The Sustainability as Stewardship Framework: A Revision of the Engineering for One Planet Framework for an Existing Civil Engineering Program at a Christian Institution

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Introduction

The Engineering for One Planet (EOP) Framework [1] was developed from 2017 to 2022 by the Lemelson Foundation, VentureWell, Alula Consulting and hundreds of individual contributors, and consists of 92 "essential sustainability-focused learning outcomes." The framework has a stated goal to "Transform engineering education to ensure all engineers are equipped with the skills, knowledge, mindsets, and understanding to protect and improve our planet and our lives" [1]. Ultimately, the most significant concept defined by the framework is the acknowledgement of the interconnected nature of sustainability education – producing truly sustainable designs requires a combination of (1) systems thinking, (2) knowledge and understanding, and (3) skills, experiences, and behaviors across a variety of different topical areas, as shown in Figure 1. The framework also self-identifies alignment with the seven current student outcomes in the Engineering Accreditation Commission of ABET as well as with the 17 United Nations Sustainable Development Goals [1]. The framework is supported by ASEE and has been growing in popularity recently.

While the framework itself includes a wealth of information through the assembly of the ideas and opinions of many different experienced professionals, it also includes an overwhelming amount of information and outcomes if the intent is for it to be integrated into an existing engineering curriculum. There are also some unique challenges that accompany efforts to integrate the framework into an engineering curriculum at a Christian institution, such as the one at which the authors teach. This paper explores the development of a heavy adaptation of the EOP framework as the authors worked to produce an alternative framework for sustainability education that would be a better fit for their context.

Background on the Development of the Sustainability as Stewardship Framework

Sustainability in engineering design, and even more specifically in civil engineering (the area in which the authors teach), has been an increasingly more discussed and desired outcome [2, 3, 4]. The American Society of Civil Engineers highlights this fact in its Policy Statement 418, in which it affirms that civil engineers should be committed to principles of sustainable development [5]. This statement originated in 1993 but continues to be regularly updated to reflect the increasing focus on sustainable design practices.

While the concept of sustainability has long been important to the field of civil engineering, the way it has been included in engineering education curricula has rarely been formalized. Common approaches include the offering of sustainability-focused degree programs or concentrations [4], the integration of specific, sustainability-dedicated courses into existing programs [2, 3, 4], or the integration of sustainability topics into existing courses [2, 3, 4]. While ABET requires that some

basic elements of sustainability be present for several specific programs, it largely leaves the responsibility with individual institutions to determine what that sustainability curriculum should include. Reviewing several engineering textbooks, a common trend seems to be that the topic of sustainability appears to only be added on in a recent edition as a separate section, typically toward the back of the book where few courses and even fewer students might ever encounter the material. If included as a topic of discussion in a course, there is also a tendency for sustainability topics to be "tacked-on;" not a critical part of the content of the course, but only presented as semi-useful additional information that instructors want to place in front of students without any real expectations of achieving related outcomes. The EOP framework offers a more holistic consideration about how the way engineering educators teach sustainability can better match with the importance attached to sustainability in practice.

Figure 1. The Engineering for One Planet Framework [1]

With a civil engineering program already in place, integrating sustainability topics into existing courses seemed to be the most efficient approach for developing a holistic sustainability education. This approach can be practical and effective and can help students link sustainability concepts to their field across their curriculum [2]. An initial review of the EOP framework for this intended purpose revealed a significant problem, however. The EOP framework consists of

nine topic areas, and collectively assembles 92 outcomes (46 identified as “core” and 46 as “advanced”) described as essential and necessary for preparing graduating engineers [1]. Many of these outcomes are also phrased such that they possess a multiplicity of sub-outcomes. While these outcomes are helpful for defining the ideas and values behind each topic, a direct incorporation of this quantity and complexity of outcomes into an existing program was determined to be unrealistic. An effort was then made to condense and simplify the framework into a system that could more easily be adapted into an existing curriculum.

While considering how to simplify the framework, several other objectives were included. The first was to create a framework that would more directly relate to ABET accreditation outcomes and program criteria. While the EOP framework identifies outcomes that are ABET-relevant, these outcomes greatly exceed ABET’s requirements [1] and are in some cases only loosely correlated with ABET’s expectations and terminology. In narrowing the scope of the framework, then, an effort was made to focus more directly on ABET-associated sustainable design concepts, most specifically the societal, environmental, economic, and global design contexts [6].

The second objective of the development of a new framework was to keep the framework applicable to a variety of different design disciplines. This is an area the EOP framework has already addressed well. While the new framework was intended to most immediately serve only a civil engineering program, the goal was to not sacrifice the ability for the framework to be adapted to other disciplines by defining its focus too narrowly.

Finally, the last objective of the development of an alternative to the EOP framework was to create a framework that would align with and support the mission and values of a Christian institution. The EOP framework does not directly conflict with religious education, but neither does it take advantage of a religious context to help students recognize the value and importance of designing sustainably.

The development of this religious basis is important since some religious institutions, particularly those associated with conservative, evangelical Christianity, have historically held a negative view of sustainability concepts, most often as related to the environmental design context. This conflict has been highlighted ever since Lynn White’s publication of “The Historical Roots of our Ecological Crisis” in 1967, in which White pointed out the tendency of some protestant sects to overemphasize an anthropocentric value system to the detriment of the environment [7]. While White’s hypothesis has been evaluated and reconsidered in many ways in the years since [8, 9, 10, 11, 12], one particular correlation has been shown to be valid: a negative view of environmentalism correlates with Christians who believe in the literal interpretation of the Bible, referred to by several authors as “fundamentalism.” More in-depth considerations of this correlation reveal that the association may have less to do with the view of literal interpretation than with specific theological positions, such as dispensationalist eschatology [8, 11], and conservative political ideologies that are not directly related to Christianity [8, 9, 10, 11].

The authors' institution is a conservative Christian university. It does not identify as fundamentalist, but it is consistently committed to belief in the Bible as inerrant, infallible, and reliable. While the university's doctrinal positions may not precisely align with some of the characteristics researchers have shown to correlate with a negative view of environmentalism, it is reasonable to assume that many of the students who attend the university may come from a background in which they have developed an aversion to environmental and, by association, sustainability topics. Based on the findings of Guth et al. [11] among others, much of this perspective may be due to political perspectives rather than theological ones. As a result, one potential pathway to helping students at a Christian university develop an appreciation for sustainability is to highlight the theological consistency of viewing care for creation as an application of a stewardship mentality [9]. This approach along with the other previously mentioned objectives were adopted in the development of the Sustainability as Stewardship (SaS) Framework.

The Sustainability as Stewardship Framework

The SaS framework consists of a series of thirteen curriculum modules addressing eight topic areas, as shown in Figure 2. Each module consists of a single class lecture and suggestions for follow-up assignments that instructors can include if they want to extend students' engagement with the topic outside of the classroom. These modules are not intended to be the entirety of a sustainability-related education, but instead to provide instructors with a framework that can help relate, structure, and formalize all additional sustainability-related learning experiences students receive during the completion of their degree programs.

The core principle and first module of the SaS framework is that producing sustainable engineering and technology solutions is a faithful application of the concept of stewarding well the resources God has given us as human beings and designers. Producing sustainable designs ultimately requires an understanding of how design decisions are interrelated with environmental, economic, and societal contexts as well as their impacts on all of society through the global context (topics 2-5, respectively, with one module for each topic). All of the first five curriculum modules are intended to be generally applicable to students from any engineering, computer science, or other technology design majors, and the design contexts defined in the framework align directly with the contexts described in the ABET Engineering Accreditation Commission's student outcomes 2 and 4. In addition to the general understanding of sustainability developed through these introductory modules, it is also critical that students learn to apply these concepts within their intended fields. In the remainder of the SaS Framework, students are introduced to the topics of systems thinking (*implications of design*), design (*applications of design*), and communication & teamwork (*implementation of design*) that are specific and relevant to their field of study. A total of eight modules most directly relevant to the field of civil engineering were developed for these topics as a part of this first application of the SaS framework. The specific outcomes for all of the SaS modules are included in Appendix A.

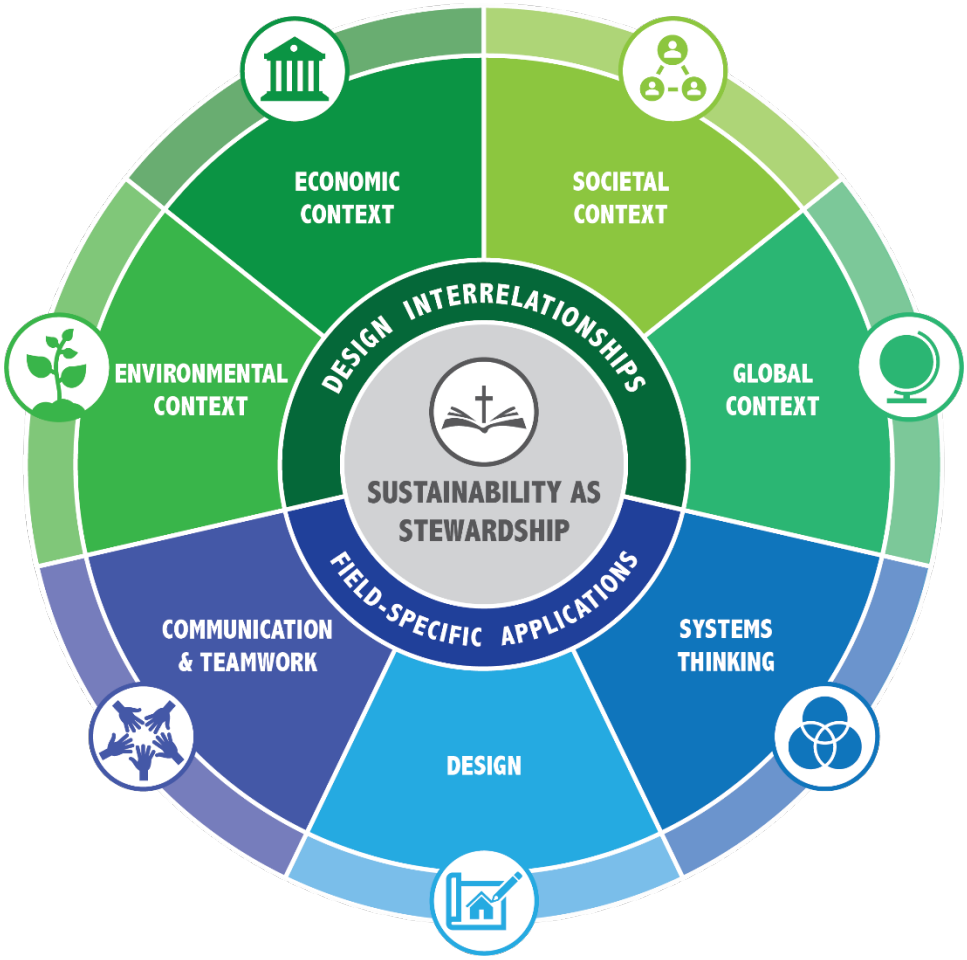

Figure 2. The Sustainability as Stewardship Framework

The Biblical Basis for Sustainability as Stewardship

The first and core module of the SaS Framework aims for students to be able to identify their responsibility to be faithful stewards of the resources God has given them and recognize their associated role as design professionals to produce good and sustainable solutions. The lesson plan for this module introduces students to ASCE's definition of sustainability as "a set of environmental, social, and economic conditions (aka 'The Triple Bottom Line') in which all of society has the capacity and opportunity to maintain and improve its quality of life indefinitely without degrading the quantity, quality, or the availability of environmental, social, and economic resources" [5]. This definition works particularly well in relating sustainability to ABET's engineering design contexts, as it explicitly refers to environmental, social, and economic contexts and implicitly refers to the global context ('all of society').

After students are introduced to a number of examples that highlight the importance of each of these contexts from practical and ethical perspectives, they are then introduced to the Biblical concept of Christian stewardship. The SaS framework defines Christian stewardship as the

responsibility Christians have to actively manage and make use of the resources God has entrusted to them in a manner consistent with God's commands and character. This idea can be most succinctly captured by 1 Corinthians 4:2, which states "Now it is required that those who have been given a trust must prove faithful" [13]. In order to tie the concept of sustainability to stewardship, students are then presented with a theological progression, with items 1-9 thoroughly supported with Biblical references (included in Appendix B). This progression culminates in item 10, in which students are presented with the proposal that designing sustainably is a faithful act of stewardship.

1. God created, sustains, and affirms all creation, both human and non-human, as belonging to Him.
2. God gave human beings the responsibility of stewardship.
3. God desires for people to care for the non-human creation.
4. God desires for people to care for other humans.
5. Sin leads to all humans having a broken relationship with God and damaged and exploitative relationships with each other and the rest of creation.
6. God values justice for both the guilty and innocent but has mercy for those who repent.
7. God's plan for the future culminates in a restoration of creation, both human and non-human, through the life, death, and resurrection of Jesus Christ.
8. As followers of Jesus Christ, we are not our own, but are instead members of His body and servants of God.
9. Our work matters to God, should reflect God's values, and should align with God's purposes.
10. Designing for sustainability, with its conscientious use of resources and consideration of environmental, economic, societal, and global contexts, is a helpful framework for approaching design work in a manner consistent with faithful stewardship and obedience, reflecting God's love for humans and the rest of His creation, upholding His values of justice and mercy, and aligning with his plan for future restoration.

Students are encouraged to consider how each of the above points may impact their work as a designer and share their responses in a class discussion. An optional follow-up assignment has students reviewing the Biblical references for each point and considering how they deepen their understanding of the proposed statements. Ultimately, the purpose of this module is to help students develop their own personal motivation related to their Christian faith to learn more about how they can incorporate sustainability principles into their designs.

The Environmental Context Module

The environmental context module presents a biblical framework for environmental stewardship, creating a relationship between human thriving, God's care for creation, and humanity's responsibility as stewards of creation. The principle of environmental stewardship helps stir students' interest in environmental topics and motivates them to consider the impacts of their decisions on the environment. From this foundation of environmentalism and sustainability as

stewardship, students can respond to design challenges with empathy and insight while making sustainable choices.

The lesson provides a brief background on the history of conservationist or environmentalist thought, especially as it relates to how evangelical Christians have viewed these ideas, and presents a worldview from the "environmental steward" with a Biblical basis, paired with common dissenting beliefs. Five statements of the biblical basis for stewardship (developed for the application of this framework) are included in this discussion. Students are given multiple opportunities to think, respond, or counter ideas presented. As a follow-up assignment, students write a short response paper to the principles of environmental stewardship introduced in the class.

The Economic Context Module

The economic context module introduces students to the fundamental economic principles of risk and opportunity that govern design decisions, relates these concepts to sustainable design, and highlights one application in which sustainability, risk, and opportunity converge in Environmental, Social, and Governance (ESG) ratings. The goal of covering these topics is to help students begin to consider how to weigh economic factors, both near and long term, on the potential sustainability of their future design decisions.

Students are first introduced to some basic economic terminology, particularly related to the ideas of risk and opportunity. They are presented with a hypothetical situation where they have to consider sourcing an engineered component from either a known and proven supplier or from a new supplier who offers a reduced price, then tasked with considering how they would go about making that decision. Students are also introduced to some basic risk assessment tools and risk management strategies. Long-term costs and values are identified as key factors for evaluating the sustainability of various design solutions. Finally, students are introduced to ESG as a framework by which organizations can identify potential sustainability-related risks companies are embracing with their business decisions.

Students are encouraged to consider their own feelings toward taking economic risks, particularly related to sustainable business practices and designs. As a follow-up assignment, students are introduced to a case study involving C.C. Myers, a construction contractor renowned for taking risks on big jobs, and asked to consider whether they would want to work with or for companies with similar practices.

The Societal Context Module

The societal context module aims to help students recognize the various social impacts that can result from designs and to develop an appreciation of these design considerations that can flourish within a Biblical worldview. The lesson plan includes introductory discussions about public health, safety, and welfare, cultural implications, and social justice (accessibility,

diversity, equity, and inclusion). The goal of this lesson is to help students be able to identify and make ethical decisions regarding the social impacts of their professional behaviors and designs.

The overarching importance of the public's health, safety, and welfare in engineering designs is reinforced to students and a number of examples are considered in which poor design decisions can and have produced negative outcomes for the general public. Students are then introduced to a definition of culture and some examples of how designs either failed to correctly account for cultural considerations or produced negative cultural outcomes. Finally, as the main topic of the lesson, students are introduced to the social justice principles of accessibility, diversity, equity, and inclusion. Some of these social justice topics include ideas that may conflict with students' beliefs and values, particularly at a conservative Christian institution. As with the authors' approach to the topic of sustainability as a whole, the social implications discussion is based on comparing these topics against Biblical principles. Ultimately, students are shown both Biblical and professional justifications for including practical and ethical consideration of principles of accessibility, diversity, equity, and inclusion in their future work as designers.

As a follow-up activity, students are asked to complete an ethnographic study. For this assignment, the students each choose some sort of designed solution on campus with which they can observe a reasonably large number of people interacting (for example, the flow of traffic through the cafeteria, a particular entry into a building, equipment in a computer lab, etc.). Students record observations about how users interact with the solution, noting whether the solution fails to take into consideration people with particular characteristics and proposing design modifications that would produce more equitable and inclusive outcomes.

The Global Context Module

To acquaint students the idea of sustainability in practice on a global scale, the global context module introduces globalization and the UN Sustainable Development Goals (SDGs) [14]. The goal of this module is to help students recognize the implications their design decisions may have outside of their immediate community and identify ways their careers as designers could include work toward addressing some of the SDGs.

The lesson plan for this module first introduces the concept of globalization, including both positive aspects like economic growth and cultural exchange and negative aspects like overconsumption and exploitation. The UN SDGs are then presented as an international effort to align countries and major organizations toward positive globalization outcomes. After a brief history of the development of the SDGs, students are encouraged to evaluate the SDGs in light of Biblical principles. Finally, students work in small groups to research one or several SDGs to determine the importance of each topic, current progress toward each topic's achievement, and progress yet needed. As a follow-up assignment, students are asked to write a short paper or create a poster highlighting the SDG(s) they studied.

Discipline-Specific Systems Thinking Modules

With the final three topic areas (systems thinking, design, and communication & teamwork), multiple learning modules were developed for each relating the topics to specific applications within the field of civil engineering. The first five modules of the SaS framework were constructed was to allow them to remain the same for any design discipline, while modules for the last three topic areas would need be adapted to the specific field for degree programs other than civil engineering. While modules similar to those presented below may be applicable to fields other than civil engineering, the best possible introduction of each of these topics would involve applications as directly relevant to the students' intended field as possible.

The first systems thinking module presents the concept of systems thinking in an engineering context by exploring life cycle assessment as a tool to characterize the dynamic impact of a specific industry. The lesson plan includes a short introduction on the distinction between renewable and nonrenewable sources of energy. Then, life cycle assessment is discussed as a way to develop systems thinking. Following a published study, the class uses the life cycle assessment tool to provide a framework for evaluating the impacts of a coal power plant. The class furthermore is directed to an example of the complications of unintended consequences, with an anecdote concerning an Appalachian coal mining operation using mountaintop removal from 1978-1987 that resulted in drinking water contamination and environmental impacts. As a follow-up assignment, students perform an abbreviated life cycle assessment with an inventory analysis on an item, like several ingredients of their favorite cookies. This assignment was introduced in Fall 2023. Students inventoried the cookie ingredients (flour, eggs, sugar, chocolate chips, etc.) and addressed the possible environmental impacts from the life cycle of each ingredient, identifying that pollution could result from farming, transportation, processing, production and distribution, and disposal.

The second civil engineering-specific systems thinking module introduces students to climate change and stormwater management. Students discuss what causes climate change and focus attention on its impacts on the hydrologic cycle. A connection is drawn between climate change and flooding, and the role of civil engineers is characterized by structural and non-structural responses. Finally, Hurricane Harvey is used as a case study to demonstrate the complexity of how civil engineers prepare for disastrous flooding events using sustainable designs. With a reference handout of the hurricane timeline, aftermath, and effects on the surrounding areas, groups of students evaluate a particular strategy set with both structural and non-structural components, defining advantages and disadvantages of the selected approach. A follow-up assignment expounds on the in-class discussion with questions for further research on any of the selected approaches.

The third civil engineering module of the systems thinking topic identifies the tradeoffs in formalizing environmental policy. The approaches to pollution control laws are categorized as regulatory or market based. Five regulatory approaches (technology, performance-based, cost-benefit analysis, health-based, and environmental-based standards) and two market-based

approaches (permits and sanctions, taxes and cap-and-trade methods) are developed. Students are prompted to identify specific examples of current or past regulations and tradeoffs of using each approach. Students can discuss which approach appears most sustainable, how to determine sustainability in this context, and which approach combinations could produce best results. As a follow-up assignment or in a later class period, student groups prepare a debate, supporting either technology-based or performance-based standards.

Discipline-Specific Design Modules

The first civil engineering-specific design module consists of an introduction to sustainable design and construction aimed to help students identify key initiatives in the history of sustainable construction in the US and recognize applications for a few basic concepts of green building design and construction. The lesson plan for this module starts with a brief background on how the construction industry has historically viewed and valued sustainability principles. Students are then introduced to sustainable design and construction practices and examples in the areas of:

- Systems thinking approach to design
- Consideration of natural systems and surroundings
- Efficient consumption and minimal waste of water and energy resources
- Conscientious selection, efficient use, and minimal waste of materials
- Creation of durable, adaptable, and resilient structures requiring minimal maintenance
- Provision of a healthy interior environment
- Social and cultural acceptability at a financially competitive cost

Finally, students discuss how they can introduce sustainable concepts into their designs from their roles as civil or structural engineers. A follow-up assignment asks students to research a particular sustainable design method or construction practice that is of interest to them.

The second civil engineering module of the design topic includes a lesson on sustainable materials and green building design. Students are introduced to the challenges associated with materials consumption and scarcity, sustainability considerations associated with material selection, and the various sustainability tradeoffs associated with steel, concrete, and wood as the primary three building materials. Finally, students are acquainted with the US Green Building Council's Leadership in Energy and Environmental Design (LEED) rating system [15]. As follow up assignments, students are asked to research sustainable wood production and harvesting or to complete a brief case study of a project that received a high LEED certification.

The third civil engineering module of the design topic introduces students to culture and community needs assessments. This lesson plan aims to equip students with the ability to assemble an effective plan for collecting relevant cultural information from a community in order to define design specifications for an international development project. Students are introduced to human-centered design as an approach to make informed design decisions. As an application of collecting human-centered information, students learn about community needs assessments and evaluate the culture and community-focused content of the assessment

checklists provided in the Sphere Handbook for humanitarian response [16]. As a follow-up assignment, students are asked to create and complete a community needs assessment on their own, either for a location in which they live or, as best as they are able, for an international community that is significantly different from their own.

Discipline-Specific Communication & Teamwork Modules

Communication and teamwork are acknowledged by the EOP framework to be necessary skills for designers to be effective advocates for sustainable practices. Students' first introduction to this topic involves a lesson plan addressing teamwork in civil engineering education. This module is intended to be incorporated into a course with a heavy emphasis on group project work. Students first discuss destructive and constructive group behaviors, identifying some of their own strengths and weaknesses when it comes to group work. Students then complete anonymous mini-resumes, where they identify their own most frequent destructive and constructive behaviors, as well as their strengths and weaknesses on skills related to the upcoming project. A few students are randomly selected to serve as 'team captains,' taking turns selecting their teammates based on their mini-resumes. Once teams have been formed, they work through several exercises together identifying function-specific group roles for each member and establishing team expectations regarding inclusion and communication. This approach to initiating group work has been shown to be effective in a previous study [17].

As a second module related to the topic of communication and teamwork, students take part in a discussion about how to effectively communicate with different audiences, demonstrate characteristics of good leadership, and incorporate Biblically consistent principles of diversity, equity, and inclusion (DEI) into their professional interactions with clients and team members. This discussion about DEI values goes into greater depth than the discussion in the societal context module, encouraging students to consider how these topics will be relevant to them not just as students, but soon as civil engineering professionals. The discussion includes a number of examples and responses to frequently asked questions about professional engagement with DEI and concludes with an assignment requiring students to develop their own plan for how they intend to engage with topics of DEI in their future workplaces.

Framework Implementation

In order to integrate students' learning through the SaS framework most effectively into an existing civil engineering curriculum, the class modules were split up and assigned to different courses throughout the curriculum. As much as possible, the first five modules were attributed to courses that teach a variety of engineering disciplines and kept as early in the curriculum as possible. The modules related to the final three civil engineering-specific topics were mostly assigned to later courses, where students are able to learn the sustainability principles alongside more advanced design topics. While not all students are likely to take all of the courses in which the SaS Framework is taught, the first five modules are taught in required courses and regardless

of which electives students take, they will each take at least one course including a topic from each of the last three topics.

While all the lesson plans were developed by the authors of the SaS Framework, only a handful of the modules are intended to be taught by them; the overall intent was for the lesson plans to be handed off to the instructors of the various courses. In order for this to work well, all faculty teaching the assigned courses must be willing to consider how best to implement the lesson plans into their courses. Highlighting the relevance of the SaS framework to professional preparation and ABET accreditation proved to be helpful for persuading faculty members to become willing participants with the project. The overall implementation plan for the SaS framework for the civil engineering program is shown in Table 1. The topics are identified as either being general (intended to be applicable to any design discipline) or civil engineering-specific, and the semester listed is the semester of a typical 4-year plan (8 semester) in which most students in the civil engineering program are likely to take each course.

Preliminary Feedback

Since the SaS Framework was just developed over the summer of 2023 and is being implemented for the first time during the 2023-24 school year, no formal assessment of the effectiveness of the framework has yet been planned or conducted. However, some selected student responses from an assignment in one class can demonstrate some anecdotal evidence on the initial reception of some of the topics included in the framework.

The environmental stewardship module was delivered during the first week of class in EGCE-3610 Environmental Engineering in the fall semester of 2023. This class had 16 students in it, all juniors majoring in civil engineering. Students were actively engaged in the discussion, and several students stayed for continued conversation after the class session. The assignment related to Environmental Stewardship had an open-ended question that led students to respond to two or more of the SaS Biblical framework points identified in the lecture. Some students drew a strong connection between personal action and the stewardship principles, like limiting electricity and material usage, recycling, buying goods locally, picking up trash, educating oneself on environmental policy, and supporting or working for organizations that prioritize green initiatives. Some example comments highlighting how students were able to relate these principles to their Christian faith are included below.

> “I try to conserve when I can, such as using less electricity if possible, carpooling, and sometimes buying locally made goods (at farmer’s markets and such). I also try to enjoy the good gifts God gives when possible, such as food, fellowship with others, the comforts of electricity, etc., in a humble and thankful manner.”

Table 1 – Example Implementation of the SaS Framework

Topic	Module	Discipline	Course	Semester
Sustainability as Stewardship	1 Sustainability as Stewardship	General	EGGN-1110 The Engineering Profession	1
Environmental Context	2 Environmental Stewardship	General	EGCE-3610 Environmental Engineering	5
Economic Context	3 Risk and Opportunity: Environmental, Social, and Governance	General	EGCE-3910 Civil Engineering Management	4
Societal Context	4 Social Impacts of Engineering Decision-Making	General	EGGN-3110 Professional Ethics	6
Global Context	5 Globalization: United Nations Sustainable Development Goals	General	EGCE-1920 Introduction to Civil Engineering	2
Systems Thinking	6A Introduction to Systems Thinking	CE-Specific	EGCE-3610 Environmental Engineering	5
	6B Climate Change and Stormwater Management	CE-Specific	EGCE-4220 Hydrology	8
	6C Tradeoffs in Formalizing Policy	CE-Specific	EGCE-4620 Environmental Management and Policy Development	8
Design	7A Introduction to Sustainable Design and Construction	CE-Specific	EGCE-3410 Construction Engineering	5
	7B Sustainable Materials and Green Building Design	CE-Specific	EGCE-4520 Design of Wood Structures	8
	7C Culture and Community Needs Assessment	CE-Specific	EGCE-4920 Infrastructure for Developing Contexts	8
Communication and Teamwork	8A Teamwork in Civil Engineering Education	CE-Specific	EGCE-1920 Introduction to Civil Engineering	2
	8B Diversity, Equity, and Inclusion in the Civil Engineering Workplace	CE-Specific	EGCE-4910 Civil Engineering Practice	8

> "This project has made [me] wonder what Christian environmental groups are out there. I am curious in what way other Christian groups would argue about the role of environmentalism as stewardship and how that should play out in the real world. As a step toward learning more about this, I could easily use Google to see what organizations exist and what their stance on the issue is."

> "In my personal life, my family and I have always prioritized recycling and gardening during the summers, as efforts to reduce our total waste and use the land God has given us for cultivation and to its fullest potential… To learn more, it's important to remember how science can be used to better predict long-term environmental effects, but also (and more importantly) how wisdom from the Bible can be applied to the handling of such policies that affect many different issues that we face today as a society."

While many students concluded similar feelings and beliefs to what was presented in the lesson plan, a few students reached different conclusions, agreed more with the dissenting views presented, or offered suggestions for other viewpoints or foci. A few examples of these critiques or deeper thoughts are included below.

> "Though this approach clearly prioritizes human life in a responsible, biblical way, it is vague and theoretical. I think a more clear way to state the objective is to identity the priority as human life and if environmental initiatives can effectively and responsibly uphold and further human life, then these practices and policies should be implemented."

> "I find that the environmental steward response is accurate and in line with my personal beliefs, although not entirely comprehensive…However, the essence of "finding value" in God's creation is more than having just a mere "awe" or appreciation for our physical surroundings. I believe we are to actively be expressing the need to care for the environment as faithful stewards of what God has given us for both our everyday needs and physical resources for living, as well as His general revelation to us [Creation]."

Overall, students were appreciative of the curricular change to spend time on the environmental stewardship topic both through discussions in class and developing their own viewpoints in written form. Some of the students' final thoughts about the topic are shown below.

> "For my whole life, I have viewed these debates as necessary, but never have I felt strongly about the issue. I found it very beneficial to hear about and ponder what God has to say about the topic, and how others would refute those ideas."

> "I appreciated that the dissenting beliefs were presented which help us find the boundaries of what these biblical truths actually mean for Christ-followers. My beliefs do align with the environmental steward responses given as it is the way that I think about creation. I think something that I feel challenged in was how I'm actually living out what I believe. I realized that while I don't seek to destroy the environment, I'm not seeking to better it, at least consciously."

> "I felt challenged by this Biblical truth since I personally feel more inclined to worry about my own comfort and ease instead of the rest of God's creation… This assignment has given me a certain level of conviction when it comes to my impact on creation while also giving me confidence in my ability to tell dissenters my point of view."
>
> "Side note: I really enjoy these kinds of assignments. It allows me to look at my studies and future career through a bigger lens. I thank you and the other Civil Faculty for being intentional about bringing these things up in our studies."

While these preliminary responses are limited to only one lesson plan, they highlight an important conclusion related to the purpose of the framework: introducing sustainability principles within the Biblically centered SaS Framework can prove to be an effective way to develop interest and motivation related to sustainable design for students at Christian institutions.

Conclusions and Further Work

The SaS Framework was developed as a modification of EOP Framework in an attempt to create a comprehensive sustainability curriculum that could be integrated into an existing civil engineering program and that could use a Biblical worldview to develop the appreciation for sustainable design in students at a Christian university. The framework includes thirteen lesson modules aimed at developing students' understanding of the Biblical basis for sustainability as stewardship, engineering design contexts for sustainability, and sustainable design applications within the field of civil engineering. By integrating these lessons across an entire civil engineering curriculum, students should have ample opportunity to acclimate to a sustainability mindset and will see multiple examples of how they could incorporate sustainability principles into their future careers. Preliminary responses from students have demonstrated that the framework can be successful at impacting students' values and motivations related to sustainable design.

Future work with the SaS Framework will involve extending the discipline-specific curriculum modules to other fields in engineering and design, both at the authors' university and at other Christian institutions where the Biblical approach may be similarly effective. As the SaS Framework is adapted to other programs and institutions, the aim is also to implement a more formal assessment to evaluate the framework's effectiveness at achieving its sustainability education goals.

The proposed model of relating Christian beliefs to sustainable design as a means of developing interest and motivation may also serve other religious or even secular institutions through further adaptations or modifications. Considering and incorporating the most meaningful motivators behind students' worldviews is an important step in developing effective educational methods, particularly when incorporating topics with broader implications like sustainable design.

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References

[1] Engineering for One Planet, "The Engineering for One Planet Framework: Essential Sustainability-focused Learning Outcomes for Engineering Education," The Lemelson Foundation, 2022.

[2] F. S. Crofton, "Educating for Sustainability: Opportunities in Undergraduate Engineering," *Journal of Cleaner Production,* pp. 397-405, 2000.

[3] J. A. Mesa, I. E. Esparragoza and H. E. Maury, "Sustainability in Engineering Education: A Literature Review of Case Studies and Projects," in *15th LACCEI International Multi-Conference for Engineering, Education, and Technology*, Boca Raton, 2017.

[4] C. F. Murphy, D. Allen, B. Allenby, J. Crittenden, C. I. Davidson, C. Hendrickson and H. S. Matthews, "Sustainability in Engineering Education and Research at U.S. Universities," *Environmental Science & Technology,* pp. 5558-5564, 2009.

[5] American Society of Civil Engineers, "Policy statement 418 - The role of the civil engineer in sustainable development," 6 June 2023. [Online]. Available: https://www.asce.org/advocacy/policy-statements/ps418---the-role-of-the-civil-engineer-in-sustainable-development. [Accessed 3 January 2024].

[6] ABET Engineering Accreditation Commission, "Criteria for Accrediting Engineering Programs," ABET, Baltimore, 2023.

[7] L. White, Jr., "The Historical Roots of our Ecological Crisis," *Science,* vol. 155, no. 3767, pp. 1203-1207, 10 March 1967.

[8] H. H. Boyd, "Christianity and the Environment in the American Public," *Journal for the Scientific Study of Religion,* vol. 38, no. 1, pp. 36-44, March 1999.

[9] D. L. Eckberg and T. J. Blocker, "Christianity, Environmentalism, and the Theoretical Problem of Fundamentalism," *Journal for the Scientific Study of Religion,* vol. 35, no. 4, pp. 343-355, December 1996.

[10] A. Greeley, "Religion and Attitudes toward the Environment," *Journal for the Scientifc Study of Religion,* vol. 32, no. 1, pp. 19-28, March 1993.

[11] J. L. Guth, J. C. Green, L. A. Kellstedt and C. E. Smidt, "Faith and the Environment: Religious Beliefs and Attitudes on Environmental Policy," *American Journal of Political Science,* vol. 39, no. 2, pp. 364-382, May 1995.

[12] W. Jenkins, "After Lynn White: Religious Ethics and Environmental Problems," *The Journal of Religious Ethics,* vol. 37, no. 2, pp. 283-309, June 2009.

[13] "Holy Bible, New International Version," Biblica, Inc., 2011.

[14] United Nations, "Transforming Our World: The 2030 Agenda for Sustainable Development, A/RES/70/1," United Nations, 2015.

[15] US Green Building Council, "An Introduction to LEED and Green Building," US Green Building Council, 2023.

[16] Sphere Association, The Sphere Handbook: Humanitarian Charter and MInimum Standards in Humanitarian Response, 4th ed., Geneva, CH: Sphere Association, 2018.

[17] D. B. Dittenber, "Project Based Learning in an Introduction to Civil Engineering Course: A Cascade Effect on Student Engagement and Retention in Subsequent Years," in *ASEE 124th Annual Conference*, Columbus, 2017.

Appendix A: Topic and Module Learning Outcomes

Topic/Module 1: Sustainability as Stewardship
Students will be able to identify their responsibility to be faithful stewards of the resources God has given them and recognize their associated role as design professionals to produce good and sustainable solutions.

Topic/Module 2: Environmental Context
Students will be able to identify the biblical framework environmental stewardship - the relationship between human thriving, God's care for creation and humanity's responsibility as stewards of creation - and the practical implications of such beliefs.

Topic/Module 3: Economic Context
Students will be able to examine financial risks and opportunities and weigh near- and long-term costs and values related to design solutions.

Topic/Module 4: Societal Context
Students will be able to identify and make ethical decisions regarding the social impacts of their professional behaviors and designs, including concepts such as diversity, equity, inclusion, and accessibility, as well as public health, safety, and welfare.

Topic/Module 5: Global Context
Students will be able to identify how globalization has led to the UN Sustainable Development Goals and recognize potential intersections between these goals and their professional aspirations.

Topic 6: Systems Thinking
Students will be able to explain the dynamic interrelationships of environmental, economic, social and/or global contexts, and study real-world problems and their solutions as they relate to applications within their field.

> **Module 6A (Civil): Introduction to Systems Thinking**
> Students will be able to identify renewable and nonrenewable sources of energy, understand how life cycle assessments (LCAs) work, and participate in a guided LCA of coal power.
>
> **Module 6B (Civil): Climate Change and Stormwater Management**
> Students will be able to identify major causes of climate change (natural and anthropogenic) and the effects of climate change on water quantity, and discuss long-term effects of flooding.

Module 6C (Civil): Tradeoffs in Formalizing Policy
Students will be able to identify the various approaches to pollution control laws and decipher complex information to make decisions about policy-related tradeoffs.

Topic 7: Design
Students will be able to evaluate design options within their field, considering the four sustainable design contexts and selecting solutions that will maximize positive and minimize negative impacts.

Module 7A (Civil): Introduction to Sustainable Design and Construction
Students will be able to identify key initiatives in the history of sustainable construction in the US and recognize applications for a few basic concepts of green building design and construction.

Module 7B (Civil): Sustainable Materials and Green Building Design
Students will be able to evaluate material alternatives based on their sustainability characteristics and identify key features of the USGBC LEED building assessment standard.

Module 7C (Civil): Culture and Community Needs Assessment
Students will be able to assemble an effective plan for collecting relevant cultural information from a community in order to define design specifications for an international development project.

Topic 8: Communication & Teamwork
Students will be able to effectively communicate with different audiences, demonstrate characteristics of good leadership, and incorporate Biblically consistent principles of diversity, equity, and inclusion into their professional interactions with clients and team members.

Module 8A (Civil): Teamwork in Civil Engineering Education
Students will be able to self-identify their own team-related strengths and weaknesses and work effectively on a team, creating a collaborative and inclusive environment where individual contributions are welcomed and appreciated.

Module 8B (Civil): Diversity, Equity, and Inclusion in the Civil Engineering Workplace
Students will be able to demonstrate positive behaviors related to principles of diversity, equity, and inclusion in their professional interactions and incorporate related concepts into their engineering designs.

Appendix B: Extended Biblical Basis for Sustainability as Stewardship

1. God created, sustains, and affirms all creation, both human and non-human, as belonging to Him.
   (Genesis 1:31, 9:9-10; Job 38-39; Psalm 24:1-2, 104:1-35, 139:13-14; Isaiah 40:21-26; Matthew 6:26-30, 10:29; John 3:16-17; Acts 17:26-28)

2. God gave human beings the responsibility of stewardship.
   (Genesis 1:26-28, 2:15,19-20; Matthew 25:21; 1 Corinthians 4:1-2)

3. God desires for people to care for the non-human creation.
   (Leviticus 25:1-7; Deuteronomy 20:19-20, 22:6-7; Job 12:7-10; Psalm 8:3-9, 115:16; Proverbs 12:10; 1 Corinthians 10:26)

4. God desires for people to care for other humans.
   (Leviticus 19:9-10,33-34; Deuteronomy 22:8; Psalm 82:2-4; Habakkuk 2:9-11; Zechariah 7:9-10; Matthew 22:36-40, 25:35-40; Galatians 6:2-10; Philippians 2:3-4; James 1:27, 2:1-26; Hebrews 13:1-3)

5. Sin leads to all humans having a broken relationship with God and damaged and exploitative relationships with each other and the rest of creation.
   (Genesis 3:17-18; Isaiah 24:4-6, 59:1-2; Romans 3:23, 5:12, 8:22-23; James 4:17; 1 John 2:11)

6. God values justice for both the guilty and innocent but has mercy for those who repent.
   (Deuteronomy 32:35-36; Psalm 146:5-9; Ecclesiastes 3:17; Isaiah 1:16-17; Jeremiah 22:3; Micah 6:8; Matthew 23:23; Luke 6:36; Hebrews 10:30)

7. God's plan for the future culminates in a restoration of creation, both human and non-human, through the life, death, and resurrection of Jesus Christ.
   (Psalm 96:10-13; Isaiah 65:17-25; Matthew 28:19-20; John 3:16-17; Acts 3:19-21; Romans 8:18-21; Colossians 1:19-20; 2 Peter 3:10-14; Revelation 5:13, 7:9-10; 21:1-5)

8. As followers of Jesus Christ, we are not our own, but are instead members of His body and servants of God.
   (John 12:26; 1 Corinthians 6:19-20, 12:14-27; 2 Corinthians 5:17-20; Galatians 1:10; Colossians 3:23-24)

9. Our work matters to God, should reflect God's values, and should align with God's purposes.
   (Deuteronomy 8:17-18; Luke 12:47-48; 1 Corinthians 3:12-13; Ephesians 2:10)

10. Designing for sustainability, with its conscientious use of resources and consideration of environmental, economic, societal, and global contexts, is a helpful framework for approaching design work in a manner consistent with faithful stewardship and obedience, reflecting God's love for humans and the rest of His creation, upholding His values of justice and mercy, and aligning with his plan for future restoration.