Final Project Report

James Brewer

PSQF:6205

Dr. Callie Sung

17 December 2024

Table of Contents

Project Overview

The title for this project is “Designing an Urban Greenhouse using Sustainable Building and Operational Techniques”. The institutional client is <client name>. The client received several grants for developing sustainable projects and has opted to design and build a prototype greenhouse using sustainable building practices, using passive heating, cooling, and hydration techniques in the prototype stage. This prototype will provide the basis for building multiple greenhouses, distributed throughout <neighborhood>, using progressively more sophisticated use of technology, including solar power collection and storage, computer controlled environmental controls, and autonomous plant maintenance and monitoring systems.

Instruction and prototype construction will occur at the <client site> in the <neighborhood>, one of the most diverse in the City of Chicago. <Client site> is a hub for community activism and neighborhood improvement, as well as serving as a food distribution center. Even so, the neighborhood has been described as a “food desert” with limited availability of fresh fruits and vegetables. This project is expected to offer a sustainable, cost-effective supply of these nutritious foodstuffs for the families of <neighborhood> as part of a Food Equity program sponsored by the City of Chicago.

Our cohort for executing this project was comprised of young adults from the City of Chicago, who as part of a funded program, were to be given generative instruction in the facts, concepts, and procedures required to design, construct, stock, and maintain urban greenhouses using sustainable practices. The curriculum was developed in concert with experts in the field and was scheduled to launch in November 2024.

An unexpected development occurred several weeks before the project was scheduled to launch. The administrators of funding for our project determined that these resources would be allocated elsewhere. Our project team had no advance warning of the decision, and certainly no control over it. The team decided to proceed with the initial phase of training, with adjustments both to the curriculum and lesson delivery. We engaged five members of <client> professional staff for classroom instruction and positioned them for a "Connoisseur" type of formative assessment (Morrison, p 340). The project team modified the curriculum to relate to the "connoisseurs" by altering the orienting, instructional, and transfer contexts in an effort to deliver a meaningful learning experience for adult learners (Morrison, p. 60).

The results of this refactored curriculum were surprisingly positive, given the limited time to effect such changes. Both qualitative and formative assessments evidenced satisfaction with the course delivery (demonstrating high levels of engagement), meeting learning objectives (good performance on quizzes and lab exercises), and showing potential for attaining project objectives when (and if) the original cohort is re-formed (based upon expert opinions captured at the end of the course. Details on each of these points can be found in the Analysis and Design sections that contrasts the initial direction of the project, with the modifications made in response to the change in circumstances.

Analysis

Needs Analysis

Following Rossett (1999), of the four opportunities requiring intervention, two were clearly identified: the rollout of a new product, and a need to develop a cohort for technical and vocational roles. Using this insight, a high-level needs assessment was performed to:

1) Identify the needs for a particular set of tasks

2) Identify critical needs, especially those relating to the health and safety of the cohort during construction
3) Establish priorities for an instructional intervention
4) Gather “baseline” data to assess of the impact of the instruction. (Kaufman, Rojas, and Mayer, 1993)

As to point 4) above, the data gathered was neither granular nor invasive enough to establish a normative need. Hence, the team based its decision on a comparative need, by reflecting on the qualifications gathered through interviews with greenhouse operators with background in sustainable operations methods, with academics from the University of Illinois at Chicago, experts from the UI Extension Service Urban Agriculture team, and through literature reviews. The high-level needs analysis indicated that some members of the cohort showed deficiencies in scientific and mathematical knowledge (based upon quiz outcomes administered at cohort formation) along with experience with sustainable construction practices (based upon resumes), to successfully meet the project objectives. The primary objective involves the ability to design greenhouse structures using sound engineering practices. Therefore, a need for formal instruction was identified and confirmed with <client> project leadership. Other factors that may have contributed to a performance gap, such as environmental, motivational, and lack of feedback, were ruled out, based primarily on our understanding of the characteristics of each person in the cohort from entry interviews and background evaluations (Rossett, 1999) and (Kalman, 1987). Taking all of these findings together, an instructional program was the method of intervention selected.

Since building and operating a greenhouse is a multi-faceted enterprise, and since the <client> is fully committed to sustainable practices, it was decided that the first module would involve the fundamentals of sustainability. This module defines the scope of this paper, since including the other modules (i.e., plant science, sustainable design/construction, sustainable operations practices), would make this analysis unwieldy. Suffice it to say that similar analysis was performed for these three areas, using subject matter experts and reviews of academic literature, to arrive at the same instructional intervention recommendation

Learner Analysis

A select group of young men and women comprise the cohort for this project. They are part of a program funded by the City of Chicago, along with several corporate sponsors, to provide vocational training with the goal of obtaining full-time employment. All members have (or are pursuing) high-school level background in communications (written and spoken English), science (chemistry, physics, and biology), mathematics (algebra, geometry, and trigonometry) obtained through the Chicago Public Schools. All members have basic computer literacy (Microsoft Office, Google G Suite) and several have taken programming coursework. These qualifications were deemed sufficient to classify the cohort as appropriate learners (those with a basic background in STEM, but not in sustainability).

Each member of the cohort completed a questionnaire and was interviewed several times to gain admission into the cohort. As part of that experience, each member was asked to describe their motivations and interests. Unanimously, the cohort expressed a desire to acquire skills to qualify for gainful employment and emerge from a lower-level socio-economic background into "middle-class" status. Furthermore, they identified education (formal and vocational) as the primary means to achieving that objective.

These facts, taken together, formed the basis for defining personas to further guide learner contexts (described more fully in the next section). A male and female persona were developed, each with similar backgrounds but with different goals, likes, and dislikes. These are provided in the Appendix (Figures).

Context Analysis

Context is a set of factors in which learning is embedded (Tessmer & Richey, 1997). Context dominates every learning experience, and seldom can an instructional designer control these factors, much less avoid or ignore them. An ideal balance is achieved when the Orienting, Instructional, and Transfer contexts actually facilitate learning activities, a condition referred to as environmental favorability (Noe, 1986). The design approach is to attain that condition toward meeting our instructional objectives.

The Orienting Context will involve getting to know each member of the cohort, and learner factors, the environmental factors, and the organizational factors impacting them as members of the <neighborhood> and the <client site>. Some of the findings included:

- Learner Factors, such as establishing prior knowledge in STEM and construction practices, and confirming the value of the project, were strong influences on the design of the curriculum.
- Environmental Factors, such as ensuring that social support (in the form of mentoring, peer support, and cultivating volunteer instructors aligned to the purpose of the project) influenced both the curriculum and the organization of the project.
- Organizational Factors, such as prominently demonstrating the commitment of the Y in this project, by providing counseling for attitudinal adjustments, workplace behaviors, and job placement, offered a layer of affirmation to the cohort that their effort would pay off and their experience would be positive.

The Instructional Context will be highly collaborative and centered on each cohort member, supported by "more knowledgeable others" from industry and academia, with scaffolding provided based upon individual learner needs. This will be attuned to the community standards and expectations, as well as that of the grant projects sustaining this project. Some of the findings included:

- Learner Factors, such as offering a curriculum that promoted self-efficacy and subject mastery, selecting instructors open to forming collegial relationships as "more knowledgeable others", an atmosphere of safety in requesting (and accepting) scaffolding and cognitive support, and acknowledging feedback on course cadence and scheduling (i.e., pace of learning, adequate break times, etc.)
- Environmental Factors, such as making collective decisions with the cohort about the learning environment (spatial orientation, light sound and temperature control, and adequate computer and technology services.
- Organizational Factors, such as designing lessons to be opportunistic and directly applicable to project goals, presenting learning transfer opportunities (within but especially outside the Y), and developing leadership and collaborative capabilities along with technical skills.

The Transfer context will focus on establishing the utility of the urban greenhouse program, while any coping mechanisms evidenced will compel modifications in the learning cycle. Particular attention will be paid to the transfer of knowledge as well as the repeatability of the principles and practices learned from these experiences.

Some of the findings included:

- Learner Factors, such as ensuring the cohort remained mindful of the utility and purpose of the lessons, and that the learnings would be applicable to the project (and beyond), awareness of coping strategies (i.e., dealing with frustration with cognitive overload, interpersonal difference in learning styles), and developing experiential learning through labs and prototype building exercises.
- Environmental Factors, such as emphasizing the congruence between project goals and he mission and values of the <client>, including the many support systems that it confers (i.e., childcare, safe harbor, etc.).
- Organizational Factors mesh closely with those in the Orienting Context. The mission and values of the <client> infuse the instructional design and deliver of the course content as well as the execution of the project itself. The cohort showed that they expected to feel empowered and "agents of change" in their community through this learning experience.

A detailed description of the activities for the Learner, Environmental, and Organizational levels within each contextual category can be found in the Appendix (Table 12).

Content Analysis

The project team collaborated with experts in sustainability from academic (UI – Chicago). Service (UI Extension Service) and industry (Exelon) to develop a curriculum that was stimulating and engaging, while providing a solid presentation of the key ideas. Accordingly, the lessons were designed to combine textual, visual, and hands-on exercises to provide variety. The original plan involved three modules, comprised of five lessons each, for a total instructional time of 40 hours (see Table 12 in the Appendix) A team-centric approach, wherein small groups of 2-4 students formed to jointly approach lessons, provide peer support on a cognitive and emotional level, while also supporting the goal of active learning. As the transition from a full cohort to a team of “connoisseurs” occur, the curriculum underwent two changes. First, the time of the first lesson (Principles of Sustainability) was reduced from 6 total hours to 2 hours of instructional time and 1 hour of lab time. Second, the emphasis changed from a utilitarian perspective to coverage of some of the “big ideas” in sustainability that was thought to be more relevant to <client> management, without losing too much of the practical flavor of the original lessons. The particulars of these changes are discussed in the Design section.

In developing the UbD (backward design) lesson plans, and with the objectives in mind, a concept-sequenced approach, specifically using the class-relations method was indicated (Posner & Strike, 1976), (Morrison, p. 134). This facilitates progression from general concepts (i.e., whole-carbon-lifecycle, affecting the entire planet), to specific applications (i.e., sourcing recycled/repurposed materials, utilizing sustainable building methods, maintaining healthy working environments, etc.), and setting the learning objectives accordingly. This was thought to support the contextual analysis performed (and described in the previous section).

During the instructional design process, we became acutely aware than lesson activities are not congruent to instructional objectives or goals. Wiggins & McTighe (2011) warn against framing instructional goals as merely content with pronouns in front. They should relate to the true meaning of the instructional program, incentivizing learners toward intellectual engagement by interacting with and challenging the instructional design constraints – in this case, the overarching objectives for learning about sustainability and applying it with intelligence and intention. Thus, our instructional objectives were carefully specified, taking the unique characteristics of the cohort mindfully into account. These objectives are discussed in the Design section of this document and covered in detail in Table 11 in the Appendix.

Design

Learning Objectives

Sustainability is a discipline so broad and of such vital concern to society that it is difficult to select themes and topics. After conferring with experts from academia, service, and industry, I have developed two sets of cognitive instructional objectives – one with global orientation, another with project focus (Stapleton-Corcoran, E, 2023). Note that the objectives at the global level utilize verbs from the higher levels of the cognitive domain, while those at the project level take verbs from the lower levels (Morrison, p. 111)

Global Learning Objectives (higher cognitive level)

- Argue for the concepts of sustainable infrastructure and industrialization and society's needs for a systemic approach to their development.
- Differentiate the local, national, and global challenges and conflicts in achieving sustainability in infrastructure and industrialization from those driving local economic development and growth in Chicago neighborhoods.
- Embrace the role of ethics as intrinsic to sustainable principles, as a decision mechanism for distinguishing "good" from "bad" practices.
- Combine and create relationships among these concepts to propose new opportunities and markets for sustainability innovation, resilient infrastructure, and industrial development.

Project Learning Objectives (lower cognitive level)

- Describe a sustainable ecosystem and the role the greenhouse project (i.e., sourcing of materials, assembling structural elements, siting considerations to maximize sunlight, configuring utility systems, energy usage and storage, etc.).
- Prepare a life-cycle assessment (LCA) of the prototype greenhouse (e.g., data review, scope of the greenhouse lifecycle, take-out assessment, waste-removal approach).
- Demonstrate an understanding of the LEED standard, and apply it to evaluate a prototype greenhouse, and report on its compliance toward LEED certification of the structure.
- Demonstrate that sustainable principles impact people in the neighborhood, particularly in terms of food equity, stewardship of resources, and economic responsibility.
- Illustrate interconnectivity in the context of sustainability, using the greenhouse as an exemplar for LEED building, green energy, food equity, and economic development.

These learning objectives motivate the instructional design decisions for the project.

The project team determined that a backward-design framework for specifying learner goals, assessments, and lesson plans represented the best approach for integrating desired results, success criteria, and learning plans for instruction. In developing the UbD (Understanding by Design, or backward design) lesson plans, the learning objectives (stated below) guide the instructional design of a module on Sustainability, comprised of five lessons. These lessons will cover the importance the integrated and holistic nature of sustainability, including the goal of minimizing Whole Life-Cycle Carbon (WLC) footprint in our construction and operational practices, the importance of healthy construction and operational practices (for the designers, builders, operators, and users alike), the sourcing, preparation, and utilization of recycled/reclaimed materials, the focus on minimizing waste, and the importance of prevailing standards (i.e., LEED.

All modules are framed in a Understanding by Design (UbD) template (Wiggins & McTighe, 2011), starting with the *desired results* (developing the appropriate knowledge and practical understanding of sustainable construction practices, and to evaluate structures for conformity to LEED standards), *acceptable evidence, or criteria for success* (assessing a structure and confirming its LEED conformity or deficiencies), and a *plan for learning experiences and instruction* (a topically structured and time-boxed schedule for each lesson).

Design Decisions

Design Decision 1: Define cognitive learning objectives based upon complexity of topics.

Lesson activities are not congruent to instructional objectives or goals. As noted elsewhere, Wiggins & McTighe (2011) warn against framing instructional goals as merely content with pronouns in front. They should relate to the true meaning of the instructional program, incentivizing learners toward intellectual engagement by interacting with and challenging the instructional design constraints – in this case, the overarching objectives for learning about sustainability and applying it with intelligence and intention.

Design Decision 2: Apply a context-sequenced approach, using a class-relations method.

Given the objectives stated above, a concept-sequenced approach, specifically using the class-relations method was indicated (Posner & Strike, 1976), (Morrison, p. 134). This facilitates progression from general concepts (i.e., whole-carbon-lifecycle, affecting the entire planet), to specific applications (i.e., sourcing recycled/repurposed materials, utilizing sustainable building methods, maintaining healthy working environments, etc.), and setting the learning objectives accordingly. An initial lesson will verify this method as appropriate for the learning cohort.

Design Decision 3: Combine lecture presentation with activities commensurate with the lesson content, while exercising different learning patterns.

In order to maintain interest, stimulate engagement, and promote active learning, the lecture sessions are augmented by three types of learning and assessment: close (activity-based dialogue and dialectic), to promote engagement with real-time assessment of content retention; proximal (curriculum-centric quizzes that provide an objective measure of individual understanding); and distal (virtual laboratory investigations to measure the impact of the curriculum and the learner's ability to apply it away from a formal lecture context) (Hickey, et al., 2012). Given that the project objectives require the learners emerge with the ability to apply their learnings in a "hands-on" fashion, the motivation for a medley of classroom experiences seems intuitive. A research-based rationale for this decision is provided in the Implementation and Evaluation section of this paper.

Design Decision 4: Combine expert lecturers with well-designed presentation material to minimize both intrinsic and extraneous cognitive load.

We follow Knowles' principles that the most important elements of an andragogical experience is to establish an environment where experiences, desire for knowledge, and the application of learnings can be fostered. (Knowles, et al., 2015). This means that the presentation material should use concise verbiage, consistent layout and style, and visuals when indicated to illustrate dynamic concepts. Equally important, in our view, is the ability of the cohort to ask direct questions to a "more knowledgeable other" (in this case, the lecturer) to validate their self-concept as learners, while also sparking their motivation to learn more. We also intend to implement a generative learning strategy by promoting open dialogue within the lectures to foster active learning, along with providing real-time responses to the exercises embedded within the lecture (Morrison, p. 208).

Artifacts

Each student will be provided with a workbook. Each page will represent a slide from the lecture, along with room along the margin for notes and questions. A page for individual and group exercises will offer a framework for ideating, designing, and producing a solution. For example, when the lecture covers global temperature trends, a workbook page replicates the slide displayed, along with space for recording notes and questions for subsequent discussions (refer to Figures 1 and 2 in the Appendix). It is expected that the students will frequently discuss course content (e.g., the implications of certain climate change projections on surface temperature, sea levels, meteorological impacts, etc.), among themselves in an ad hoc manner. A second page in the workbook will support the recording of those ideas and prepare the student for more formal presentations.

These objectives guided the instructional design of a module on Sustainability, comprised of five lessons. These lessons will cover the importance the integrated and holistic nature of sustainability, including the goal of minimizing Whole Life-Cycle Carbon (WLC) footprint in our construction and operational practices, the importance of healthy construction and operational practices (for the designers, builders, operators, and users alike), the sourcing, preparation, and utilization of recycled/reclaimed materials, the focus on minimizing waste, and the importance of prevailing standards (i.e., LEED).

As noted above, the curriculum was revised to implement only the first of the five lessons (sustainability principles and whole-carbon lifecycle). The summary of the revised curriculum can be found in the Appendix (Tables 4 & 5), along the PowerPoint slides delivered during the "connoisseur" formative assessment section immediately below the summaries.

Implementation and Evaluation

Purpose of the evaluation

Determining the impact of instruction is of particular significance, given the interests of the stakeholders (i.e., grant providers, <client> management, the project team, and the learners themselves). Impact is defined in two ways: first, to assess the degree of learning achieved by the cohort; second to evaluate the effectiveness and efficiency of the instructional design to deliver content. To accomplish both, we intend to apply situative theories of assessment, which "extends prevailing views of formative assessment for learning by embedding 'discursive' formative assessment more directly into the curriculum" (Hickey, et al., 2012, p. 1240). We chose to adopt a broad view of learning that challenges widely held distinctions regarding assessment, including "distinction between 'formative' and 'summative' assessment and between 'assessment' and 'instruction'" (p. 1241). This approach involves embedding informal assessments that target curriculum improvement, while "simultaneously invoking more formal assessments to guide those improvements and obtain valid evidence of achievement impact" (p. 1242).

Description of evaluation plan

Philosophically, the project team adopts situative theories of cognition, focusing on knowledge that is situated in the social and technological context - in other words, the context in which knowledge is created and acquired is a fundamental part of that knowledge. We view the evidence obtained from individual assessments and tests as ''secondary'' representations of primarily social knowledge (Gee, 2003; Hickey & Zuiker, 2005).

Consequently, our situative approach uses three different ''levels'' of assessment:

close, proximal, and distal (Ruiz-Primo, Shavelson, Hamilton, and Klein, 2002).

We believe that these different forms of assessment can help utilize and align the very different formative and summative functions that follow from each. This is because doing so makes it possible for a single assessment to function summatively for one type of learning while functioning formatively for another. Refer to Table 1 for a summary of each level's characteristics.

Level	Assessment Orientation and Type	Relative time scale	Assessment Format	Primary Outcome	Primary Summative Functions	Primary Formative Functions
Close	Activity-based Dialogue and Dialectic	Hours	Rubric evaluating Level of Participation, Listening skills, Preparation, and Quality of Comments,	Collective Discourse	Interpret enactment of activities and classroom discourse	Guide refinement of activity and classroom discourse
Proximal	Curriculum Oriented Quizzes	Days	Selected multiple choice and short-answer items.	Individual understanding	Assess impact of activity and feedback conversations	Refine curriculum and support remediation
Distal	Laboratory Exercises	Days	Laboratory investigations targeted toward classroom content	Individual/Group understanding	Measure impact of curriculum on performance in externally developed lab exercises	Provide stakeholders with evidence of curricular impact in practical application.

Table 1

Examples of three levels of assessment (Hickey, et al., 2012)

Details and reasoning for evaluation plan.

- For the close level, learners were assessed in their ability to engage in dialogue with the instructor and each other, when prompted either by a question posed, or on their own initiative. A rubric (see Table 4 in the Appendix) that scores their degree of participation, their listening skills, their preparation, and the quality of their responses will be used to give a qualitative assessment of their ability to identify the key point, to form a constructive argument, and to respond to others who may challenge their point of view in a civil and respectful manner.

- For the proximal level, students completed several quizzes, configured either for true/false, multiple choice, or short answer (see table 13). This will trigger both refinement of lesson design/activities, and the quality of classroom discourse. Analysis of results will involve tabulation of T/F and multiple-choice responses, and qualitative evaluation of short-answer responses (see Table 14 in the Appendix).

For the distal level, a group lab exercise was performed, based upon instruction on lab techniques. This is expected to show the impact the curriculum has on hands-on activities (see Table 15 in the Appendix). Evaluation will consist of observing manipulative, observational and interpretive skills and scoring against a performance rubric. An example of a Type 3 experiment is provided in Table 16. Note that the students will have access to PCs to carry out this experiment.

Stakeholder involvement

The project team will collect and analyze evaluation data using spreadsheets and will produce reports that interpret and display the outcomes. These reports will be distributed to each learner to identify areas of strength as opportunities for growth. Aggregated reports will be provided to stakeholders, including grant donors, <client> management, and other interested parties. The confidentiality of the learners will be strictly enforced.

As indicated previously, modifications to the curriculum or delivery were made, owing to the dramatic change in the cohort. Instead of the 15-20 learners anticipated in the development of curriculum, we engaged five members of <client> professional staff for the implementation of the material. With fewer learners, we could adjust several elements of the curriculum and the lesson delivery.

Much less time was required for introductions, instructions, and training on accessing and utilizing class materials, since the "connoisseurs" knew each other well. This enabled "round table" seminar-type environment, supplemented by an overhead projector, and distributed handouts for note taking and individual observations. This familiar social fabric allowed the instructor to use the "Socratic Method" for maintaining learner engagement and interest, by calling on each cohort member to play back or explain a concept covered in the material. This method could have been interpreted by the original cohort as possible threatening, challenging, or insensitive - however, this cohort embraced the more inquiry-driven approach. Moreover, since the new cohort were familiar to one another, there was greater interaction and more candid dialogue than was planned for in the original curriculum. In fact, there was so much dialogue that a backup scribe (in addition to the instructor) was assigned to capture key conversational points.

The class was held in the Kelly Hall Makerspace lab, which offered adequate lighting, sound control, and other instructional materials (i.e., easels, whiteboards, etc.). This provided an excellent basis for providing positive instructional context for the learners (Morrison, p. 63). Lectures took the form of a conversation, instead of using a more formal delivery mode. This enabled occasional "deviations" from the lesson plan to entertain questions and provide background and context on the material. This also provided opportunities for learners to share their experiences and knowledge more freely than in a purely lecture setting.

The lecture materials, quizzes, the lab exercise, and the ending survey was delivered to every computer. This replaced a model where computers would have been shared among every 3-4 learners. Also, quizzes, lab execution, and surveys would have been delivered in an analog (i.e., paper) format.

Data and Observational Evidence

It was vital to capture evidence of learner acceptance of the lessons, through observing informal cues indicating attentiveness, retention and interest, as well as outcomes on a set of assessments. Our situative approach to assessment evaluated learners on three different "levels" - close, proximal, and distal (Gee, 2003; Hickey & Zuiker, 2005; Ruiz-Primo, et al., 2002).

- We assessed close learning through a situative focus on collective participation in social discourse (Gee, 2003), which took the form of both qualitative assessment of participation, as well as the quality of responses to Socratic dialectic during the lecture.
- At the proximal level, learning was conceptualized using pair of quizzes at intermediate points in the lecture.
- At the distal level, learning was conceptualized using the associationist view of learning that warrants the use of multi-dimensional measures of achievement. In this case, we evaluated the learner's execution of a lab exercise, and the correct steps in performing that exercise.

We believe that these different forms of assessment gave key insights for future modifications to the instructional design, and also confirmed the majority of the techniques in place (Morrison, p. 277).

Description of the data

A group of 5 adults comprised the cohort for this instruction. All had college degrees, with an emphasis in science (chemistry, physics, and biology), obtained through accredited universities. All members had basic computer literacy (Microsoft Office, Google G Suite) and several had taken programming coursework.   These qualifications were deemed sufficient to classify the cohort as appropriate learners (those with a foundational background in STEAM, but not in sustainability).

Each member was asked to describe their motivations and interests. Because everyone was employed as a professional in the STEAM area, there was no motivational gap. Even so, the instructional design worked toward creating a high level of interest and enthusiasm (Morrison, p. 193).

We observed and recorded evidence of lecture acceptance cues. Class participation was evaluated using a form used in other academic settings (Appendix, Table 5). Table 2 indicates that, in general, learner engagement was strong.

Learner	Engagement	Listening	Preparation	Quality of Comments	Total	Remarks
A	25	25	25	20	95	Fully engaged, interested in content, and willing to learn.
B	25	25	25	25	100	Excellent classroom performance and astute commentary
C	20	20	20	15	75	Good effort, but appeared distracted at times, taking frequent breaks, and contributed minimally to class discussions.
D	25	25	20	25	95	Fully engaged and interested in content. Incisive and well-informed comments.
E	20	25	20	20	85	Good engagement given lack of experience with content.

Table 2
Qualitative scoring of class participation and acceptance.

Summary statistics on quiz results are provided in Figures 1 and 2 below. They illustrate quiz performance for each learner on two quizzes, conducted after the first third and the second third of the course respectively. Due to the small number of both learners and questions, the summary statistics are not significant, but they do reveal interesting reactions to the quiz questions (see Appendix Tables 9 & 10 for more information).

- There was consistency in performance by each learner. This was attributed to the fact that two of the learners (B and D) had extensive experience in STEAM concepts and instructional methods.

- The cohort overall did reasonably well, given the close attention paid by the instructor to the learning process. However, some learners grappled with quiz questions, given their relative lack of exposure to STEAM and sustainability concepts.

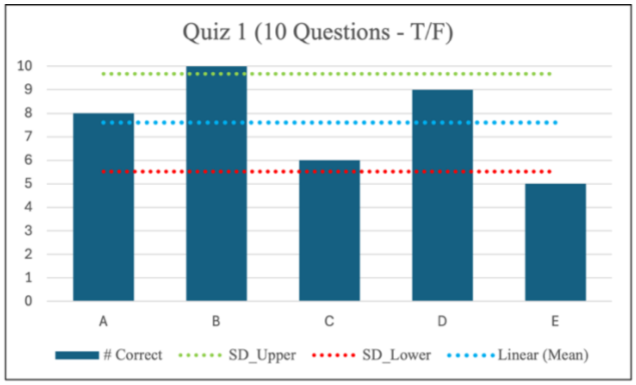


Figure 1 Performance on Quiz 1 with summary statistics

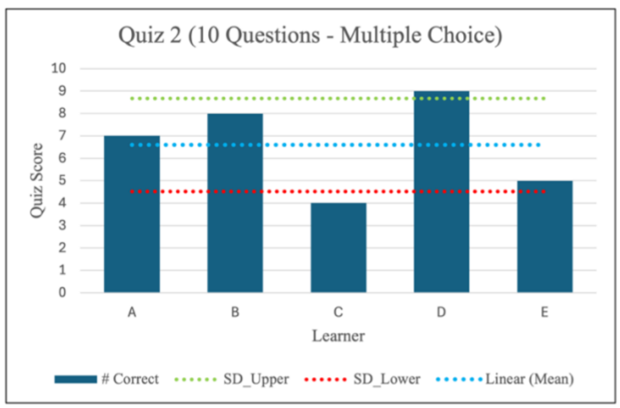


Figure 2

Performance on Quiz 2 with summary statistics

A qualitative evaluation of performance on lab exercise was conducted. Observations were made on each learner's pace, accuracy, interpretation, and reporting of their findings from the exercise. These observations were then mapped to a scale from 1 to 10 (with 1 representing poor performance, and 10 outstanding performance) using a baseline developed by the project team. A summary of these findings is presented below:

Learner	Speed	Accuracy	Interpretation	Reporting	Total
A	8	8	8	8	32
B	8	9	9	9	35
C	5	7	6	8	26
D	9	9	8	9	35
E	5	6	6	7	24

Table 3

Qualitative performance on Lab Exercise

In summary, the transfer context was deemed successfully met, in that the instructional design and delivery enabled the learners to apply their knowledge to lab performance, quiz performance, and class dialogue.

Conclusion and Reflection

The consensus was that the instructor established a sound orienting context for each learner, by understanding their background, motivations, and vested interest in the success of the program (Morrison, p. 63). This was evidenced by the responses from the class-ending survey, which revealed general acceptance of material quality, instructor delivery style and knowledge, appropriateness of assessments, quality and relevance of lab exercise, and level of complexity of the material.

Learners clearly struggled at times with technical jargon and required some scaffolding through instructor input (drawing analogies, etc.) and illustrations from industry practice. Even so, learners demonstrated overall good retention as evidenced by quiz results. They also evidenced the ability to apply, interpret, and extend information from lectures, as evidenced by lab outcomes. It was suggested that a glossary of key terms be provided in advance of the course. Given the compact nature of the lessons, an advance organizing approach was used to level-set the learners on the very broad scope of sustainability (Morrison, p. 171). Because the learners were relatively well-informed on STEAM topics, a knowledge map was used to identify key concepts and the linkages between them (Appendix, Figure 4). The content for the course was highlighted in the map both to set context for the course, as well as to allay any anxieties over covering a complex topic with substantial implications for the global and local ecosystems, as well as the economic and social milieus.

Technological issues inhibited lab performance due to lack of bandwidth at the Kelly Hall Y. It was suggested that future courses download the virtual labs to a local drive, thus eliminating the dependence on available network resources, and improve performance in any case.

The design of lecture slides in PowerPoint was largely appreciated, in consideration of adherence to Mayer's principles, specifically:

- Signaling Principle – key information was underlined or otherwise highlighted to draw the learner's attention toward it.
- Redundancy Principle – the instructor used the slides as guides while "reading between the bullet points" by offering deeper insights and commentary on leading practices in industry.
- Spatial Contiguity Principle – graphics in the slides were coupled with informative labels to add depth to the presentation.
- Personalization Principle – the instructor used familiar language, regulated tone and volume, appropriate pacing, and the appropriate use of the Socratic Method (in an non-challenging, non-threatening manner) (Mayer, 1984), (Morrison, p. 174)

However, more multimedia-oriented presentation was desired, to augment basic PowerPoints, through videos illustrating climate change dynamics, carbon cycle processes, construction site examples, etc.

The roundtable, seminar-type class design was enthusiastically received, with the suggestion that, for a larger cohort, they split into groups of 3-4 learners for the entire curriculum, coming together strategically for group presentations and guest speaker engagement. This of course implies that more people taking an instructor-role would need to work with the groups and provide adequate cognitive and emotional support.

In summary, the “connoisseurs” who participated in the instructional sessions believed that the value of the lessons was clear, and the distillation of the lessons toward a new group of learners was successful. They were unanimous (as were <client> leaders) that funding for the project could be found, and another cohort could be formed. The mission of eradicating the “food desert” in <neighborhood> is still on the top of mind for community leaders, activists, and other concerned citizens (including myself). We ended our learning experience with renewed commitment to make that a reality.

References

Gee, J. P. (2003). Opportunity to learn: A language-based perspective on assessment. *Assessment in Education: Principles, Policy, & Practice, 10*(1), 27–46.

Hickey, D. T., & Zuiker, S. J. (2005). Engaged participation: A sociocultural model of motivation with implications for assessment. *Educational Assessment, 10*, 277–305.

Jonassen, D. H., & Hernandez-Serrano, J. (2002). Case-based reasoning and instructional design: Using stories to support problem solving. *Educational Technology Research and Development*, *50*(2), 65–77. https://doi.org/10.1007/bf02504994

Kalman, H. K. (1987, March) Is it a training problem? Paper presented at the National Society of Performance and Instruction, Washington, DC.

Kaufman, R. A., Rojas, A. M., & Mayer, H. (1993). Needs assessment: a user's guide. Educational Technology Publications.

Knowles, M. S. (1988). *The adult learner: A neglected species.* London: Gulf.

Knowles, M. S., Holton III, E. F., & Swanson, R. A. (2005). The adult learner: The definitive classic in adult education and human resource development (6th ed.). San Diego, CA: Elsevier.

Knowles, M. S., Holton III, E. F., & Swanson, R. A. (2014). The adult learner: The definitive classic in adult education and human resource development. Routledge. Morrison, G. R. (2019). Designing Effective Instruction. Wiley.

Mayer, R. E. (1984). Twenty-five years of research on advance organizers. *Instructional Science (8)*, pp. 133–169.

Morrison, G. R., Ross, S. M., Kalman, H. K., Kemp, J. E. (2019). *Designing Effective Instruction*. Wiley.

Noe, R.A. (1986). Trainees' attributes and attitudes: Neglected influences on training effectiveness. *Academy of Management Review, 11(*4), 736-749.

Pierrakos, O., Nagel, R., Pappas, E., Nagel, J., Moran, T., Barrella, E., & Panizo, M. (2014). A Mixed-Methods Study of Cognitive and Affective Learning During a Sophomore Design Problem-based Service-Learning Experience. *International Journal for Service Learning in Engineering, Humanitarian Engineering and Social Entrepreneurship*, 1–28. https://doi.org/10.24908/ijsle.v0i0.5145

Posner, G. J., & Strike, K. A. (1976). A Categorization Scheme for Principles of Sequencing Content. Review of Educational Research, 46(4), 665. https://doi.org/10.2307/1169945

Rossett, A. (1999) Analysis for Human Performance Technology. In Pershing, J. A., Stolovitch, H. D., & Keeps, E. J. (Eds). Handbook of Human Performance Technology: Principles, Practices, and Potential. John Wiley & Sons.

Ruiz-Primo, M. A., Shavelson, R. J., Hamilton, L., & Klein, S. (2002). On the evaluation of systemic science education reform: Searching for instructional sensitivity. *Journal of Research in Science Teaching, 39*(5), 369–393.

Stapleton-Corcoran, E. (2023). “Sustainability Learning Outcomes and Learning Objectives.” Center for the Advancement of Teaching Excellence at the University of Illinois Chicago. Retrieved [22 September 2024] from Sustainability Learning Outcomes and Learning Objectives | Center for the Advancement of Teaching Excellence | University of Illinois Chicago (uic.edu)

Tessmer, M., & Richey, R. C. (1997). The role of context in learning and instructional design. *Educational Technology Research and Development, 45*(2), 85–115. https://doi.org/10.1007/bf02299526

Wilensky, U. (1999). NetLogo. http://ccl.northwestern.edu/netlogo/. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.

Wiggins, G., & McTighe, J. (2011). The Understanding by Design guide to creating high-quality units. Alexandria, VA: ASCD.

Create an Urban Heat Island Profile Using ArcGIS Online | Science Project. (2015). Science Buddies. https://www.sciencebuddies.org/science-fair-projects/project-ideas/Weather_p030/weather-atmosphere/urban-heat-islands Accessed 6 November 2024.

Appendix

Tables

The curriculum involved two lessons of 60 minutes each, and a virtual lab session of 60 minutes.

Lesson 1 - Foundations of Sustainability

- Describing sustainability in conceptual terms
- Explaining the elements of an ecosystem
- Defining biodiversity
- Specifying how sustainable principles impact people in the community
- Illustrating the concept of interconnectivity in the context of sustainability
- Differentiating between linear vs circular approaches to sustainable design
- Describing the triple bottom line concept
- Citing examples of stakeholders in sustainable projects
- Describing the role of ethics as part of sustainable practices.
- Showing how sustainable practices can influence corporate social responsibility.

Table 4 – Outline of Lesson 1

PowerPoint Presentation – Principles of Sustainability

Lesson 2 - Whole Life Cycle Carbon

Emission of greenhouse gases characterize a building's lifecycle, from the raw materials used in construction, through to the electricity used to run the building, right up until the demolition

and end of life treatment of the building's materials. Whole Life Carbon describes this phenomenon and can be defined as "the combined total of embodied and operational emissions over the whole life cycle of a building".

Key lesson points:

What are greenhouse gases?

- Kg CO2e ("equivalent") considers all the main GHGs emitted: CO2, CH4 and N2O

What is a carbon footprint?

- Commonly used to describe the total amount of CO2 and other greenhouse gas (GHG) emissions attributable to an organization, project or product."
- A carbon footprint = activity data (e.g., gallons of fuel used) x an emissions conversion factor (e.g. GHGs emitted per gallon expended)

Class Exercise - How to do carbon foot-printing?

- Instructor provides inputs for a hypothetical site in the form of a spreadsheet.
- Use the data provided to calculate the carbon footprint of your site's activities:
    - Fork-lift trucks and other construction equipment
    - Electricity for offices and sites
    - Fuel for outsourced logistics
    - List responses as scopes 1, 2, and 3, and the overall total

Table 5 – Outline for Lesson 2

PowerPoint Presentation – Whole Life Cycle Carbon

What are the key drivers for reducing carbon?

- **More efficient energy use in equipment and transport**
  - Invest in energy-efficient equipment (e.g. lighting, welfare cabins, plant & equipment, HVAC, IT).
  - Upgrade fleet to electric / hybrid. Uses less carbon and provides a bonus in air quality benefits
  - Consider infrastructure needs: provision of charging points for EV and land for ground-source heat pumps or solar PV.
  - Think about alternative transport modes (e.g. river barges, rail, etc.).
  - Green travel plans: public transport, more tele- / videoconferencing than travel for face-to-face meetings: as demonstrate during the Covid-19 pandemic
  - Take an eco-design approach to enable easier maintenance, repair and upgrade later in the asset's lifetime - 'future proof'
  - Use less material in absolute terms – work with design and procurement teams
  - Switch to alternative materials with lower carbon impacts encourage innovation
  - Increase reuse and the recycled content of materials – engage suppliers
  - Reduce waste and promote circular economy – leaner processes
  - Install insulating materials to reduce in-use energy consumption
  - Pursue offsite production where possible: lower environmental impacts as well as output efficiency, reduced safety risks
- **Improve behaviors**
  - Implement Energy Management Systems and automatic switches & sensors
  - Train colleagues and suppliers in how to use equipment efficiently:
  - Choose the right equipment for the job and don't over specify requirements.
  - Turn off equipment that's not being used, and avoid machine idling Use correct power modes including in low / eco power modes
- **Energy and power sources**
  - Increase onsite renewable energy provision in offices and building sites (e.g., solar PV, micro-CHP, battery-operated instead of diesel or gasoline). Alternatives to diesel: GTL, HVO
- **Different, lower-carbon business models**
  - Service / rental rather than ownership. Consider SaaS for IT implementations.
  - Emphasize remote interactions and virtual or hybrid educational models, rather than face-to-face
  - Identify, document, and communicate sources of data in your organization and identify potential areas for carbon reduction

Table 6 – Outline for Whole Carbon Lecture – Talking Points

Lab Exercise - Evaluation of a Heat Island

Objectives

Using a free web-based tool called ArcGIS Online, each student will create an urban heat island profile for a selected city, and investigate the relationship between surface type, tree canopy cover, and air temperature.

Concepts for Mastery

- Urban heat island
- Albedo
- Land cover type
- Impervious surface
- Evapotranspiration
- Tree canopy cover
- Temperature sensor network
- Remote sensing
- Geographic Information System (GIS)
- Map projection
- Latitude and longitude
- Decimal degrees
- Geospatial data
- Raster data
- Pixel
- Resolution
- Vector data
- Transect
- Attribute
- Attribute table

Key Questions

- What types of geospatial datasets will you need to determine the impact of surface type on temperature? Do you think these are raster or vector datasets?
- What time of day do you think would be the most useful to collect temperature data to examine the impact of surface type on temperature?
- What surface types do you expect to have the highest temperatures? The lowest?

Table 7 – Outline for Lab Exercise

STUDENT PARTICIPATION RUBRIC

Criteria Points	Level of Engagement In Class	Listening Skills	Preparation	Quality of comments
25	Student proactively contributes to class by offering ideas and/or asks questions more than once per class and/or works consistently on group projects the entire time.	Student always displays active listening when others talk, both in groups and in class. Student always incorporates or builds off the ideas of others in their responses.	Student is always prepared for class with assignments and required class materials.	Comments are always insightful & constructive; always uses appropriate terminology. Comments are always balanced between opinions and specific factual evidence.
20	Student proactively contributes to class by offering ideas and/or asks questions once per class and/or works on group projects for most of the allotted time.	Student frequently displays active listening when others talk, both in groups and in class. Student frequently incorporates or builds off the ideas of others in their responses.	Student is frequently prepared for class with assignments and required class materials.	Comments are frequently insightful & constructive; frequently uses appropriate terminology. Comments are frequently balanced between opinions and specific factual evidence.
15	Student sometimes contributes to class by offering ideas and asking questions and/or works on group projects only some of the allotted time.	Student sometimes displays active listening when others talk, both in groups and in class. Student sometimes incorporates or builds off the ideas of others in their responses.	Student is sometimes prepared for class with assignments and required class materials.	Comments are sometimes insightful & constructive; sometimes uses appropriate terminology. Comments are sometimes balanced between opinions and specific factual evidence.
10	Student rarely contributes to class by offering ideas and asking questions and/or has trouble staying on task during group project time.	Student rarely displays active listening when others talk, both in groups and in class. Student often interrupts when others speak.	Student is rarely prepared for class with assignments and required class materials.	Comments are rarely insightful & constructive; rarely uses appropriate terminology. Comments are rarely balanced between opinions and specific factual evidence.
0	Student does not contribute to class by offering ideas and asking questions and/or has trouble staying on task during group project time.	Student does not display active listening when others talk, both in groups and in class.	Student is not prepared for class with assignments and required class materials.	Student never offers comments in class.

****Students who have been absent for the entire class session will receive a participation grade of 0%

Table 8 - Rubric for Class Participation

Quiz 1 Results (10 Questions - T/F)		
Learner	**# Correct**	**Comments**
A	8	
B	10	Felt quiz was too easy.
C	6	Felt the questions were not reflective of lesson content.
D	9	
E	5	Shared that they had difficulty understanding some terms and concepts.
Mean	7.6	
SD	2.07	

Table 9 – Quiz 1 scores with learner comments

Quiz 2 Results (10 Questions - Multiple Choice)		
Learner	**# Correct**	**Comments**
A	7	
B	8	
C	4	Shared that the questions did not use the same language as the lecture, causing confusion.
D	9	
E	5	Stated that they had difficulty understanding some terms and concepts.
Sum	33	
Mean	6.6	
SD	2.07	

Table 10 – Quiz 2 scores with learner comments

<table>
<tr>
<td rowspan="6">ESTABLISHED GOALS

• Summarize the concepts of sustainable infrastructure and industrialization and society’s needs for a systemic approach to their development.
• Recognize the local, national, and global challenges and conflicts in achieving sustainability in infrastructure and industrialization.
• Define the term resilience in the context of infrastructure and spatial planning, understand key concepts such as modularity and diversity, and apply them to their local community and nationwide.
• Describe the pitfalls of unsustainable industrialization and in contrast share examples of resilient, inclusive, sustainable industrial development and the need for contingency planning.
• Name new opportunities and markets for sustainability innovation, resilient infrastructure, and industrial development. (Stapleton-Corcoran, E, 2023).</td>
<td colspan="2">Transfer</td>
</tr>
<tr>
<td colspan="2">Students will be able to independently use their learning to…

…describe the elements within the three pillars of sustainable development (environmental, social, and economic) explain the importance of minimizing Whole Life-Cycle Carbon (WLC) footprint, healthy construction practices, the using recycled/reclaimed materials, and the minimization of waste, as they participate in the Greenhouse project and in describing the benefits of the project to others.</td>
</tr>
<tr>
<td colspan="2">Meaning</td>
</tr>
<tr>
<td>UNDERSTANDINGS
Students will understand that…

• Sustainable construction means sensitivity to environment impacts
• A sustainable building prioritizes protection of the environment above the users’ well-being.
• Building and renovating in a sustainable way means giving a preference to local and bio-sourced materials.
• Sustainable construction means healthier materials: for those who install them on building sites, and for those who use them afterwards</td>
<td>ESSENTIAL QUESTIONS

• What is the role of sustainability of information and communication technology (ICT) including supply chains, waste disposal, and recycling?
• What is the relationship between quality infrastructure and the achievement of social, economic, and political goals in the community?
• How does the need for carbon-neutral infrastructure like roads, information and communication technologies, sanitation, electrical power, and water contribute to sustainable ecosystems in the community?
• How can inclusive and equitable sustainability practices promote innovation and community development?
• Why does sourcing electricity from renewable resources (solar, wind, etc.) both reduce dependence upon, as well as strengthen, local energy grids?
• Why do sustainable practices create expanded job markets, opportunities, and investments?</td>
</tr>
<tr>
<td colspan="2">Acquisition</td>
</tr>
<tr>
<td>Students will know the elements of the three pillars of sustainable development:

• Environmental pillar: climate change, adaptation, and mitigation, pollution prevention and zero</td>
<td>Students will be skilled at…

• Describing sustainability in conceptual terms
• Explaining the elements of an ecosystem
• Defining biodiversity</td>
</tr>
</table>

<table>
<tr><td></td><td>waste, life cycle approaches, biodiversity, disaster risk reduction.

• Social pillar: human rights, hunger and poverty eradication, security, clean water and sanitation, health and well-being, reduced non-equalities (gender, income, living standard ones), decent work, social responsibility, quality education, cultural diversity, sustainable urbanization, and sustainable lifestyles.

• Economic pillar: resources (raw materials, energy, water, air, land) and their efficiency, circular economy, affordable and clean energy, sustainable consumption and production, research and development (R&D), innovations and entrepreneurship of all stakeholders, and economic growth.</td><td>• Specifying how sustainable principles impact people in the community
• Illustrating the concept of interconnectivity in the context of sustainability
• Differentiating between linear vs circular approaches to sustainable design
• Describing the triple bottom line concept
• Citing examples of stakeholders in sustainable projects
• Describing the role of ethics as part of sustainable practices.
• Showing how sustainable practices can influence corporate social responsibility.</td></tr>
<tr><td colspan="3">Stage 2 – Evidence and Assessment</td></tr>
<tr><td>Evaluative Criteria</td><td colspan="2">Assessment Evidence</td></tr>
<tr><td rowspan="2">Criteria will include standards developed for post-secondary coursework in sustainable development practices, along with collaboration and collective design skills, presentation skills, and a broad understanding of the relevance and impact of sustainable practices in the community as well as in society at large.</td><td colspan="2">PERFORMANCE TASK(S):

• Apply design thinking, principles, and tools
• Demonstrate holistic and critical evaluation of design artifacts
• Demonstrate competence in customizing a design process to meet the needs of the project and the team
• Understand fundamental principles of psychology of design and human factors decisions
• Apply reliability analysis in design decision making
• Demonstrate analytical modeling in design decision making
• Work effectively on a collaborative design project
• Demonstrate individual and collaborative technical presentation skills
• Develop a professional career development plan and artifacts</td></tr>
<tr><td colspan="2">OTHER EVIDENCE:</td></tr>
</table>

	Formative assessments will consist of reflective discussions on subject matter, small group projects involving the three pillars of sustainability, and exploration of sourcing of materials, impact of designs on completed structures, and the role of climate and energy sources.

Stage 3 – Learning Plan

Summary of Key Learning Events and Instruction (40 hours)

Lesson 1: Overview of Sustainability (4 hours).

The first objective is to provide students with definitions of key concepts. An ecosystem is defined as an integrated network of living things, including plants, animals, and microorganisms. These entities have specialized systems to interact with physical environments, like air, water, sun, weather, climate, and soil. We refer to the living components of an ecosystem are called biotic components, and the non-living components are called abiotic components. Visual examples are provided in the form of videos and diagrams.

A sustainable ecosystem as a self-sustaining biological system that can support life without external inputs. It meets the needs of current populations and is capable of expanding (or contracting) to interact with future populations. In addition, it has the following characteristics:

- Diversity: Maintains its characteristic diversity of major functional groups
- Productivity: Maintains its productivity through survival and procreation mechanisms
- Biogeochemical cycling: Maintains its rates of biogeochemical cycling through adaptation to changes in the environment
- Stable controls: Interactive controls, such as climate, soil, and disturbance regime, vary in a stable manner toward an equilibrium state.

The second objective relates to the Whole Life-Cycle Carbon (WLC) footprint of a structure. Greenhouse gases are emitted throughout a building's lifecycle, from the raw materials used in construction, through to the electricity used to run the building, right up until the demolition and end of life treatment of the building's materials. Whole Life Carbon is a way to describe this and can be defined as 'the combined total of embodied and operational emissions over the whole life cycle of a building'.

The third objective is to perform a lab exercise to demonstrate one or more of the above characteristics.

A fourth parallel objective is to provide instruction on how to perform lab work. A typical framework for this exercise includes the following activities:

- Observe the phenomenon and formulate questions
- Conduct background research
- Formulate a hypothesis
- Design an experiment
- Collect data
- Analyze data
- Draw conclusions.

Alternatively, an agentic simulation tool such as NetLogo could be used instead of a traditional, physical lab bench to carry out this assignment.

Lesson 2: Sustainability Life-Cycle Assessments (12 hours)

Life Cycle Assessment (LCA) is a scientific method to measure the environmental footprint of a product. A typical result could include 15 or more impact outcomes. Before measuring, a prototype greenhouse design is provided to the cohort.

The first lesson objective is to think about this structure, and consider the energy usage and emissions, along with factors such as utilities, transport, materials, etc.

The second objective is to assign roles and responsibilities among the cohort. These will include

- Who needs to collect this data (a sustainability analyst title is assigned)
- What data is needed (this involves gathering information on the structure, covering, environmental, and security aspects of the greenhouse),

- Where to collect the right data (pointers to existing information from the University of Illinois Extension Service, the Chicago Architecture Center, and other resources from academia and industry. Ensure informing entities in time and give them adequate time for their data delivery).

The third objective is data collection from primary sources. It should cover raw process- and site-specific data, estimates, statistics, and bookkeeping. By creating a list of all the necessary inputs and outputs of the greenhouse's lifecycle, they are aligned to corresponding impacts when performing an LCA. Primary data is crucial for LCA, since it makes the LCA more credible through accurate raw data that's specific the greenhouse study – instead of relying on averages. And it offers more reliable, authentic, and objective footprint insights. This enables focused and effective sustainable efforts and gives the cohort more ownership over their LCAs.

The fourth objective is to determine the measurement scope of the greenhouse lifecycle, utilize a five-phase approach:

1. Raw Material Extraction and Reclamation (concrete and aggregates for footings, lumber for structures, etc.)
2. Manufacturing & Processing (recycled PEL for covering and water reclamation)
3. Transportation (for all phases, from supplier to site – in this case the site is the <client site).
4. Usage (forming and fitting materials using of low-emissions tools, etc.)
5. Waste Disposal (minimizing waste through thoughtful measurement and handling, identifying reuse potential, disposal of unusable remnants through reputable local agencies)

The fifth objective is to define take-out Phases. Once the greenhouse has exceeded its useful life, provision is made for its disposal. Students will evaluate two lifecycle scopes:

1. *Cradle-to-grave* includes all the 5 life phases in the measurements. *'Cradle'* is the inception of the greenhouse with the sourcing of the raw materials. '*Grave'* is the deconstruction of the greenhouse, and the disposal of its constituent parts. It shows a full footprint from start to end.
2. *Cradle-to-cradle* is a variation of *cradle-to-grave* but exchanges the *waste* stage with a recycling/upcycling process that makes it reusable for another product. This lifecycle effectively "closes the loop" and accounts for the disposal, recycling, or repurposing of all materials.

Students will learn the importance of selecting the correct model and communicating that model to their stakeholders.

The sixth objective involves finding average rates of waste treatment options (mainly: incineration, landfill, composting, or recycling) from local statistics, or possibly from specific providers who is capable of executing the waste method for the project. Collect data on:

- The exact waste-disposal method and its processes.
- The emissions connected to your waste disposal method.
- Possible energy recovery in the disposal processes.
- Possible recycling processes of (part of) the materials.

The use phase and end-of-life are essential for determining the greenhouse's ecological footprint.

Lesson 3: Introduction to Rating Systems (6 hours)

The first objective is to present students with the fundamentals of sustainable building standards and rating systems including LEED, Green Globes, BREEAM, and Green Star. These systems are the prevailing industry standards for sustainable building and are recognized worldwide as authoritative. Students will emerge with a good understand of why standards are important and how to apply them.

The second objective is to ask students to work in groups and provide an overview for each of these sustainability rating systems, and their suitability for greenhouse design and construction. Each group will focus on one of the systems. Students are expected to leverage prior knowledge, as well as to harvest findings from academia, industry, and other entities. The instructor and the subject matter experts will go around the room and provide mentoring and insight to each group.

The third objective is to ask each. group to present and submit its understanding of the system, as well as its applicability to the "cradle-to-cradle" and "cradle-to-grave" lifecycle scopes, and how the system specifies guidelines for each.

The fourth objective is for the instructor to moderate a class discussion wherein all students reflect on each other's opinions and are expected to reach mutual understanding of the term "construction rating system".
The fifth objective is for each student is asked to utilize the in-class discussion as well as citations from their research to write a brief paper on how a certain construction material or construction system that is chosen by the student can be used to promote high performance sustainable construction.

Lesson 4 – Applying LEED standards to Greenhouse Design (12 hours).
The first objective is that students are asked to create a reference guide for greenhouse construction using LEED standards. Previous experience indicates that students work most effectively and efficiently by with some prior exposure to the regulations and standards outlined by the United States Green Building Council in its LEED manual. This material was covered in Lesson 3 and is now applied in this lesson.
The second objective is to pair students to reading and understanding the 2009 USGBC LEED manual and develop the requested reference guide pertinent to greenhouse construction.
During this session, the instructor observes, guides discussions, and answers questions. Repeated questions from various groups are addressed to all class members.
The third objective is for each group to submit and make presentations pertaining to their LEED-based reference guide. The presentation findings are aggregated and collectively discussed, leading to a single version of the guide that all are aligned to.

Lesson 5 – LEED Certification (6 hours)
The first objective is for students to use the reference guide from Lesson 4 to develop a report on how to attain LEED certification for a new greenhouse construction project. This will demonstrate the importance of service learning and is expected to create enthusiasm for the emerging design and construction phases of the project, because they see their future and the future of their community given relevance through the coursework.
The second objective is to use the prototype design introduced in Lesson 2 is distributed, and students are divided into groups to analyze one or more of the major LEED credits. Each group develops a report pertaining to its assigned credit using their previously developed reference guide, and any other required supporting material. In the analysis, the students need to show (1) which credits are attainable in light of the prototype greenhouse design; (2) which credits are not incorporated in the prototype greenhouse design but are achievable with some modifications and amendments; and (3) which credits are not obtainable regardless of any reasonable new design proposals.
The third objective is to bring all groups together and work collectively to integrate their findings into a comprehensive assessment report.
The fourth objective is for students to submit a final report, make presentations, and reflect on each other's work.

Table 11

Backward Design Framework for Sustainability Module

Lesson	Time (hours)	Key Learnings	Lab
Overview of Sustainability	4	Definition of ecosystem, define criteria to determine system's Whole Lifecycle Carbon footprint, instruction on lab methods	Y
Sustainability Life-Cycle Assessments	6	Definition of Life Cycle Assessment (LCA), identify data collection strategies, define measurement scope, define take-out Phases, identify waste treatment options	N
Introduction to Rating Systems	6	Fundamentals of sustainable building standards and rating systems including LEED, describe relationship of LEED to LCAs, articulate how LEED supports sustainable construction	N
Apply LEED standards to Greenhouse Design	12	Create LEED reference guide relevant to greenhouse construction (teams to prepare sections), aggregate sections to create a comprehensive reference guide for evaluating prototype greenhouse design.	Y
LEED Certification Simulation	12	Evaluate each section of prototype greenhouse structure (one section per team), assign LEED credits to each section (jigsaw method), assess attainability of credits as is/with modifications/not at all, and aggregate findings into a single report.	Y

Table 12

Lessons for Sustainability Module with summary of key learnings (structure inspired by El-adaway, et al., 2015).

Factors	Orienting Context	Instructional Context	Transfer Context
Learner Factors	Establishing learner profiles (academic, experience, goals) to establish pre-requisite knowledge. Determining skills in working toward goals, based upon academic and work history. Understanding beliefs in the utility of the <client> greenhouse project. Assessing degree of accountability for their in the project (expected to be high, based upon their selection for the <client> cohort).	Learner role perception (clarity on the need for self-efficacy through mastery, openness to forming relationships to the instructors as "more knowledgeable others", representing the greater goals of the <client>. Learner task perception (attentiveness during lectures, completing pre-reading assignments, need for transparency in requesting scaffolding and cognitive support)	Updated utility perceptions (applicability of sustainability to the project phases and tasks, confidence that instruction will properly equip them to understand and communicate project objectives). Coping strategies (signaling frustration with pace/level of content in a rational manner, identifying and emulating social models, establishing relationships of trust with peers for support) Developing experiential background (using labs to project knowledge gained from lessons/ assignments into the prototype project realm).
Environmental Factors	Social support (leveraging peer relationships within the cohort, cultivating relationships among instructor/MKOs, developing network of	Asserting preferences for learning environment (spatial orientation,	Cultural Alignment

Factors	Orienting Context	Instructional Context	Transfer Context
	mentors and collaborators). The cohort is believed to be relatively mature in this regard but will be monitored to provide additional resources when indicated.	assistive needs, lighting and acoustics, temperature). Some flexibility for each of these factors is available within the <client site> Communicating perceptions of instructors/MKOs (clarity in narrative, tone and timbre of voice, physical posture gestures and cues) and a sense of safety in identifying areas of discomfort. Conveying preferences for learning cadence and scheduling (pace of instruction, time of day, adequate breaks)	The curriculum is designed to achieve congruence between <client> organizational values and learning practices. There is nothing to be gained by pushing the cohort into areas of discomfort or stress. Rewards/Value The <client> and the grant organization does reward and value all cohort members who complete specific actions within the learning context and offers special recognition to those who provide exemplary leadership and performance. Support systems The <client> provides significant support systems for learners (i.e., childcare, safe passage and safe harbor, etc.).
Organizational Factors	The <client> has committed to the project's goals and objectives and, together with the organization whose funding provide the financial support, substantially contribute to the orienting context including: • providing a framework for supervisor and peer support networks through the <client> counseling teams • demanding and communicating unambiguous expectations of learners through well-execute instructional design • job placement services for cohort members both within and outside the neighborhoods and <client> communities served • promotion of work environment behaviors that conform the <client's> mission and organization values for development, innovation, and growth mindset.	The transfer context is intentionally designed to be opportunistic in that the cohort will directly apply their learnings to the project. Learner transfer opportunities should not be limited to project tasks, which are controlled by the <client> team. An honest conversation on the potential obstacles to learning transfer outside project boundaries and ideating on strategies to remove or mitigate these impediments, is a core element of the social and professional of the cohort. A key design goal is to promote the development of professional "soft skills" as an integral part of the transfer context.	The organizational factors in the transfer context align closely to those within the orienting context. The <client's> culture and values will permeate the project culture and the instructional design as well. This means that creativity is valued, initiative is stressed, control and power is centralized in terms of core values but decentralized regarding project execution. The cohort will be coached to feel empowered by their mission, and only constrained or restricted by policies and rules so far as the health and safety of the cohort (and other patrons of the <client>) are concerned.

Factors	Orienting Context	Instructional Context	Transfer Context
		Cohort members are explicitly expected to develop the technical and leadership skills to move into instructor and project management positions coveted as a critical aspect of career development.	

Table 13

Learning Contexts, including Orienting, Instructional, and Transfer (following formatting from Tessmer and Richey, 1997):

Table 14

Proximal Assessment - Quiz #1

Question	T/F	Short Answer
Sustainable construction means sensitivity to environment impacts.	TRUE	A building's Whole Life-Cycle Carbon (WLC) footprint consists of embodied carbon (in materials) and the operational carbon. Sustainable building practices aim to minimize both carbon sources.
Sustainable construction is the same as light construction.	TRUE	Light construction involves usage of lighter wall, ceiling, façade, flooring and roof systems that are easier to dismantle and reuse or recycle at the end of life
A sustainable building prioritizes protection of the environment above the users' well-being.	FALSE	A sustainable building combines both a reduced environmental footprint with enhanced health and wellbeing for both jobsites' workers and buildings' occupants.
Sustainable construction means creating low-carbon buildings	TRUE	While a goal is to significantly reduce Whole Life-Cycle Carbon (WLC) emissions it is also about building with a more efficient use of natural resources, without generating non recovered waste.
Building and renovating in a sustainable way means giving a preference to local and bio-sourced materials.	TRUE	Reducing the carbon impact of the transport and packaging of materials helps to reduce impact; however, bio-sourced materials are not necessarily more sustainable than other materials.
Sustainable construction is about preserving/saving natural resources.	TRUE	Sustainable construction is fundamentally about using renewable resources and circularity - reducing the use of non-renewable resources and freshwater over the entire lifecycle of the building.
All construction practices, sustainable or not, produce an equal amount of waste	FALSE	Sustainable design and building can generate very limited amounts of waste on site and allowing for easy dismantling at their end of life to facilitate reuse or recycling.
Sustainable construction means healthier materials: for those who install them on building sites, and for those who use them afterwards	TRUE	Sustainable construction reduces builders' exposure to hazardous substances during installation and improves their working conditions (lighter products, less dust, non-irritant products). It also implies safer and more comfortable indoor environments for the occupants: improved indoor air quality, better acoustics, better thermal comfort and better visual comfort

Final Project Report

A sustainable building means a building that can be easily demolished/dismantled/deconstructed	TRUE	At the end of its operational life, sustainable construction yields a reduced amount of non-recovered construction and demolition waste
Sustainable construction or renovation is more expensive.	TRUE	A potentially higher upfront cost is typically offset by lower operational costs. The World Green Building Council states that a newly built green building is 14% cheaper to operate over five years than a conventional one. Reclaimed materials (structural steel and timber) are cheaper, as are recycled aggregate and sand.

1. This program is promoted by the EPA as beneficial to an organization's sustainability policy.
a. Violence Prevention Program (VPP)
b. Accident Investigation Program (AI)
c. Environmental Management Systems (EMS)
d. Disaster Preparedness System (DPS
2. Which of the following corporate sustainability policy objectives will most likely involve EHS manager?
a. economic objectives
b. ecological objectives
c. mutual objectives
d. social objectives
3. Sustainability is an attempt to provide the best outcomes for the _________ environments both now and into the indefinite future.
a. corporate and social
b. local and national
c. physical and psychological
d. human and natural
4. Sustainability relates to the ________ of economic, social, and environmental aspects of human society, as well as the non-human environment.
a. stability
b. health
c. continuity
d. future
5. Sustainability configures corporate activities to help preserve which of the following?
a. social awareness of environmental threats
b. biodiversity and natural ecosystems
c. fiscal response to crisis
d. recovery due to natural disaster
6. Which of the following sustainability concepts describes the policy in which an organization places equal importance on the social, environmental, and economic impacts of its business practices?
a. Triple Bottom Line
b. Green Line Initiative
c. SEE Strategies
d. New World Planning
7. Corporate sustainability is an attractive business approach to create long-term shareholder value by ___________economic, environmental, and social success factors.
a. promoting
b. valuing
c. prioritizing
d. integrating
8. The ultimate goal for sustainability-driven companies is _______________.
a. minimizing loss
b. maximizing profit
c. the triple bottom line
d. increase market share
9. Which of the following is not one of the 'Three Rs' that form the basis for sustainability:
a. recycle
b. refuse
c. reuse
d. reduce
10. Which of the following is a sustainability goal?
a. fully integrating safety and environmental protection
b. striving for zero safety incidents
c. striving for zero environmental incidents
d. all of the above

Correct responses:

1. c. Environmental Management Systems (EMS)
2. b. ecological objectives
3. d. human and natural
4. c. continuity
5. b. biodiversity and natural ecosystems
6. a. Triple Bottom Line
7. d. integrating
8. c. the triple bottom line
9. b. refuse
10. d. all of the above

	Full control on interventions	**Participatory control on interventions**	**No control on interventions**
Experiments on sustainability problems	**Type 1.** *Problems-Full* Producing evidence about causes of sustainability problems with full control on interventions	**Type 2.** *Problems-Participatory* Producing evidence about causes of sustainability problems with participatory control on interventions	**Type 3.** *Problems-NoControl* Producing evidence about causes of sustainability problems without control on interventions
Examples	Lab and Field experiments	Adaptive experimentation	Implicit, natural, quasi-natural experiments
Experiments on sustainability solutions	**Type 4.** *Solutions-Full* Producing evidence about solutions to sustainability problems with full control on interventions	**Type 5.** *Solutions-Participatory* Producing evidence about solutions to sustainability problems with participatory control on interventions	**Type 6.** *Solutions-NoControl* Producing evidence about solutions to sustainability problems without control on interventions
Examples	Innovation experiments in living labs	Experiments in real-world, transitions, and living-labs	Studies in strategic niche management

Table 15

Sample Lab Experiment Typology (Caniglia, et al., 2018)

Figures

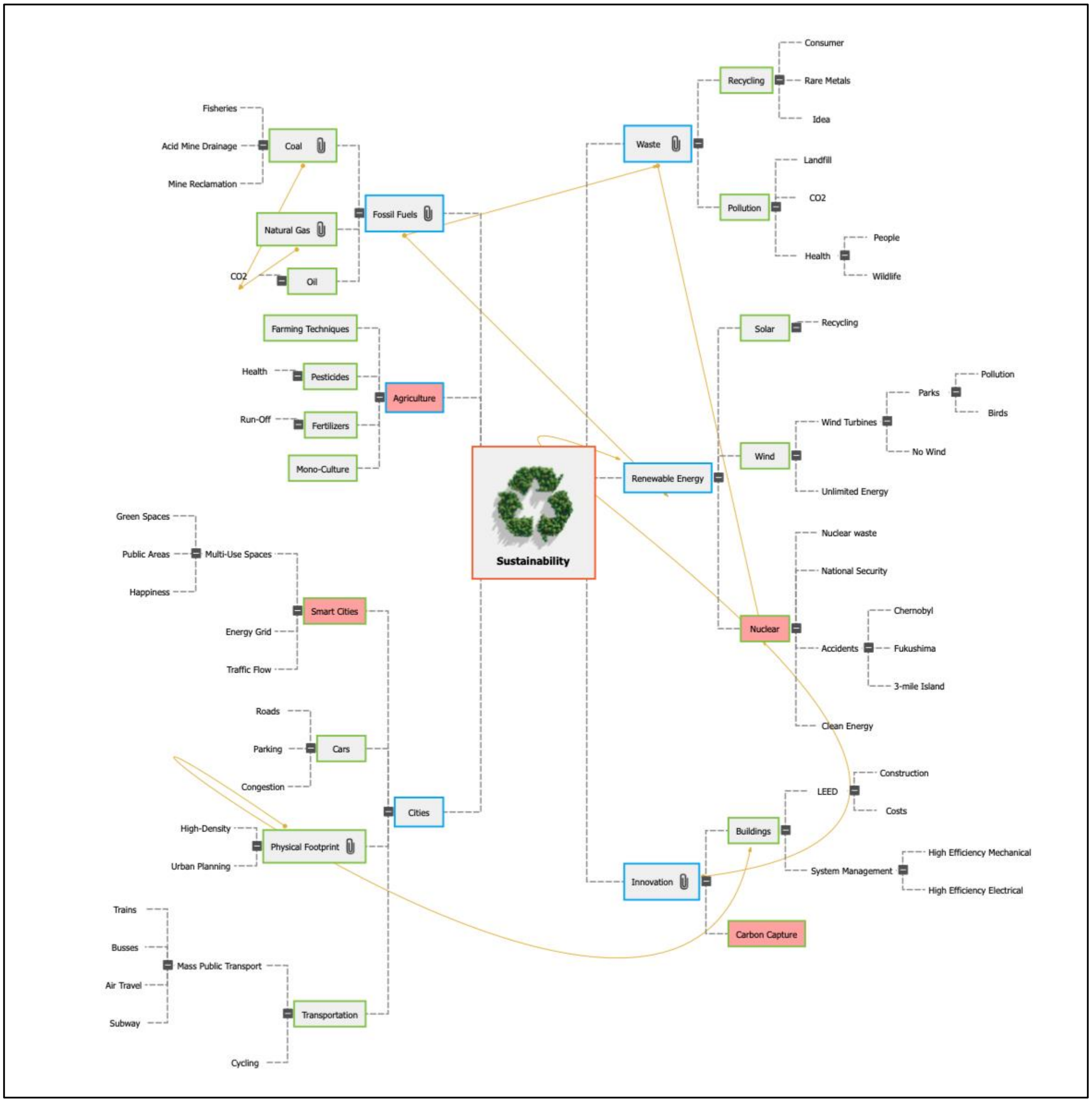


Figure 3 – Knowledge Map for Sustainability

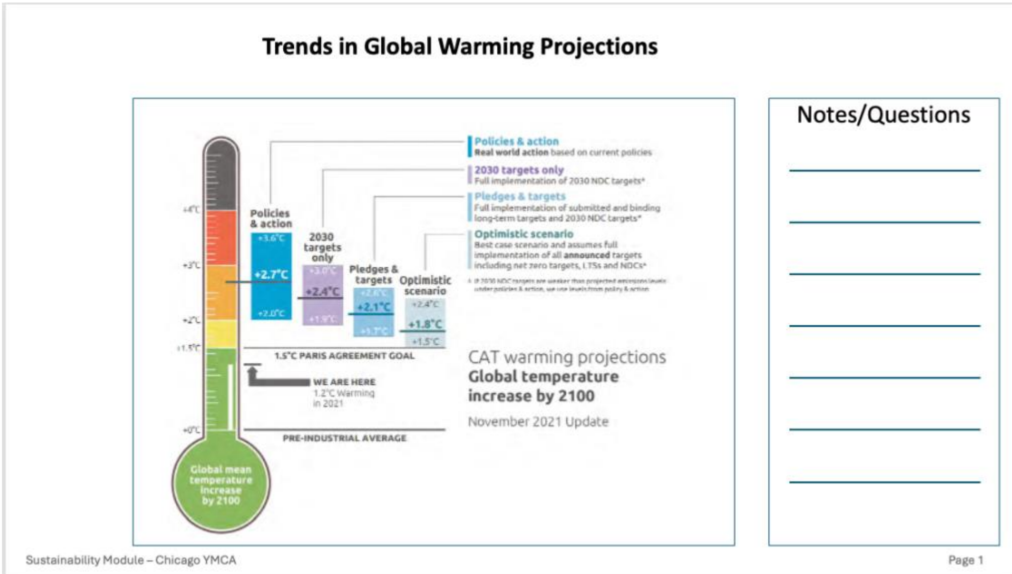


Figure 4

Slide from workbook on Sustainability for knowledge transfer (in progress).

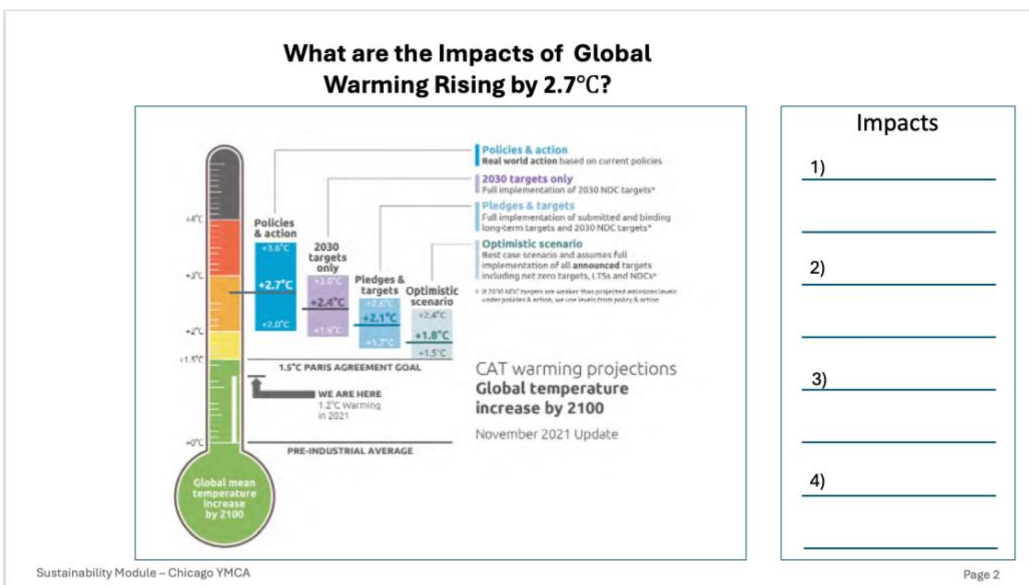
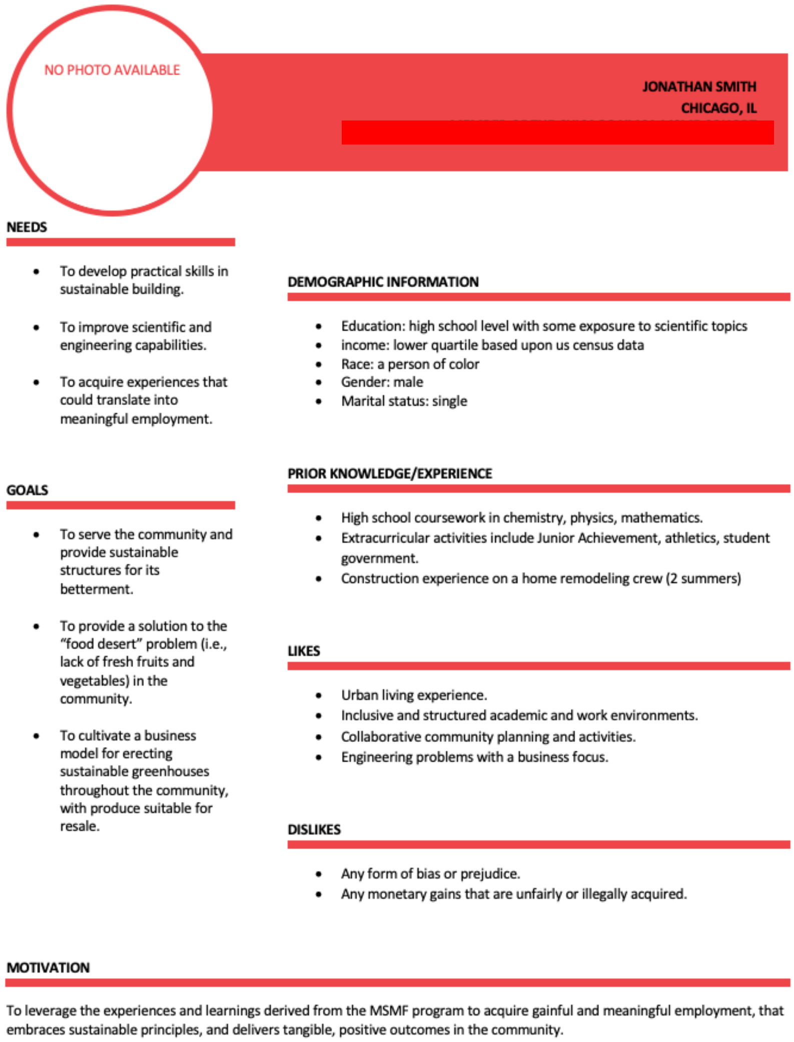


Figure 5

Slide from workbook on Sustainability for problem solving (in progress).



NO PHOTO AVAILABLE

JONATHAN SMITH
CHICAGO, IL
[redacted]

NEEDS

- To develop practical skills in sustainable building.
- To improve scientific and engineering capabilities.
- To acquire experiences that could translate into meaningful employment.

GOALS

- To serve the community and provide sustainable structures for its betterment.
- To provide a solution to the "food desert" problem (i.e., lack of fresh fruits and vegetables) in the community.
- To cultivate a business model for erecting sustainable greenhouses throughout the community, with produce suitable for resale.

DEMOGRAPHIC INFORMATION

- Education: high school level with some exposure to scientific topics
- income: lower quartile based upon us census data
- Race: a person of color
- Gender: male
- Marital status: single

PRIOR KNOWLEDGE/EXPERIENCE

- High school coursework in chemistry, physics, mathematics.
- Extracurricular activities include Junior Achievement, athletics, student government.
- Construction experience on a home remodeling crew (2 summers)

LIKES

- Urban living experience.
- Inclusive and structured academic and work environments.
- Collaborative community planning and activities.
- Engineering problems with a business focus.

DISLIKES

- Any form of bias or prejudice.
- Any monetary gains that are unfairly or illegally acquired.

MOTIVATION

To leverage the experiences and learnings derived from the MSMF program to acquire gainful and meaningful employment, that embraces sustainable principles, and delivers tangible, positive outcomes in the community.

Figure 6

Persona #1 from <client> Cohort

NO PHOTO AVAILABLE

JANET FOSTER
CHICAGO, IL

NEEDS

- To develop practical skills in sustainable building and project planning
- To improve scientific and engineering capabilities.
- To acquire leadership experiences that could translate into management role

GOALS

- To serve the community and provide sustainable structures for its betterment.
- To provide a solution to the "food desert" problem (i.e., lack of fresh fruits and vegetables) in the community.
- To create an entrepreneurial business model for erecting sustainable greenhouses and marketing both standard and gourmet produce to consumers and restaurants

DEMOGRAPHIC INFORMATION

- Education: high school graduate with strong record with to scientific topics
- income: lower quartile based upon us census data
- Race: a person of color
- Gender: female
- Marital status: in a relationship, one child, age 3

PRIOR KNOWLEDGE/EXPERIENCE

- High school coursework in chemistry, physics, mathematics.
- Extracurricular activities include Junior Achievement, music, Conflict Resolution board
- Retail experience with promotion to assistant manager

LIKES

- Urban living experience with amenities for partner and child.
- Inclusive and structured academic and work environments.
- Collaborative community festivals and celebrations
- Entrepreneurial initiatives with a local focus

DISLIKES

- Any form of bias or prejudice.
- Misogynistic language and behavior

MOTIVATION

To acquire solid experience from the MSMF program to learn the principles of urban agriculture, that embraces sustainable principles, and can deliver tangible, positive outcomes in the community through an entrepreneurial model.

Figure 7

Persona #2 <client> Cohort

Table 16

Experiment – Evaluation of Heat Island
https://www.sciencebuddies.org/science-fair-projects/project-ideas/Weather_p030/weather-atmosphere/urban-heat-islands

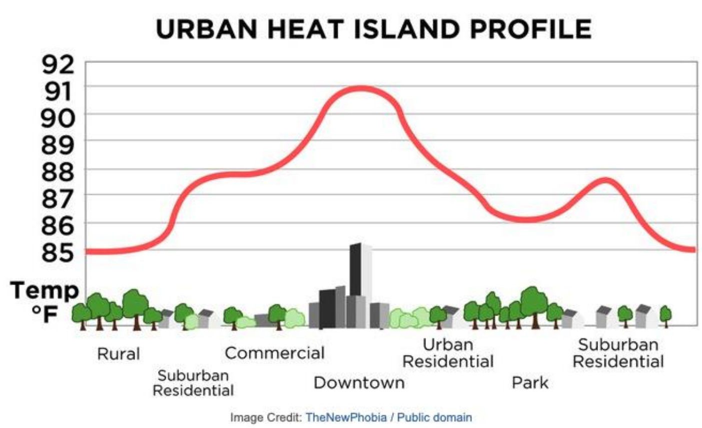
Objective

In this project, you will use a free web-based tool called ArcGIS Online to create an urban heat island profile for a city of your choice and investigate the relationship between surface type, tree canopy cover, and air temperature.

What are Urban Heat Islands?
Have you ever noticed that the weather forecast for a city often says it will be hotter than in the surrounding suburbs or farmland? Or that when you walk through a city on a hot day, some streets make you sweat while others provide much-needed relief from the blazing sun? These experiences can be explained by the urban heat island effect, which is when urban areas experience higher temperatures than surrounding rural areas. Watch the video below to learn more about urban heat islands.

What Causes Urban Heat Islands?
Urban heat islands form primarily because of the abundance of heat-absorbing surfaces in urban areas. Albedo refers to the reflectivity of a surface; the higher the albedo, the more sunlight is reflected off of it and therefore the less heat it holds. Albedo and heat retention depend on the land cover type. Light-colored surfaces, such as snow, have high albedo and therefore reflect most of the heat back into the atmosphere or space. However, in urban environments, dark-colored impervious surfaces created by buildings, concrete, and asphalt roads absorb and retain more heat than natural surfaces like grass or farmland. As a result, these surfaces radiate heat back into the lower atmosphere, leading to higher temperatures in the city compared to the surrounding suburbs or farmland. See Figure 1 for an example of what an urban heat island profile might look like for a typical city.

Figure 1
Urban Heat Island Profile



Additionally, the lack of vegetation and concentration of human activities also contribute to the formation of urban heat islands. Trees and plants help to cool the environment through a process called evapotranspiration. They release moisture into the air, which cools the surrounding area. In urban areas, the limited green spaces and trees prevent this natural cooling process, resulting in higher temperatures. We can measure the amount of tree canopy cover using satellite imagery.

Finally, the constant use of energy, such as that by air conditioning, vehicles, and industrial processes, generates heat, which becomes trapped in urban environments. This excess heat further raises the temperature in cities.

Final Project Report

Why do we care about Urban Heat Islands?
Urban heat islands have several impacts on urban areas and their residents. Higher temperatures can lead to increased energy consumption as people rely more on-air conditioning to cool their homes and buildings. This, in turn, contributes to higher greenhouse gas emissions. Furthermore, the increased temperatures in urban heat islands can have negative health effects on individuals, particularly vulnerable populations such as the elderly and those with pre-existing medical conditions. The elevated temperatures can cause heat-related illnesses, heat strokes, and even exacerbate respiratory problems.

How do we study Urban Heat Islands?
Have you ever wondered how scientists create maps that show different temperatures or other data throughout a city? We can create these types of maps or data sets using a combination of temperature sensor networks and remote sensing. Remote sensing refers to the process of acquiring information about an object or phenomenon without coming into physical contact with it. It involves the use of various sensors, such as cameras or satellite imagery, to collect data from a distance. This allows for the study of large areas and the monitoring of changes over time.

Geographic Information Systems
One of the ways we can visualize and analyze remote sensing data is by using **Geographic Information Systems**, or **GIS**. GIS is a system designed to manage and analyze spatial or geographic (sometimes called 'geospatial') data. It combines data from various sources, such as maps, satellite imagery, and survey data, and allows us to overlay these data sets in order to visualize the relationships between the data and analyze them to find patterns.
In order to compare geographic datasets, it is important to make sure that they use the same **map projection**. Map projection refers to the process of representing the curved surface of the Earth on a flat surface, such as a map. Due to the Earth's spherical shape, it is not possible to create a perfectly accurate flat representation. Different map projections exist, each with its own strengths and weaknesses. We can identify a given location on a map projection using a coordinate system, the most common of which is **latitude and longitude.** Latitude is the angular distance north or south of the equator, while longitude is the angular distance east or west of the Prime Meridian. Together, these coordinates provide a unique identifier for any location on the Earth. Latitude and longitude can be reported either using degrees, minutes, and seconds. (e.g., 40°45'11"N, 73°58'59"W) or in **decimals degrees** (e.g., 40.753056, -73.983056).

Types of GIS Data
To do your GIS data analysis, you must understand the two major types of GIS geospatial data: raster and vector (see Figure 2).

- **Raster data** is a type of spatial data that is represented as a grid of cells or pixels. Each pixel contains a value, such as elevation, temperature, or land cover type. Raster data is commonly used in remote sensing and other applications that require continuous data over a large area. A **pixel** is the smallest unit of information in a raster dataset. It represents a single cell in the grid and contains a value that corresponds to a specific attribute or measurement. The **resolution** of a raster dataset refers to the size of each pixel and determines the level of detail that can be captured.
- **Vector data** is a type of spatial data that represents geographic features as points, lines, or polygons. Points represent individual locations, such as the coordinates of a city. Lines can represent straight or curved linear features, such as roads or rivers. Polygons represent areas or regions, such as the boundaries of countries or neighborhoods. A special kind of vector data that you will use in your study is a transect. A **transect** is a line or path that is used to sample or study a specific area or feature. It is often used in environmental or ecological studies to collect data along a predetermined route. Transects can be straight or curved, and multiple transects can be used to capture variation across a landscape.

Figure 2
Raster spatial data is represented as a grid of pixels, while raster data uses points, lines, or polygons.

Final Project Report

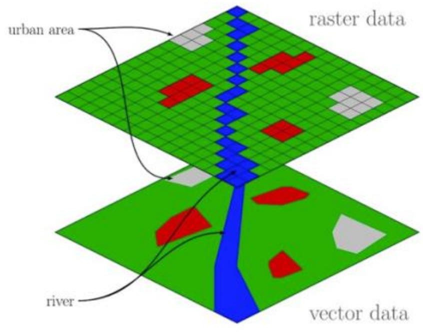


Image Credit: Johannes Rössel / Creative Commons Attribution-Share Alike 3.0 Unported license

Information about each piece of geospatial data (raster pixel or vector feature) is stored as an **attribute** and can include characteristics, measurements, or other descriptive data. An **attribute table** is a database that stores this information and allows for querying, sorting, and analyzing the attributes of different features in a GIS. For example, an attribute table for a given pixel of an elevation raster dataset will include information about the coordinates of the pixel, the pixel size, and the average elevation within the pixel.
In this project, you will use ArcGIS to analyze a variety of raster and vector datasets in your city in order to explore the relationship between surface type and temperature.

Terms and Concepts

- Urban heat island
- Albedo
- Land cover type
- Impervious surface
- Evapotranspiration
- Tree canopy cover
- Temperature sensor network
- Remote sensing
- Geographic Information System (GIS)
- Map projection
- Latitude and longitude
- Decimal degrees
- Geospatial data
- Raster data
- Pixel
- Resolution
- Vector data
- Transect
- Attribute
- Attribute table

Questions

- What types of geospatial datasets will you need to determine the impact of surface type on temperature? Do you think these are raster or vector datasets?
- What time of day do you think would be the most useful to collect temperature data to examine the impact of surface type on temperature?
- What surface types do you expect to have the highest temperatures? The lowest?