.

Limitations

The proposed research study has several limitations. First, survey participation is voluntary which may introduce self-selection bias. The students who choose to participate may already be more motivated or engaged. The study is limited to a single institution and a single course which may affect generalizability. The study is planned to be conducted over multiple semesters to capture a more diverse and larger pool of applicants. Additionally, the knowledge-based quiz is intentionally brief, which may limit the depth of conceptual assessment.

Conclusion

This study explores how chocolate can serve as an accessible, engaging medium for teaching scientific and engineering principles to non-STEM majors. This work-in-progress paper describes the study design and planned analysis that will be used to evaluate the impact of *the Chocolate Class*. The course aims to reduce STEM anxiety, increase motivation, and make engineering more approachable by contextualizing STEM concepts within a familiar and delicious material, chocolate.

The anticipated findings of this study may inform future designs of contextualized STEM courses and inspire instructors to incorporate relatable materials to enhance student engagement and learning. Although this course is rooted in chemical engineering concepts, chocolate offers opportunities for meaningful connections across many engineering disciplines. Processes such as farming, fermentation, drying, roasting, and cracking & winnowing involve equipment and principles relevant to mechanical, electrical, and environmental engineering. For example, the cracking & winnowing step, where roasted cacao beans are mechanically broken and separated, can be used to illustrate engineering design, optimization and separation processes in mechanical engineering.

More broadly, this work aims to inspire educators to identify materials and contexts that resonate with their students, whether food-based examples like chocolate or coffee, or other everyday systems that students encounter more frequently than traditional engineering equipment. By leveraging familiar contexts, instructors may strengthen conceptual understanding, reduce barriers to STEM learning, and create more inclusive and engaging educational experiences.

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