2023 Annual Conference & Exposition
Baltimore Convention Center, MD | June 25 - 28, 2023
The Harbor of Engineering Education for 130 Years
Paper ID #36724

Work in Progress: Student Reflections from a Semester-Long Place-Based Photovoltaic Solar Energy Project

Dr. Marissa H. Forbes, University of San Diego

Marissa Forbes, PhD is an Assistant Professor in Mechanical Engineering at the University of San Diego. She is co-creator and co-leader of the Water Justice Exchange, a cross-campus, inter-community initiative fostering synergistic research, teaching and solutions for water challenges in the San Diego/Tijuana region. Dr. Forbes earned her MS and PhD from the University of Colorado Boulder in Civil (environmental) Engineering, and conducts research that aims to advance water justice and sustainability, as well as sociotechnical engineering education research. She previously served as the project manager and lead editor of the NSF-funded TeachEngineering digital library (TeachEngineering.org, a free library of K-12 engineering curriculum), during which she mentored NSF GK-12 Fellows and NSF Research Experiences for Teachers (RET) participants on the creation and publication of their original engineering curriculum. Dr. Forbes is a former high school physics and engineering teacher and a former NSF GK-12 Fellow.

Dr. Susan M. Lord, University of San Diego

Susan Lord is Professor and Chair of Integrated Engineering at the University of San Diego. She received a BS from Cornell University in Materials Science and Electrical Engineering (EE) and MS and PhD in EE from Stanford University. Her research focuses on the study and promotion of equity in engineering including student pathways and inclusive teaching. She has won best paper awards from the Journal of Engineering Education, IEEE Transactions on Education, and Education Sciences. Dr. Lord is a Fellow of the IEEE and ASEE and received the 2018 IEEE Undergraduate Teaching Award. She is a coauthor of The Borderlands of Education: Latinas in Engineering. She is a co-Director of the National Effective Teaching Institute (NETI).

Work in Progress: Student Reflections from a Semester-Long Place-Based Photovoltaic Solar Energy Project

Abstract

In spring of 2022, the University of San Diego integrated engineering department offered a new sociotechnical solar energy course for junior and senior students. The course differed from traditional, technical upper-division engineering electives by facilitating student learning through a semester-long, team-based solar energy project that students worked on while concurrently gaining technical insights through lectures and problem sets. Informed by place-based pedagogies and culturally sustaining pedagogies, we designed the course to be relevant to the students' lived experiences by coupling the learning about technical elements of solar energy with a focus on solar energy projects on campus. Prior to running the course, we studied the university's Energy Master Plan, learned about the current state of solar energy on campus, and identified four potential new solar projects. We divided the 14 students in the class into four teams, with each team conducting a feasibility assessment for their solar project over the course of the class. Students started by exploring the solar we already have on campus. Once familiarized with the current system, we guided the students in completing their assessments of the new projects through four, two-week phases, with each phase focusing on a different sociotechnical analysis for their project: 1) social, 2) technical, 3) economic, and 4) environmental. During the fifth and final phase, 'integration,' we supported the students in integrating their analyses from each phase and making final, all-class recommendations to the university about how to proceed with solar energy investments on campus. In this paper, we share our findings from implementing this sociotechnical learning approach gained from student reflections, and our own observations and reflections from the course experience.

Introduction

Course Design

In spring of 2022, the University of San Diego integrated engineering department offered a new sociotechnical solar energy course for junior and senior students. This course counted as an elective in the Sustainability concentration of the major. As such, it was advertised to juniors and seniors who could choose to take this course or others to fulfill their electives. This was the first offering of the course. The course differed from traditional, technical upper-division engineering electives by facilitating student learning through a semester-long, team-based solar energy project that students worked on while concurrently gaining technical insights through lectures and problem sets. The course objectives were as follows:

1. Describe, using diagrams and appropriate equations, the operation of solar cells.
2. Explain the operation of photovoltaic (PV) modules and arrays.
3. Compare grid-connected and stand-alone PV systems.
4. Explain important economic, environmental, social, and technical considerations for the design and use of PV systems.
5. Identify at least two topics related to photovoltaic solar energy on campus.

6. Conduct effective research including critically evaluating technical papers, reports, podcasts, videos, or websites and expressing information orally and in writing.

The beginning of the semester addressed the first three objectives using active-learning lectures and homework assignments that were technical in focus. The fourth goal was addressed throughout the course, including through modules about solar energy in South Sudan developed by an alumnus in South Sudan who owns a solar energy company [1] and a Zoom class session with him.

A semester-long project addressed the fifth and sixth course objectives, listed above. We used the three pillars of sustainability (economic, environmental, social) [2-4], place-based pedagogies [5-7], and culturally sustaining pedagogies (CSPs) [8-12] to inform the project design. Both pedagogical models incorporate classroom learning experiences that are relevant to the students' lived experiences, with place-based pedagogies specifically engaging students in their local community, culture, history, and/or physical environment. For this course, we coupled learning about the technical elements of solar energy with a focus on potential solar energy projects on the university campus.

This approach is consistent with the overall goals of the integrated engineering department at the University of San Diego which aims to help students see engineering as a sociotechnical endeavor. More details about courses in this curriculum are available in additional publications [13-17], including a deeper discussion about this specific course [18].

Course Context

Prior to running the course, we studied the university's Energy Master Plan (EMP), learned about the current state of solar energy on campus, and identified four potential new solar projects. The university currently has a ~1.2 MW photovoltaic (PV) solar system that provides ~7% of the energy consumed on campus. While a good start, this contribution is low considering the university's location in Southern California; there is an opportunity to greatly increase campus reliance on solar energy, and the university has committed to reaching carbon neutrality by 2035.

The course was taught by a lead instructor with a background in electrical engineering, materials science, and engineering education research, and a secondary instructor with a background in environmental engineering. Both instructors were White women.

Project Design

The four student projects included exploring: 1) upgrades to the current solar panels and system which currently span 11 buildings on campus, 2) adding a solar carport to the main parking structure, 3) adding solar panels to the university athletic stadium, and 4) transitioning the campus pool heating system (currently a natural gas boiler) to PV, solar thermal, or hybrid (i.e., panels that can do both thermal and PV). We divided the 14 students in the class (five women, nine men; five juniors, nine seniors; all majoring in integrated engineering) into four teams, with each team conducting a feasibility assessment for their solar project over the course of the class.

Students started by exploring the solar we already have on campus. Once familiarized with the current system, we guided the students in completing their assessments of the new projects through four, two-week phases, with each phase focusing on a different sociotechnical analysis for their project: 1) social, 2) technical, 3) economic, and 4) environmental. During the fifth and final phase, 'integration,' we supported the students in integrating their analyses from each phase and making final, all-class recommendations to university leaders in a ~30 minute presentation about how to proceed with solar energy investments on campus.

In this work in progress paper, we share our preliminary findings from implementing the course project based on student written reflections, a post-semester student debrief session, and our own observations and reflections from teaching the course.

Methods

Student Reflections

To help cultivate the students' development as reflective practitioners, we prompted them to complete a ½-to 1-page reflection at the end of each project phase. The reflections were completed collaboratively, by each team. However, following the final project phase, 'integration,' we requested that students complete their reflections individually, and that they respond to the following prompt:

> *What is not included in our analysis for this phase that should be taken into consideration?*

We also provided a hint for students to *"*think about 'invisible', long-term, or ripple effects. Think about hidden costs, people not considered, and/or impacts to an ecosystem."

We analyzed the final individual student reflections using inductive thematic analysis [19]. We use pseudonyms to share select quotes from the students in this paper. We anticipated that the student responses would be thematically grouped in relation to the reflection prompt. However, that wasn't the case; the students reflected thoughtfully on a broad range of topics. As such, we let themes emerge authentically. We identified preliminary themes, then went through an iterative process of mapping the student reflections to the themes, making adjustments, and then finalizing four themes.

Student Debrief

A few hours after the final presentation, which was held on the last day of class and was given to several faculty and university stakeholders with an interest in the campus sustainability and energy future, the main instructor held a voluntary debrief session. Twelve students attended in person and one on zoom. Students were asked to reflect on a whiteboard about a highlight of the presentation experience, an emotion about it, and something they would change. Because of the small number of students, we provide the raw student responses and comment on them directly in this paper, without aggregating them.

Results

Student Reflections

Student submissions ranged from 13 to 45 lines with an average of 25 lines and were typically one to three paragraphs. These were graded for depth with grades ranging from 85% to 110%.

We identified four primary themes from the final student reflections: 1) course commentary, 2) student takeaways and personal development, 3) students' self-criticisms and project shortcomings, and 4) student perceptions of project broader impact. Below, we provide a brief summary from our preliminary findings on each theme.

Student Reflection Theme 1: Course Commentary

Students shared overall positive feedback about the course and its structure, including favorable commentary about the course's focus on technical content during the first weeks before turning the focus to the sociotechnical project. For example, Rob felt that "being able to focus on the project made the work and deliverables much higher quality." In Adam's words:

> *The lectures, handouts, and homework we worked through during the first few weeks of this course helped me build a foundation of knowledge on PV solar energy that was crucial to my [project] efforts.*

Several students expressed appreciation that the course incorporated a real-world project, such as Dane, who stated:

> *This course was more than just a class on solar energy and solar panels. [It also] shifted into a real-world project replicating what we might be faced with upon entering the engineering workforce.*

The students also conveyed appreciation that the course wasn't 'just technical.' For example, Chris stated:

> *I really appreciated the focus on economic, environmental, and technical aspects that we had to focus on for this project. I have been exposed to lots of technical and economic situations over time, but the environmental aspects have always been a bit foreign to me due to the culture I grew up in.*

The students enrolled in the course had self-selected the integrated engineering major, which is known within the school of engineering for emphasizing sociotechnical pedagogical approaches across all courses. As such, each of these students had previous experiences with nontraditional engineering courses, and had chosen to continue in the major, so their favorable feedback about the sociotechnical nature of the course is not unexpected.

Student Reflection Theme 2: Student Takeaways and Development

The students also reflected on the development of professional skills they got from the course. For example, Rob felt that he grew from having to give numerous presentations for the course, at the end of each project phase (approximately every two weeks):

> *The public speaking part of this project helped me grow tremendously. I do not like public speaking and the biweekly presentations forced me out of my comfort zone. The presentations gradually got better and better and I got more confident in articulating myself clearly.*

In Della's reflection she articulated the sociotechnical and reflective mindset that were hoping to nurture in students through the project experience:

> *As a sociotechnical engineer, I realize that not every aspect of an engineering project can be quantified or captured in feasibility analyses. Therefore, I must practice the responsible engineering process of reflecting on who and what my team may have forgotten or left out as a part of our estimates, designs, and recommendations. In this reflection, I will consider whose voices were left out throughout the entirety of my team's project as well as what role I can play as an integrated engineer to incorporate these voices in the future.*

Largely the students' self-perceived developments mirrored what we saw in the students over the course of the semester from their presentations and written deliverables.

Student Reflection Theme 3: Students' Self-Criticisms and Project Shortcomings

In some cases, the students were critical of their own work, and unsure of their findings. For example, Dane felt his team fell short in their social analysis, stating:

> *We should have spent more time explaining the social impact and context since the aesthetic is likely the main roadblock of installing the solar PV carport…We could have also looked (in more detail) into the impacts that PV manufacturing sites have on residents that live near them (usually tied to environmental racism).*

Della also expressed that her team should have put more focus on their social analyses, and felt they left an important stakeholder—the university neighborhood—out of the conversation:

> *One of the largest and most geographically relevant communities that my team left out of our feasibility conversations is the [neighborhood] community. Located right next to [the university], it would have been very beneficial for our team to work with community members directly instead of speaking on their behalf based on assumptions that we made.*

The students' unsureness of their findings was connected to their assumptions and technical calculations. For example, Dane reflected that they should have included "accuracy/tolerance numbers (e.g. +/- 5%) on [their] calculations, a feature which would help evaluators look critically at [their] proposal." He went on to state that, "it is likely that our estimates are very rough and could vary heavily." In Adam's words:

> *Although we conducted a thorough societal, technical, economic, and environmental feasibility analysis, we cannot say that our calculations are completely accurate because there are many aspects of the project that required us to make assumptions due to the available information.*

Lauren described wrestling with unquantifiable intangibles that necessitated the team to make assumptions:

> *We had to make assumptions about what panels and mounting hardware would be used for the new installations, as neither piece of information was specified. Lastly, there are some intangible costs and benefits that we discussed in our economic feasibility report, but that are present throughout the project. These considerations are hard to quantify, but they are still important.*

We acknowledge that making assumptions and estimates is difficult and a skill that engineering students typically don't practice as much as solving single-answer quantitative problems. Additionally, when students do practice these skills as part of open-ended design projects, often those projects are for a hypothetical situation or client. In this case, the students had to present their findings to key university stakeholders and make a recommendation for how the university should proceed. We hypothesize that the students' experience of these 'real stakes' could have contributed to their shaky confidence. We also assert that the realness of the project provided more value to the students who could see it directly translating into a professional setting.

Student Reflection Theme 4: Student Perceptions of Project Broader Impact

Students saw benefits to the project beyond their course experience and personal development. For example, Joseph hoped that the project would leave a lasting pathway for student/university administration dialogue:

> *One of the long term (sic) ripple effects this project overall hopefully is that [the university's] administration is more open to listening to students and putting their words into action. …[we are a] changemaker university, and we are supposed to be leading the way in terms of social awareness and action, I think we should let students take the lead on these. Hopefully this project serves as a pathway for students to get more involved in campus's (sic) planning and projects.*

Lisa saw a bigger picture for what the university's investment in the solar upgrades could do for university image and recruitment:

> *The prestige of implementing solar energy on campus is good for the University image. We will increase the amount of students and administrators that want to work for the University by having a more sustainable campus.*

Tony also saw the project fitting into a bigger-picture, specifically helping the university to reach carbon neutrality as committed:

> *I think the primary missed consideration is a greater understanding of how this solar project will help the university reach its Carbon Neutral goal by 2035. One of the most persuasive arguments for any solar system installation on campus will be its ability to improve the university. Whether this is by saving money, improving the school's carbon footprint, marketing the school as more green, or simply becoming a more independent and self-reliant community.*

The student comments conveyed that they felt the realness of the project, and saw it having meaning beyond themselves and the course. We hypothesize that this experience of place-based realness provided an opening for students to engage more deeply in the course and the project.

Student Debrief

The student responses to 'emotion about the presentation experience' during the post-presentation debrief session are shown in Table 1. The largest number of students expressed feeling 'proud' and a 'big sigh of relief.' Multiple key university stakeholders attended the students' final presentation, including the Provost, the Director of Sustainability, a member of the Board of Trustees, the Director of University Design, the Assistant Vice President for Facilities Management, three Senior Project Managers, the Director of the Care of Our Common Home Strategic Plan Pathway, and the Engineering Director of Development, along with several other engineering faculty members. Some attended on Zoom while others were in person. The students' relief and pride were likely heightened given the leadership positions of these attendees.

Table 1: Student Responses to Emotion about Final Presentation

Emotion	**Number of Students**
Proud	4
Big Sigh of Relief	4
Curious	1
Empowered	1
Inspired	1
Nervous until speaking	1
Excited to see what USD does	1
Project and Presentation were cute	1

The student responses to 'highlight of final presentation' are shown in Table 2; student responses to 'I would change...' are shown in Table 3.

Table 2: Student Responses to Highlight of Final Presentation

Highlight	**Number of Students**
Q & A Session	1
Support from faculty that came to the practice and final presentation	1
Everyone Presenting	1
Everyone speak very profesionally	1
Amount of admin that came to final presentation	1
Access to real blue prints	1
Proposing real change	1
Productive project	1
Presenting to important people	1
Ladauto S'ay Yes (Laudato Si ya Later)	2
Merging all of our separate presentations into one presentation	1

Table 3: Student Responses to "I would change.." about Final Presentation

I would change…
Maybe have some more class at the end in order to go over the calculations and make sure that we all use the same numbers and example.
More time to practice presentation
Include source of where power price comes from
We could all go through each other's calculations to confirm
More similarities in each proposal presentation

More time for putting together presentation!!
Less slides
Maybe incude formula/spreadsheet for calculations so they are all calculated the same way
Make sure everyone speaks
I think it would have been good to have our individual projects be more similar in calculations and numbers used

Of note, the students had a range of responses to the 'highlight of final presentation' prompt. Several highlights connect to interaction with peers, faculty, or "important people". Others connect to an appreciation of doing something that had the potential for impact. In terms of improvements, several students wished they had more time. We did provide class time for the students to collaborate and come up with an integrated final presentation, however that time was limited. We go into more detail about the schedule and dedicated class time in the section below. Several students expressed a desire to confirm one another's calculations, a sentiment also echoed in the student reflections.

Instructor Reflection

Overall the instructors were pleased with how the course went and the students' demonstrated learning and responses. The seniors were all in their capstone design course at the same time as this class so they had more experience with longer-term open-ended projects and presentations than the juniors. Initially some of the juniors were more tentative in their groups and their presentations but it was great to see improvement and by the end of the semester, all students took ownership of the projects. Note that all juniors were on teams with some seniors. One team included only seniors. Having the whole class collaborate on the final presentation to outside stakeholders was the most risky aspect of the project. This turned out to be one of the most valuable aspects of the course as reported by students at the debrief after the presentation. To enhance the quality of this final presentation, we devoted several class days to preparation as shown in Table 5.

Table 5: Preparation for Final All-Class Presentation to University Stakeholders

Date	Class Time
Wed 5/4	Phase 5 Presentations
Fri 5/6	Debrief Presentations (instructors)
Mon 5/9	Work time
Wed 5/11	Practice Final Presentation with feedback (other professors)
Fri 5/13	Work time
Mon 5/16	Final Presentation

Given the high stakes of the presentation and the short timeline, on May 6, the main instructor gave the students a potential outline for this presentation and suggested new groups to work on specific slides and a table to summarize overall recommendations. This worked well with some students commenting in the final debrief after the presentation that they appreciated this. The instructors were particularly pleased with how focused the students were during the work times on May 9 and May 13. For example, for the slides about the class, the idea of including a photo of the class emerged, and we immediately found someone to take the photo. Students did a quick survey of the class to determine which activities related to sustainability they were all involved in and included this in the presentation. Students from different project groups were comparing their methods and units for calculating economic benefits and carbon savings. Seeing students take ownership of their approach and asking insightful questions about others was rewarding for the instructors. They used Google slides to work collaboratively with all students contributing. We gave students the option of speaking during the 30-minute presentation and were happy that all but one student (a junior) chose to speak. On May 11, the students received feedback from other professors in integrated engineering, a professor in environmental and ocean sciences, and the Director of Career Services for Engineering.

Given our goal of situating this project in our local context, we were particularly pleased that one student team recognized this and introduced *Laudato Si'* in their initial presentation (Phase 0) and referred to it again in their integration presentation (Phase 5). *Laudato Si': Care for our Common Home* is an encyclical by Pope Francis which calls for connecting sustainability and social justice [20]. As a Roman Catholic campus, this is important to our context. The instructors encouraged a member of this team to focus on this context for the final presentation. The student did a great job, discovered that our university had become a *Ladauto Si'*campus, and tied this commitment to the class's recommendation for more solar energy.

An important lesson learned is the need for the different semester-long projects to be as comparable as possible. One of our projects (exploring solar panel upgrade options for the current system) was too broad, which resulted in student confusion about how their assigned task differed from the recommendations already included in the university Energy Master Plan. Although that report had many shortcomings, it was hard for the students to develop options. The other projects that focused on specific new solar installations were more successful. A possible option in the future is to have more than one team work on the same project. When discussed in the debrief, students were open to this idea. We plan to continue offering this elective every other year and look forward to implementing these changes in the next iteration of the course.

Conclusions

A new upper-division engineering elective course was successfully offered at the University of San Diego in Spring of 2022. Informed by place-based pedagogies and culturally sustaining pedagogies, we designed the course to be relevant to the students' lived experiences by coupling the learning about technical elements of solar energy with a focus on solar energy projects on campus. We divided the 14 students in the class into four teams, with each team conducting a feasibility assessment for their solar project over the semester. After the students explored the current state of solar energy on campus, we guided them in completing their assessments of the new projects through four two-week phases, with each phase focusing on a different sociotechnical analysis for their project: 1) social, 2) technical, 3) economic, and 4) environmental. During the fifth and final phase, 'integration,' we supported the students in integrating their analyses from each phase and making final, all-class recommendations to university leaders about how to proceed with solar energy investments on campus. Student feedback from reflections and a debrief at the end of the course were positive. Students appreciated considering the technical first and then connecting to the other aspects. Students reported growth in person development and skills such as communication. Students recognized the challenge of doing this work and the potential for broader impact. Students valued interacting with their peers, faculty, and administrators. They were proud of their accomplishments and presentation to university leadership. Lessons learned from the students and instructors will be incorporated into the next offering.

Acknowledgements

This research was funded by the USA National Science Foundation's Improving Undergraduate STEM Education (IUSE) program, grant #1836504. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

References

[1] Riiny, M.D., S. M. Lord, Learning about Solar Power in South Sudan: An International Collaboration, *2021 American Society for Engineering Education Annual Conference Proceedings*, Long Beach, CA, July 2021. https://peer.asee.org/37424

[2] Purvis, B., Mao, Y. and Robinson, D. Three pillars of sustainability: in search of conceptual origins. *Sustainability Science*. 2019, *14*(3), 681-695.

[3] Boyle, C. Considerations on educating engineers in sustainability. *Int. J. Sustain. High. Educ.* 2004, *5*, 147–155. [Google Scholar]

[4] Bell, S. Engineers, society, and sustainability. *Synth. Lect. Eng. Technol. Soc.* 2011, *6*, 1–109. [Google Scholar]

[5] Momo, B. Hoople, G.D., Chen, D.A., Mejia, J.A., Lord, S.M. Broadening the Engineering Canon: How Culturally Responsive Pedagogies Can Help Educate the Engineers of the Future. *Murmurations: Emergence, Equity and Education* 2020, vol. 1, no. 1, pp. 6-21, 2020. https://doi.org/10.31946/meee.v2i1.32

[6] Paris, D. Culturally Sustaining Pedagogy: A Needed Change in Stance, Terminology, and Practice. *Educ. Res.* 2012, *41*, 93–97. [Google Scholar]

[7] Paris, D.; Alim, H.S. *Culturally Sustaining Pedagogies: Teaching and Learning for Social Justice in a Changing World*; Teachers College Press: New York, NY, USA, 2017; ISBN 9780807775707. [Google Scholar]

[8] Kimmerer, R. W. *Braiding sweetgrass: Indigenous wisdom, scientific knowledge and the teachings of plants*. Milkweed Editions, USA, 2013.

[9] Watson, J. *Lo-Tek: design by radical indigenism*. Taschen, USA, 2019.

[10] Medin, D.L., Bang, M. *Who's Asking?: Native Science, Western Science, and Science Education*; MIT Press: Cambridge, MA, USA, 2014; ISBN 9780262026628. [Google Scholar]

[11] Marin, A., Bang, M. Designing Pedagogies for Indigenous Science Education: Finding Our Way to Storywork. *J. Am. Indian Educ.* 2015, *54*, 29–51. [Google Scholar]

[12] Medin, D.L., Ojalehto, B., Marin, A., Bang, M. Culture and Epistemologies: Putting Culture Back Into the Ecosystem. In *Advances in Culture and Psychology*; Oxford University Press: Oxford, UK, 2013. [Google Scholar]

[13] Lord, S.M., Przestrzelski, B., Reddy, E. Teaching social responsibility in a circuits course. In Proceedings of the ASEE Annual Conference & Exposition, Tampa Bay, FL, USA, 16–19 June 2019. [Google Scholar]

[14] Gelles, L.A., Lord, S.M. Pedagogical considerations and challenges for sociotechnical integration within a materials science class. *Int. J. Eng. Educ.* 2021, *37*,(5), 1244-1260. [Google Scholar]

[15] Hoople, G.D., Chen, D.A., Lord, S.M., Gelles, L.A., Bilow, F., Mejia, J.A. An Integrated Approach to Energy Education in Engineering. *Sustainability* 2020, vol. 12, no. 21, pp. 9145, 2020. https://doi.org/10.3390/su12219145

[16] Forbes, M.H., Lord, S.M., Hoople, G.D., Chen, D.A., Mejia, J.A. What Is Engineering and Who Are Engineers? Student Reflections from a Sustainability-Focused Energy Course. *Sustainability* 2022, 14(6), p.3499.

[17] Hoople, G.D., Choi-Fitzpatrick, A. Drones for Good: How to Bring Sociotechnical Thinking into the Classroom. *Synth. Lect. Eng. Technol. Soc.* 2020, *9*, i-148, https://doi.org/10.2200/s00984ed1v01y202001ets024.

[18] Forbes, M.H., Lord, S.M. A Place-Based Sustainability Approach to Learning about Photovoltaic Solar Energy, *Trends in Higher Education*, 2(2), pp. 306-319, 2023. https://doi.org/10.3390/higheredu2020017

[19] Clarke, V., Braun, V., Hayfield, N. Thematic analysis. Qualitative psychology: A practical guide to research methods, 2015, 222(2015), p.248.

[20] Pope Francis, *Laudato Si': On Care for our Common Home,* Vatican Press: Vatican City, 2015.