Socio-technical and Culture-inspired Projects in Freshman Engineering Design Course Bring Context and Emotion to Learning

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Abstract

Learning is not an unemotional consideration of facts but emotion is integrally woven into the experience of learning [1]. Situated cognition model [2] is a theoretical approach to learning that supports the idea that learning takes place when an individual is interactively doing something through situated activity that has social, cultural, and physical contexts. This paper presents post-activity reflections in student design projects with socio-technical and socio-cultural interventions in a freshman design course. While socio-technical and socio-cultural context in student design projects is important to help increase the level of student engagement, the semi-experiential nature of design projects can stimulate emotions that significantly influence cognitive functions leading to significant learning. This is work in progress.

Introduction and Literature

Situated cognition [2] emphasizes the importance of context in establishing meaningful linkages with learner experience and in promoting connections among knowledge, skill, and experience. Situated learning emphasizes higher order thinking rather than the acquisition of facts, encourages reflection on learning, and focuses on application rather than retention [3]. Contextual learning [4] engages students in meaningful, interactive, and collaborative activities that support them in becoming self-regulated learners. University training in problem solving is primarily done using decontextualized textbook problems with a one-size-fits-all approach in exploring subject domain concepts [5]. Teaching the abstracted concepts as well-defined independent entities leads to learning with fixed meaning and immutable concepts. A situated approach to teaching and learning, where concept, authentic activity, and context come together to guide students to produce useable, robust knowledge leads to negotiable meaning and socially constructed understanding of the subject domain concepts [6].

Emotions play a significant role in the learning process [1]. They can both positively and negatively impact how individuals acquire, retain, and apply new information and skills. Situations that contribute to educational accomplishment arouse a multitude of different emotions, including enjoyment, hope, pride, anger, anxiety, shame, boredom, and hopelessness

[7]. Positive emotions such as curiosity, excitement, and a sense of accomplishment can boost motivation to learn. When learners are engaged and interested, they are more likely to invest time and effort in the learning process. Positive emotions, such as joy and curiosity, can enhance creative thinking and problem-solving skills. A positive emotional state can lead to more flexible and innovative approaches to challenges. Emotions can also influence the source of motivation [8]. Intrinsic motivation, driven by personal interest and satisfaction, is often more effective for long-term learning compared to extrinsic motivation, such as rewards or punishments.

Fink's taxonomy of significant learning outlines a conceptual framework and technical language to pinpoint several manners in which learning can be made significant and promoted in an educational environment [9]. In addition to application and integration, Fink's significant learning includes human dimension (Learning about one-self and others) and caring (Developing new feelings, interests and values). The human dimensions and caring aspects can be assessed using personal reflections and pre- and post-activity questionnaires.

High-Impact Practices (HIP) typically refer to active learning methods that promote student engagement, development, and deep learning. HIPs can take on a plethora of forms, though typical teaching and learning practices include collaborative assignments and projects, common intellectual experiences, diversity and global learning, and learning communities, among others [10]. The application of these various HIPs give rise to characteristics such as: setting high-performance expectations; promoting extensive and in-depth faculty and peer interactions; encouraging independent learning and free thinking; providing exposure to diverse ideas, people, and multiculturalism [11]; requiring students to put theory into practice with hands-on learning; integrating reflective and interactive learning. The learning gains and outcomes that a student acquires upon completing a course consists of the knowledge and understanding (cognition), skills, and attitudes and values (emotion) that they are equipped with. Existing studies of HIPs have shown that such activities could improve learning achievements, multicultural abilities, leadership development, communication skills, and cross-cultural experiences. Additionally, HIPs have also been known to catalyze students' internal motivation and commitment to tasks by enhancing their learning objectives and initiatives, therefore improving the learning outcomes. Overall, HIPs have been found to positively impact the cognition, skill, and emotion gains in student learning development, growth, and success [12].

This paper presents post-activity reflections in student design projects with socio-technical and socio-cultural interventions in a freshman design course. While socio-technical and socio-cultural context in student design projects is important to help increase the level of student engagement, the semi-experiential nature of design projects stimulate emotions that significantly influence cognitive functions leading to significant learning. These interventions are implemented in a freshman design course, where students work on computer-aided design of culture-inspired home decorative items [13] in individual projects, and sustainable development goals (SDG)-based design [14] of large engineering structures as part of team projects. A qualitative and quantitative analysis of post-activity reflection on the role of context and emotion on student's engagement and intrinsic motivations is presented.

About the freshman design course

This is a core course for mechanical, civil and aerospace engineering students offered in all three semesters with multiple instructors. Project-based and learning-centered instructional approaches with creative ideation and sketching ([15] and [16]), introduction to CAD tools, basics of design-for-manufacturing and 3D Printing are part of the course content. Each week, two 50 minutes lectures are followed by a 3 hours lab session. Basic concepts of the course content is introduced in the lectures with relevant tutorials followed by extended hands-on lab activities in Lab. The lecture and lab activities constitute 30% of the students' overall course grade

Culture-Inspired Home Décor Individual Project and SDG-Based Socio-Technical Team Project

Traditional culture is being used increasingly in design creativity. With changing consumer needs, in addition to functionality and practicability, products today must be oriented toward consumer awareness and product demand [17]. Globalization has led to a situation in which product design teams from one cultural context often have to develop a product which will be used in a (totally) another cultural environment. As a result, cross-cultural product design has increased in value and interest [18]. Europe and the United States specialize in taking traditional craft heritage items and combining them into brand marketing, developing them into fine boutique products. This idea-to-3D print project tasks the student designer with leaning into their own culture to design home décor items inspired by their personal background. Students are encouraged to embrace cultural traits in their design, such as nationality, family structures,

community, aesthetics (art, architecture, music, dance), cuisine, mythology, ethics, manners, festivals and holidays, and fashion. Cultural aspects should be meticulously used to influence the design, usage, and purpose of the product from the conceptual stage of design, rather than as superficial or last-minute additions. This individual project consists of three parts (creative ideation and sketching, 3D CAD models of parts and assembly, manufacturing drawings and 3D printing) and constitutes 40% of the students' overall course grade.

Students also work on Team projects in the freshman design course. Five-member teams collaborate on the ideation, sketching, planning, designing, modeling, assembly and functional animations of proposed large engineering structures. Students divide the overall assembly into a manageable number of subassemblies, and delegate tasks so that each member contributes to parts modeling, assembly, animation, checks for functionality, and documentation. Using a socio-technical project-based learning model, the assignment tasks students with designing a sustainable product to address the UN's Sustainable Development Goals (SDGs). This project theme engages students through a contextualized design problem, as students are required to research and understand the factors, stakeholders (people, communities, etc.), customer needs, and engineering requirements that influence the design decisions for their product. This project consists of three design reviews (ideation and sketching, 3D CAD models of parts, and final assembly) and constitutes 30% of the students' overall course grade.

Methodology

To assess the influence of context and emotion in student learning, post-activity reflection, data collection is administered in the Fall 2023 semester. The data is collected as part of an end of the semester survey covering various components of the culture-inspired home décor project and SDG-focused team projects with socio-technical context. The online surveys were administered to students in all five sections (around 250 students) of freshman design course. Students were asked Likert-type items about their perceptions of the culture-inspired and SDG interventions in the projects, as well as open-ended items about how these projects affected their level of creativity, engagement, emotions and intrinsic motivation.

Themes from a data set can be identified inductively from raw data or deductively through pre-existing research, expected results, and theory. Both approaches of thematic analysis implement

coding, which refers to the process of grouping, labeling, categorizing, and organizing qualitative data to identify recurrent themes, patterns, and relationships. Inductive thematic analysis [19] is a ground-up approach that involves discovering themes that are strongly tied to the raw data, and not necessarily related to the specific questions asked to the participants. With inductive analysis, the results are interpreted without contextualizing the data into any existing framework or preconceptions. With this approach, themes and categories emerge from the data, not from any prior assumptions or expectations.

Alternatively, deductive thematic analysis is a top-down method that is more driven by the researchers' prior theoretical knowledge and interests. This approach generally involves framing the analysis with a set of themes or categories selected before the analysis is conducted [20]. With a predefined framework, researchers can ensure they actively seek out data that addresses the questions or objectives at hand. Deductive framework is typically more useful for organizing or sorting the data into anticipated categories, based on literature, theory, research purpose, or probing questions.

For the purpose of qualitative thematic analysis of the data collected in this paper, the "best fit" framework synthesis that combines both deductive and inductive approaches offers the most effective approach [21] to produce meaningful and reliable results. This methodology involves accounting for context during the thematic search, and uses an a priori, tentative framework, based on what is known from theory and literature. This "best fit" framework is generic, so context-specific insights supplement the predefined framework inductively to capture any additional evidence.

Results and Discussion

Students reflections on the role of context in SDG-based Socio-Technical team projects

Across a total of 207 survey responses regarding the contextual factors and associated specifications and constraints taken into consideration in the design of a sustainable products and structures, various umbrella categories, including environmental, social, economic, and health issues were addressed. By far, the vast majority of student projects targeted environmental concerns, with over 80 student responses mentioning specific issues to tackle such as clean water and energy, food waste, plastic pollution, oil spills, ocean preservation and marine ecosystems,

rainforest conservation, sustainability. Additionally, over 32 cases mentioned social issues including cities and communities, differently-abled people, urban environments, low-income communities, humanitarian efforts and disaster relief, starvation and hunger, and infrastructure, while over 23 cases addressed economic concerns like affordable energy, cost-effective product solutions, and long-term economic resilience. Finally, at least 9 responses mentioned health issues such as microplastic pollution, access to clean water, fighting disease, mental health and well-being, and zero hunger. Note also that a number of student responses indicated that their projects addressed multiple contextual factors at once, such as simultaneously tackling clean and affordable energy (both environmental and economic). The word cloud in Figure 1 illustrates the range of issues addressed by the student projects, with larger terms indicating topics more frequently mentioned in student responses.

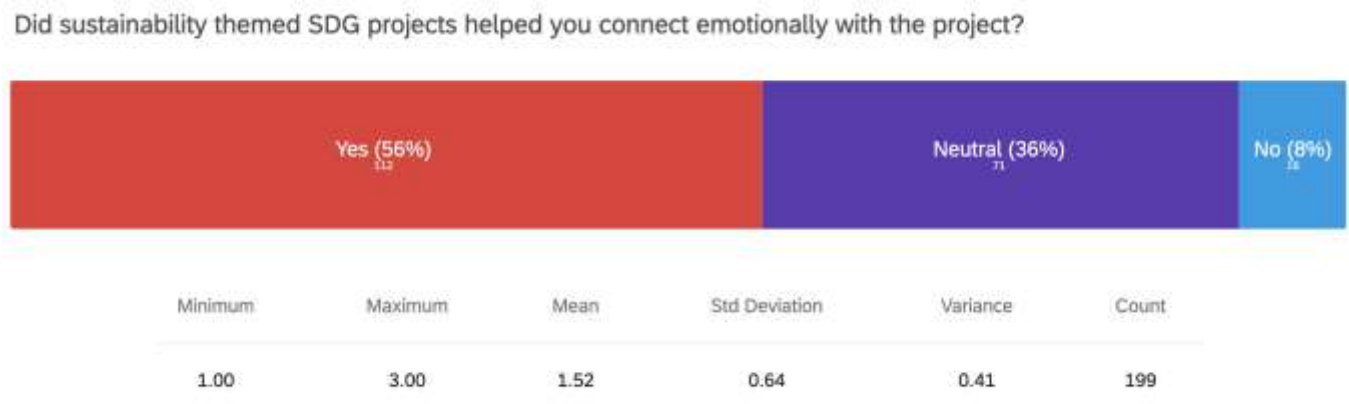
Figure 1. Range of sustainability issues addressed in the student team projects

It is worth noting that the stark majority of student-designed sustainable products referenced contextual factors within the realm of environmental, social, economic, and health issues—all of which are factors that are mentioned in a critical student outcome for accredited programs from the Engineering Accreditation Commission of ABET. This particular ABET student outcome [22] mentions "*the ability to apply engineering design to produce solutions that meet specific needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors*." Seeing as the project results demonstrate notable

consistency with the factors mentioned in this student outcome criteria, the SDG-based socio-technical project can be considered effective in fulfilling this learning objective.

With regards to the role of context, for the vast majority of students, considering the context and stakeholders was a positive influence, with responses mentioning that "the problem context and stakeholders significantly influenced the design" or that they "gave the inspiration for the design and goals for what subsystems are needed and how they should be designed." A number of responses also mentioned that consulting context provided the team with guidelines that prompted them to redesign their product to be realistically functional, rather than having the design driven purely by creativity. For instance, one student wrote "The design has to be feasible enough to work in the terms of real-world constraints and in that way that context influences our designs… thus we used real life context to model our system after what already exists and works." Further, another response stated "The context and stakeholders encouraged us to be realistic about our design and consider the functionality of our components," with another student mentioning "It brought additional constraints by putting a limit on how far our creativity could go, and how realistic our product would have to be."

To quantify the role of emotions in the team project, students were asked whether or not the Sustainable Development Goal (SDG)-themed project helped drive any emotional investment in the assignment. 56% of responses indicated that the theme did encourage their emotional interest in the project, while 36% were neutral, and 8% did not connect emotionally with the project.



Students reflections on culture-inspired home décor individual projects

Preliminary analysis of the results found that out of 229 students enrolled in the course in Fall 2023, 220 students participated in the voluntary post-activity survey reflection for the individual project, producing a response rate of 96%. Across the 220 survey responses, 87 distinctive cultures, nationalities, and ethnicities were showcased through creative ideation and product design. A number of students drew inspiration from different aspects of a single global culture or ethnicity, so the frequency of certain backgrounds increased as they appeared across multiple cases. For instance, some of the statistically larger heritages and backgrounds represented (see Table 1) included: Indian (28 cases; 12.79%), USA (26 cases; 11.87%), Chinese (21 cases; 9.59%), Hindu (16 cases; 7.31%), Georgian (13 cases; 5.94%), and Christian faith (9 cases; 4.11%). The word cloud representation shows the various heritages portrayed through students' creative product design, with larger font words representing more frequently mentioned terms.

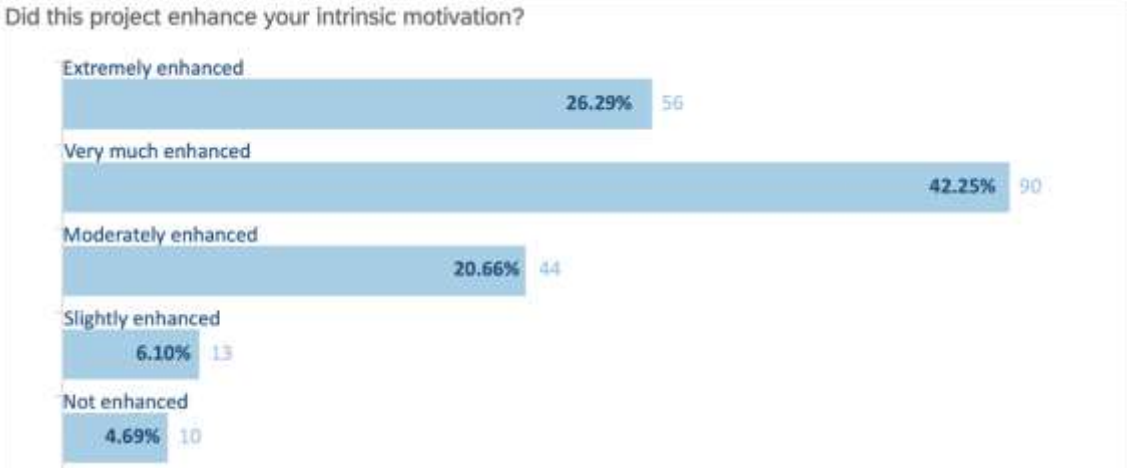
Table 1. Statistically larger cultural backgrounds mentioned

Background	Frequency	% Cases
Indian	28	12.79%
USA	26	11.87%
Chinese	21	9.59%
Hindu	16	7.31%
Georgian (state)	13	5.94%
Christian (faith)	9	4.11%
Italian	8	3.65%
SouthKorean	7	3.20%
Judaism (faith)	7	3.20%
Mexican	5	2.28%

Figure 2. The word-cloud representation of various culture / heritages portrayed in students' creative product designs

Furthermore, many students opted to integrate and interweave a multitude of microcultures, subcultures, and local communities that contribute to wider overarching national cultures by focusing on regional backgrounds in their projects. For example, many students with ancestral roots in the United States depicted their personal identities through their states, like Georgia, California, Kentucky, and Oregon, or regional subcultures like Cajun or "Mountain" (Appalachia). Similarly, some students highlighted microcultures based on distinctions through language, faith, or organized religion, such as Jewish, Catholic, Islamic, Buddhist, Taoist, Zoroastrian, Methodist, Protestant, and Moorish backgrounds. With the objective of exhibiting and preserving the importance of each culture, the microcultures and subcultures mentioned in student responses were not grouped or categorized into their dominant cultures during data processing. In addition to the wide variety of nationalities, ethnicities, and identities previously mentioned, the student responses also presented a plethora of diverse groups including the Seneca, Cherokee, Oneida, and Inca indigenous communities; countries such as Trinidad and Tobago, Egypt, and Wales; and territories like Anguilla, British Virgin Islands, and Puerto Rico.

To gauge emotional connection to the project, students were asked rate how emotionally attached they were to their product. 39.91% of students stated that they were moderately attached, followed by 27.23% responding they were very much attached, and 19.25% indicating they were extremely attached. As such, the overwhelming majority of students felt some degree of emotional attachment to the product which they designed based on their cultural background and heritage. In comparison, 4.69% of students felt no emotional connection to their product. Given these results, it seems that the project and its theme was fairly effective in eliciting emotion during the learning process for the majority of students.



To assess the effects that emotion has in the learning experience, students were asked to rate the effect that the culture-inspired project had on their intrinsic motivation. With a response percentage of 42.45%, the most students indicated that the project very much enhanced their intrinsic motivation, followed by 26.29% responding that it extremely enhanced their intrinsic motivation. In contrast, only 4.69% of students felt that the project did not enhance their intrinsic motivation. This trend is reflected in the open-ended student responses as well, given that many students mentioned that the culture-inspired theme gave them a personal connection to their project, thus making them more invested in producing a high-quality deliverable.

Concluding Remarks and Future Work

The results of socio-technical and socio-cultural project-based interventions presented in this paper supported by the post-activity reflection surveys demonstrate that design projects that enable semi-experiential opportunities for students can provide an effective channel to elicit emotions that encourage significant learning. Based on the student reflection data, both the SDG-based socio-technical and the heritage-inspired socio-cultural themes helped the majority of students connect emotionally with their work, with 56% of students agreeing in the former and 95.3% indicating emotional attachment to their product in the later. Furthermore, in relation to the socio-cultural project, 95.3% of students followed up with confirmation that the culture-inspired project enhanced their intrinsic motivation. Given the agreement between student reflection responses for both emotional attachment and intrinsic motivation, it is evident that a strong positive relationship existed between emotional connection to the project and the resultant intrinsic motivation. These results not only indicate that the project theme and context generated positive emotions triggering intrinsic motivation through personal interest, but also that the assignment was an effective tool for catalyzing HIPs that enable students to acquire cognitive and emotional learning gains. It is to be noted here that, when sharing their personal stories on culture-inspired products students' psychological safety [23] should be given utmost importance. The classroom environment should build trust, empathy and rapport with students to create a supportive and inclusive classroom culture. Some earlier studies has focused on the role of psychological safety and psychological empowerment in improving students' creativity in project-based learning from the perspective of student empowerment. Based on self-determination theory [24], there is a positive correlation between psychological safety and

creativity, and psychological empowerment plays an intermediary role in the relationship between them [25].

In the SDG-based socio-technical project, post-reflection results indicated that students were successfully able to employ their engineering skills to applications in social, cultural, and real-world contexts, which are factors that are mentioned in a critical student outcome for accredited programs from the Engineering Accreditation Commission of ABET [22]. Based on their reflection responses, students demonstrated a clear ability to generate engineering solutions to contextual design problems. Further, a general theme and shared sentiment across open-ended responses indicated the fact that considering the engineering problem in its contextual environment provided constraints and guidance to facilitate functional and realistic design that would have otherwise gone unnoticed. Such sentiments made evident that design in context provided a means by which students could harmoniously balance creativity and feasibility in the design process. In terms of emotional connection, the socio-technical project was comparatively less effective at helping engage student emotions than the socio-cultural theme; however, this discrepancy may be attributed to the fact that the SDG theme introduces a frontier design context problem, meaning the application of the problem takes place in contexts that exceed the expertise, knowledge, and firsthand experience of the freshman students, thus requiring additional understanding of contextual information for effective design. In comparison to the culture-based project which requires students to draw from their own identity, values, and backgrounds, the SDG theme challenges students to make informed decisions for an environment that they may have never personally experienced. As such, it is possible that such a challenge may inhibit the degree to which a student may connect with a frontier design problem.

A number of design methods exist to methodically understand context factors and end-user needs in frontier design problems; perhaps a future step could involve tasking students with taking a systematic approach to contextual design during the project proposal state and evaluating its impact on emotional connection [26]. Additionally, a thematic analysis of open-ended responses from post-activity reflections is underway, so the next steps may involve devising an appropriate framework for a text mining software to extract recurring patterns, themes, and quotes from student responses, with the objective of garnering a thorough understanding of student experiences.

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