emerald PUBLISHING

International Journal of Sustainability in Higher Edu

From Science Class to Studio: Supporting transformative sustainability learning among future designers

Journal:	*International Journal of Sustainability in Higher Education*
Manuscript ID	IJSHE-02-2024-0094.R3
Manuscript Type:	Research Paper
Keywords:	architecture, design thinking, ecology, higher education, sustainability, transformative learning

Tab 1

From Science Class to Studio: supporting transformative sustainability learning among future designers

Author Details:
Ashley Bales
Math and Science, Pratt Institute, Brooklyn, NY, USA

Chris X J Jensen
Math and Science, Pratt Institute, Brooklyn, NY, USA

Michael R Sekor
Math and Science, Pratt Institute, Brooklyn, NY, USA

Bryan Adinolfi
Math and Science, Pratt Institute, Brooklyn, NY, USA

Corresponding author: Ashley Bales
Abales69@pratt.edu

Paper submitted: 13-Feb-2024
Paper revised: 28-Aug-2024

Structured Abstract:
Purpose
To describe the role of design thinking in achievement of transformative sustainability learning outcomes among undergraduate Art and Design students in order to support future curricular design efforts and thereby train sustainability minded future designers.

Design/methodology/approach
Baseline and culminating sustainability concept mapping assessments and reflective surveys were administered to 70 students enrolled in a general Ecology and design-centric Ecology for Architects course. Correlation and regression analyses compared samples and case studies further elucidated patterns of variation relating to complexity and breadth of students' sustainability knowledge and transformative potential.

Findings
Students in the design-centric course performed better on transformative sustainability indicator metrics relative to those enrolled in the general Ecology course, driven by improvement in design applications. Complexity of sustainability knowledge improved more among the general Ecology students, but was accompanied by declines in transformative indicators. Increasing foundational sustainability knowledge is unlikely, on its own, to support transformative learning. Survey responses indicated students were, however, motivated to apply what they learned to their design work, with the most significant improvement in transformative indicators seen in students enrolled in the design-centric course.

Originality
This study focuses on a population of students often marginalized in STEM education and provides a unique perspective on the value of design-centric GE courses in a population of students accustomed to design thinking pedagogies.

Keywords: architecture, design thinking, ecology, higher education, sustainability, transformative learning,

Article Classification: Research Paper

For internal production use only

Running Heads:

From Science Class to Studio: supporting transformative sustainability learning among future designers

Paper submitted: 13-Feb-2024
Paper revised: 28-Aug-2024

STRUCTURED ABSTRACT

Purpose

To describe the role of design thinking in achievement of transformative sustainability learning outcomes among undergraduate Art and Design students in order to support future curricular design efforts and thereby train sustainability minded future designers.

Design/methodology/approach

Baseline and culminating sustainability concept mapping assessments and reflective surveys were administered to 70 students enrolled in a general Ecology and design-centric Ecology for Architects course. Correlation and regression analyses compared samples and case studies further elucidated patterns of variation relating to complexity and breadth of students' sustainability knowledge and transformative potential.

Findings

Students in the design-centric course performed better on transformative sustainability indicator metrics relative to those enrolled in the general Ecology course, driven by improvement in design applications. Complexity of sustainability knowledge improved more among the general Ecology students, but was accompanied by declines in transformative indicators. Increasing foundational sustainability knowledge is unlikely, on its own, to support transformative learning. Survey responses indicated students were, however, motivated to apply what they learned to their design work, with the most significant improvement in transformative indicators seen in students enrolled in the design-centric course.

Originality

This study focuses on a population of students often marginalized in STEM education and provides a unique perspective on the value of design-centric GE courses in a population of students accustomed to design thinking pedagogies.

Keywords: architecture, design thinking, ecology, higher education, sustainability, transformative learning,

Article Classification: Research Paper

INTRODUCTION

Transformative education for sustainability (TEfS) refers to the modes by which students confront the wicked problems of our times through use of sustainable solutions and problem solving. Driven by the increasing recognition that education plays an essential role in fostering sustainable development goals globally (UNECE, 2012; UNESCO, 2017), sustainability education has become a central pillar for an increasing number of institutions of higher learning. Much attention has been paid to defining sustainability learning outcomes and knowledge domains (Brundiers *et al.,* 2021, Segalàs *et al.*, 2008; Wiek *et al*., 2011), but in order for sustainability education to make progress towards achievement of sustainable development goals, moving communities towards more sustainable lifeways, our sustainability programs must accomplish transformative change in students.

Students must not simply be able to define modes and mechanisms of sustainable living and development, they must themselves choose between the trade-offs sustainable choices pose, be motivated to search for sustainable solutions where they might not be immediately apparent, and be able to envision possible futures (Dlouhá *et al.*, 2019; Lange, 2023; Schneidewind *et al.,* 2016). Sustainable education on its own does not challenge educators to ensure their pedagogies and curricular designs are directed towards more than the declarative, transmissive knowledge necessary to define sustainability and the impacts of unsustainable practices. Transformative education for sustainability includes the additional goals of destabilizing perspectives and worldviews by presenting disorienting dilemmas and wicked problems, searching for creative solutions, striving to implement those solutions, and supporting the motivation necessary to grapple with these dilemmas through addressing values, attitudes, emotions, self-awareness and consideration of possible futures (Ives et al., 2020; Jaakkola *et al.,* 2022; O'Brien, 2018; Singer-Brodowski, 2023). Appendix 1 presents discussion of the theory of TefS upon which our work rests.

This study, situated at Pratt Institute, an art and design institute in Brooklyn, NY, USA, centralizes art and design students, asking not only how to best achieve transformative sustainability outcomes in artists and designers, but what we might learn from art and design students and pedagogies that might serve TefS across the higher education landscape. Unfortunately, the broader educational landscape, through its prioritization of STEM students, and a focus on liberal arts institutions neglects artists and designers as focal populations for sustainability education. Achievement of Sustainable Development Goals (SDGs) will require designers with a deep understanding and appreciation for sustainability. We must understand the role of designers not as tools to be utilized by environmental scientists, but as active partners in the production of sustainable solutions. As such we should strive to integrate sustainability broadly throughout the education of future designers.

Defining transformative sustainability indicators

In order to address the dilemmas of assessment of transformation (see Appendix 1), this study has identified a set of indicators that can be observed across the course of a single semester and used to assess the success of the course in supporting transformation in students (Table I). Ultimately, transformation will always be personal, and there is no teaching method that can guarantee transformation (Cranton, 2002). Acquisition of content knowledge is insufficient, on its own, to support transformation (Dewey, 1938; Kitchenham, 2008; Lange, 2023; Mezirow, 2000; Pugh, 2017). Therefore, we began with the assumption that the domains of ecological sustainability knowledge traditionally presented in classroom lectures, textbooks and evaluated on exams, are simply the foundation upon which transformation must be built.

Table I. Concept map coding categories. Sustainability knowledge domains were taken from Segalàs et al. (2008). Transformative indicators are highlighted in blue.

Coding category	**Sustainability domain or Transformative indicator**	**Description**
Category 1. Environmental aspects	Sustainability knowledge domain	Pollution, degradation, conservation, biodiversity, ecological footprint
Category 2. Resources scarcity	Sustainability knowledge domain	Un-renewable resources, run out of materials, etc
Category 3. Social impact	Sustainability knowledge domain and transformative indicator	Quality of life, health, etc.
Category 4. Cultural & Values aspects	Sustainability knowledge domain and transformative indicator	Related to ethics, consciousness, etc
Category 5. Future generations	Sustainability knowledge domain	The temporal dimension
Category 6. Unbalances	Sustainability knowledge domain	The equity dimension
Category 7. Technology	Sustainability knowledge domain	BAT, Industry, efficiency, clean-technologies, energy, etc.
Category 8, Economical aspects	Sustainability knowledge domain	Role of economy, fair trade, consumption, etc.
Category 9. Education aspects	Sustainability knowledge domain	Role of education, rise of awareness, etc.

Category 10. Actors and stakeholders	Sustainability knowledge domain	Role of governments, NGOs rules, laws, international agreements, etc.
Category 11. Individual action	Transformative indicator	Referencing concrete actions available to the student, indicative of opportunities for activism, lifestyle choices, community engagement, etc.
Category 12. Design application	Transformative indicator	Referencing creative disciplinary practice, methodology, design process or applied material use, etc.

Our transformative indicators (Table I) belong to four distinct categories: social impacts, values statements, design applications, and individual action. We assembled these indicators by combining the sustainability knowledge domains as defined by Segalàs *et al.* (2008) with additional indicators that demonstrate clear pathways to individual action either professionally (designated "design applications") or in a student's daily life (designated "individual action"). This set of transformative indicators emphasizes behavior change, as we see the goals of TEfS — given the severity of the environmental crisis — to be directed towards motivating and empowering action.

An understanding of social impacts arising from the environmental crisis would demonstrate how a student relates the consequences of foundational knowledge to pressing concerns of immediate relevance to themselves or their community. Additionally, reference to values describes how students, communities, or other actors might be motivated to respond to impacts, either environmental, social or otherwise. When knowledge of social impacts converges with values statements and foundational ecological knowledge, there is the potential for motivated action. Neither foundational ecological knowledge nor knowledge of social impacts or values statements are enough, however, to plan a course of action, which must additionally involve procedural and effectiveness knowledge (Kaiser and Fuhrer, 2003; Frisk and Larson, 2011). Both design applications and individual action indicators involve procedural and effectiveness knowledge, in that they both imply specific implementations arising from prior knowledge or motivation. Individual action covers both lifestyle behaviors, such as recycling or utilizing public transit, as well as advocacy, activism, or the continued pursuit of education. Design applications involve any application to students' major course of study in art or design, as well as reference to sustainable designs outside their field of study.

The "design applications" transformative indicator is framed to apply to the particular situation of our study at a design institute, where Pratt Institute has the potential to have an outsized influence on the sustainable development of the built environment and product landscape by training future designers. This indicator can, however, translate to non-design programs and students through recognizing it as an indication of transfer of knowledge between contexts and classrooms, in this case between a student's design centric studio work and a general education sustainability course. In this way, the "design application" transformative indicator reflects the potential for behavior change and application of sustainability knowledge to future professional work along with transfer knowledge arising from curricular pathways that successfully integrate GE work with a student's work towards their major. We consider this transferral of knowledge from one context to another as indicative of a student taking ownership of knowledge in ways that might lead to broader lifestyle changes or other motivated engagement with sustainability issues.

Goals and research questions

Ecological sustainability is one of the central components of TEfS and this study assessed change in student's transformative indicators before and after taking a lower division undergraduate Ecology course as a means of investigating how best to structure ecological sustainability education to support the development of transformative sustainability potential in art and design students.

The study addresses the following questions:

1. Does improvement in the breadth and complexity of students' sustainability knowledge, reflective of success in acquisition of content knowledge, support improvement in transformative sustainability indicators?
2. Do design-centric introductory Ecology courses support development of transformative sustainability indicators and therefore, through their emphasis on design thinking, are art and design higher education institutions uniquely positioned to serve as valuable models for achievement of sustainability goals?
3. Do students enrolled in a sustainability elective, as opposed to a required sustainability course, demonstrate greater improvement in transformative sustainability indicators?
4. In what ways do students utilize the transformative sustainability indicators designated here to express their understanding of sustainability and their personal relationship to sustainability, and to apply it to their major field of study?

These questions are addressed to inform the development of curricular designs supportive of transformative sustainability learning outcomes in future designers, whether they are trained at focused design or liberal arts institutions. Design-centric courses have the potential to support transfer of knowledge between major and general education courses, but have not been comprehensively studied in the existing literature. The transfer of knowledge component has implications across higher education curricular design. It fills a gap in the literature by focusing on future designers, identifying them as essential partners in the achievement of SDGs, who have been historically marginalized in STEM centric sustainability education. Additionally, these results investigate the value of design thinking as a productive pedagogy for supporting transformative sustainability outcomes.

A foundational premise that requires further investigation and for which this study provides a valuable first step, is the presumption that design students, through their core education in design thinking, are primed for success in achievement of transformative sustainability outcomes. While many studies on the value of design thinking have been conducted among non-design students, these have often indicated difficulties in acclimating students to design thinking pedagogies as a hurdle to assessing the success of design thinking (Altringer and Habball, 2016; Lor, 2017; Retna, 2016). This study adds significantly to the limited work that has been conducted in art and design contexts where students are already accustomed to design thinking (Anderson, *et al.* 2014). Following the investigation presented here, there is opportunity for comparison with results from non-design student populations that may add to the discourse on the value of design thinking in transformative education for sustainability more broadly, including addressing the question: In what ways can design education and design thinking inform improvements to transformative education for sustainability in the broader Higher Education context?; and What motivates students to apply what they learned to their major work?

MATERIALS AND METHODS

A mixed-methods approach is utilized, integrating quantitative data coded from student concept maps and surveys, with qualitative discussion of the range and diversity of student concept maps and narrative survey responses. While primarily a cross-sectional descriptive study, interested in quantifying variation in students' engagement with and understanding of sustainability across core Ecology courses offered at Pratt Institute during Spring semester of 2021, it takes an exploratory approach to its qualitative analysis. By including both descriptive quantitative and exploratory qualitative analyses of students' work and narrative responses, this study identifies significant variation and trends, while also capturing the broader scope of our students' engagement with this complex, transdisciplinary concept.

Sampling

Students were recruited for the study from all Pratt Institute Math and Science General Education Core sustainability courses offered in Spring 2021 in Brooklyn, New York, USA, a sample of 70 primarily First- and Second-Year students (Table II). This sample was identified using a comprehensive strategy, asking all students whether they would volunteer to participate in the study, with the final sample of 70 comprising all volunteers. The sample includes seven sections across two separate courses: the design-centric 'Ecology for Architects' (EA), and the general 'Environmental Science and Ecology' (ESE). EA is a required course that Architecture undergraduates take in their second year and adjusts the focus of a more typical introductory ecology and sustainability course to more directly apply to topics relevant to architectural design and decision making. ESE is a more general ecology course, though as with all GE courses at Pratt, it is structured to broadly engage with the art and design focus of the Institute. It is one of a menu of courses that non-architects may choose to take to fulfill a lower-division math and science core general education requirement. Both courses can count towards an interdisciplinary Sustainability Studies minor. Syllabi and final project instructions for both courses are included in Appendix 2.

Table II: Composition of student participants across two environmental science courses

	Number of student participants	Number of course sections	1st year	2nd year	3rd year	4th year
Ecology for Architects (EA)	50	4	1	45	4	0
Environmental Science and Ecology (ESE)	20	3	10	7	1	1

Comparison of the learning goals and outcomes of the two courses (Table III) suggests some important structural differences. EA does not reference individual action, while ESE does. Social impacts are highlighted more clearly in ESE. Design applications are emphasized in EA, with two learning outcomes and one learning goal centered on design, while ESE does have outcomes where considering design applications would be appropriate, it has neither goals nor outcomes that would explicitly require students to consider design applications in detail.

Table III: A comparison learning goals and outcomes of the design-centric Ecology for Architects course with the Environmental Science and Ecology course

	Ecology for Architects	Environmental and Ecological foundations	Social impacts	Values aspects	Individual action	Design applications
Learning Goals	Acquire an “ecological literacy” about how the natural world works.	✔				
	Develop an understanding of how scientific methods are used to construct ecological and environmental scientific knowledge.	✔				
	Become familiar with some of the major ecological challenges facing Earth today, and the important research which needs to be done to address these concerns	✔	✔			
	Develop a deeper understanding of how human development impacts ecological communities and systems	✔	✔			
	Become familiar with the ecological justification for sustainable practice in building and design.	✔		✔		✔
Learning Outcomes	Understand and describe the non-living components of the environment that influence ecology.	✔				
	Understand and describe the major ideas of natural selection, population and community ecology, biodiversity, and wetlands. climate change, and sustainability.	✔				
	Describe and debate some of the major ecological issues relating to the current and future human condition such as ecosystem services, agricultural systems, water resources, climate change, and land use.	✔	✔			
	Describe how environmental health may be impacted by toxic materials and describe what factors contribute to toxicity	✔	✔			✔
	Describe the ecological basis of “green” movements in design and architecture.	✔				✔
	Total Number of Goals/Outcomes ➡	10	4	1	0	3
		Environmental and Ecological foundations	Social impacts	Values aspects	Individual action	Design applications

	Environmental Science and Ecology	Environmental and Ecological foundations	Social impacts	Values aspects	Individual action	Design applications
Learning Goals	Understand how ecological systems function and how those functions provides services to humans.	✔	✔			
	Explore how a variety of ecological interactions create ecological communities and allow nutrients, water, and energy to flow through ecosystems.	✔				
	Identify and understand the major ecological and environmental problems created by human activities.	✔	✔			
	Frame the major human activities that threaten the sustainability of human civilization by creating excessive ecological and/or environmental impacts.	✔	✔			
	Assess which technologies and policies have the most promising potential to reduce human impacts to sustainable levels.		✔			
	Refine students' ability to write about scientific ideas and scientific research through a process of drafting, feedback, and revision.					
Learning Outcomes	depict how different interactions in ecological communities produce the variety of ecosystems and emergent ecological flows observed on Earth.	✔				
	explain how ecologists and evolutionary biologists conduct studies to improve our understanding of how the natural world functions.	✔				
	connect the functioning of ecological systems with resources and services that human civilizations depend upon.	✔	✔			
	catalog and assess the relative severity of different ecological and environmental problems.	✔	✔	✔		
	use critical, logical, and creative thinking to devise and assess solutions to major problems of human sustainability.	✔			✔	
	perform research into the scientific literature that informs the written proposal and summary that accompany a creative Term Project.					
	Total Number of Goals/Outcomes ➡	9	6	1	1	0
		Environmental and Ecological foundations	Social impacts	Values aspects	Individual action	Design applications

The structure of the major projects for each course more clearly demonstrate the greater design focus of EA relative to ESE (Table IV). While the ESE final project is a typical research project, where students are additionally asked to produce a creative work inspired by their research, the EA project adheres closely to the design thinking process. While ESE students are asked to apply ecological research to design, EA students are guided through a design process which requires ecological research. ESE students are thereby not required to integrate all stages in the design thinking process process and while their projects may and often do engage with other transformative indicators, the openness of the project does not require this, as the specificity of the EA project does, a specificity dictated by its adherence to design thinking modes.

Table IV. Comparison of final projects between EA and ESE. The cool colored columns on the left indicate components of the EA project, while the warm colored columns on the right describe ESE project stages.

		EA major project stages					
		Build a topographical model		Impacts of pumping groundwater: choosing a preferable scenario		Land use impacts on watersheds: mediating conflict	
Content knowledge	Ecological foundations	✓	✓	✓	✓	✓	✓
Transformative indicators	Social Impacts			✓		✓	
	Values						
	Individual Action						
	Design Applications	✓	✓	✓	✓	✓	✓
Elements of design thinking	Empathize			✓		✓	
	Define	✓	✓	✓	✓	✓	✓
	Ideate		✓	✓	✓	✓	✓
	Prototype	✓		✓		✓	
	Test	✓		✓		✓	
		Conduct preliminary ecological and creative research		Present initial research and creative project proposal		Research paper with creative work or proposal	
		ESE major project stages					

Data collection and analysis

At the beginning and end of the semester, students were asked to complete concept maps defining sustainability (Appendix 3). Analysis of these maps was used to measure the breadth and complexity of their understanding of sustainability, reflecting content knowledge, as well as for indicators of transformative potential, through inclusion of nodes that demonstrated engagement with social impacts, values statements, individual action and design applications. Nodes in concept maps were coded to indicate sustainability knowledge domains (Table I). Breadth of sustainability knowledge was then calculated as the proportion of sustainability knowledge domains included in the concept map. The complexity of sustainability knowledge was calculated by multiplying the number of nodes in a concept map by its linkages relative to the number of knowledge domains (See Segalàs *et al.*, 2008 for full methods). Transformative indicators were coded as overall counts of included nodes in each of the four transformative indicator categories (social impacts, values statements, design applications, individual action) and a final transformative indicator score was calculated by summing instances from all categories. In order to account for prior knowledge and interest, all metrics were considered in terms of change across the semester. Regression analyses were performed to observe variation among concept map metrics and whether courses, instructors and student level (credits completed) had an impact of achievement of transformative indicator or knowledge metrics. Wilcoxon tests were conducted to test for significant differences between groups and from baseline to culminating metrics. Spearman's rank correlation tests were used to assess the correlation between variables.

Culminating survey asked students to reflect on what they learned in the course and their motivation to incorporate the sustainability knowledge they acquired into their daily lives, future academic work and extracurricular activities. These responses provided additional context to the quantitative analysis of concept maps, but were not part of the metric coding. Notable examples of student success and struggle were analyzed in a limited case study analysis presented in Appendix 4.

RESULTS

Relationship between transformative indicators and breadth and complexity of sustainability knowledge

Neither breadth nor complexity of sustainability knowledge are significantly correlated with any individual transformative indicator or the total transformative indicator score (Figure 1). The baseline concept maps of ESE students demonstrated greater conceptual breadth in their concept maps relative to EA students. Initial complexity, however, did not demonstrate significant relationships to either course or number of credits completed by a student. Initial and culminating assessments indicated a majority of students demonstrated significant improvement in complexity of their understanding of sustainability as expressed in concept map complexity (Figure 2). However, students in ESE — though showing a greater proportion of students that improved in complexity and greater average complexity improvement — showed an average decrease in the breadth of sustainability knowledge represented in concept maps. While a majority of EA students improved the breadth of sustainability knowledge domains, this improvement was minimal, with an average improvement approaching zero and results were not significant.

Figure 1. Correlation matrix summarizing relationship between variables. Purple boxes indicate significant correlations. Yellow boxes overlay significant results from multiple regression analyses, considering relationship between course, instructor and the number of credits completed by a student (Appendix 5 contains full results). Credits- number of credits student has completed towards graduating, EA/ESE- course number ESE = 270, EA =271, Brdth-

improvement in breadth, Cmplx- improvement in complexity, Design- improvement in proportion of design application nodes, IndAct- improvement in proportion of individual action nodes, Values- improvement in proportion of values nodes, Total T- improvement in number of total transformative indicators.

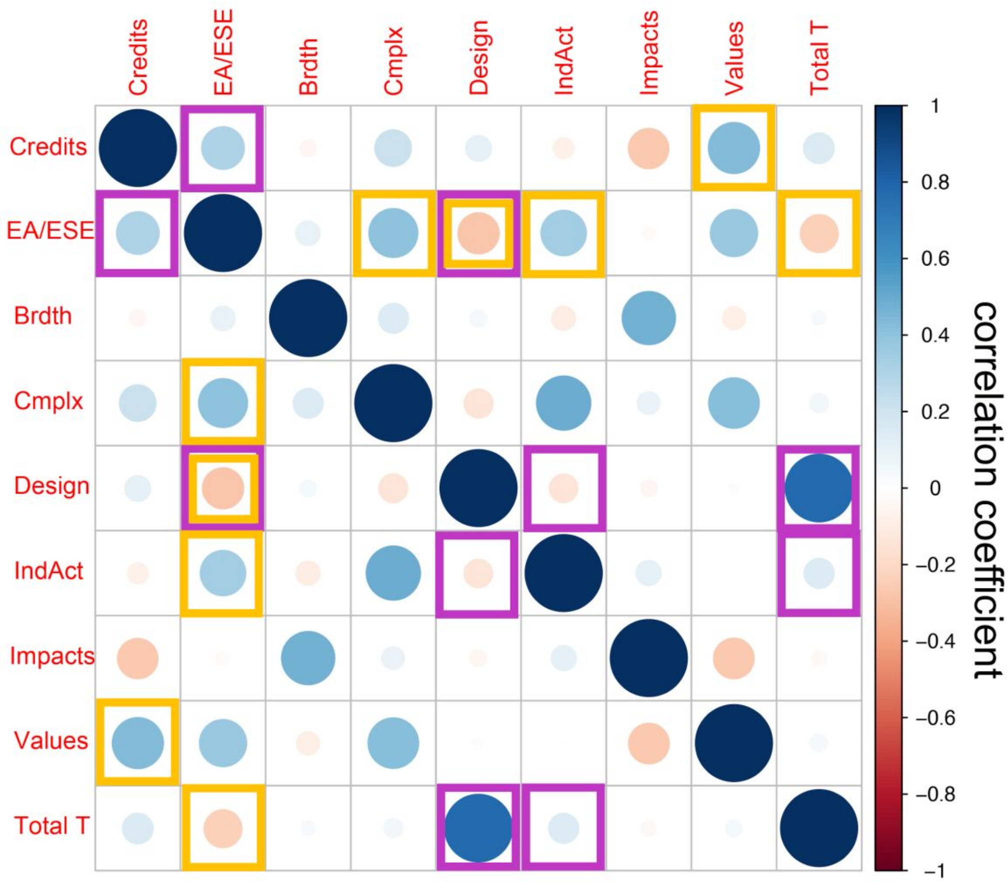
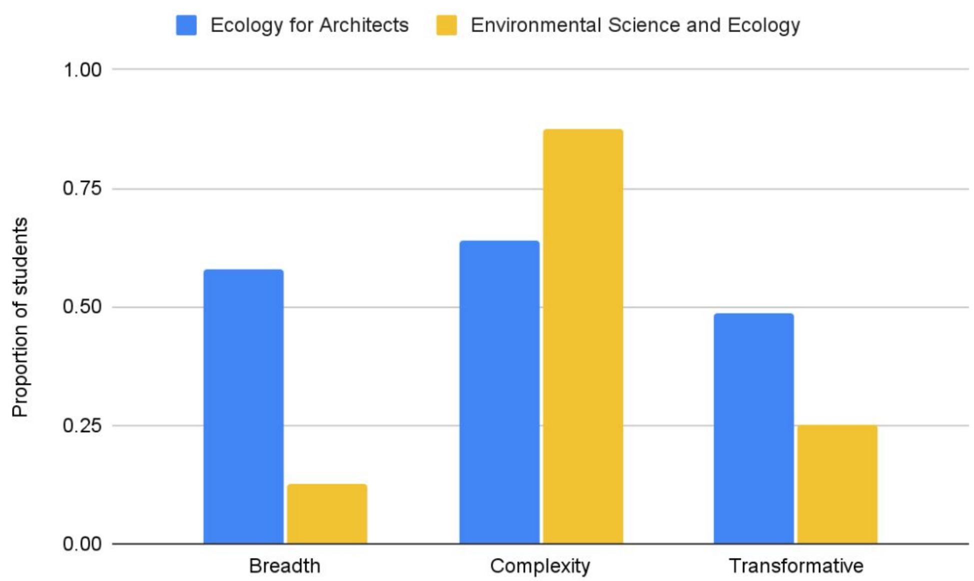


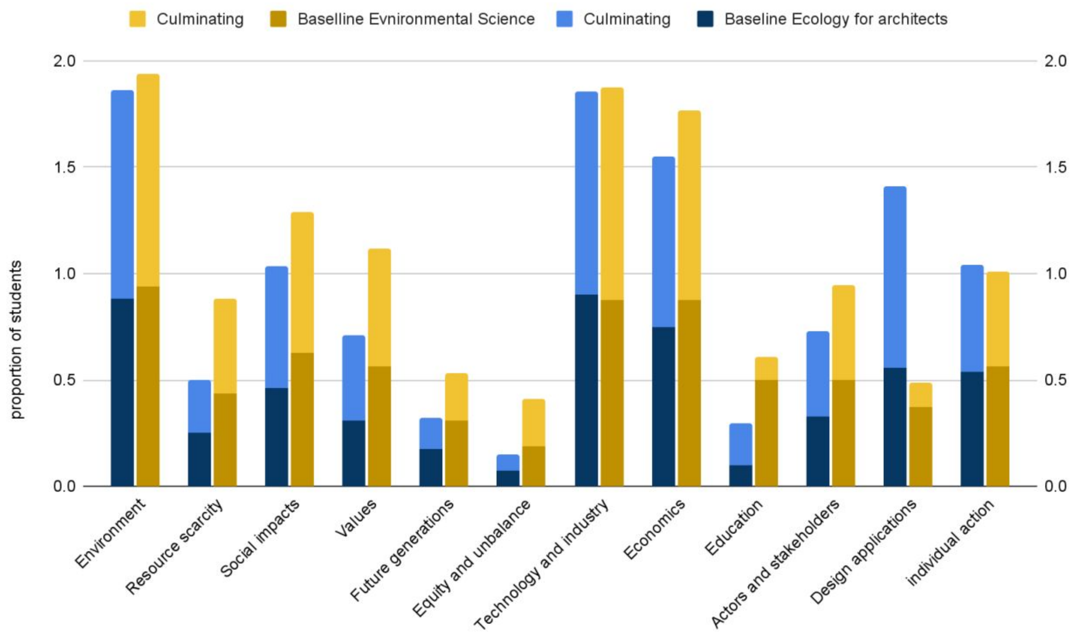
Figure 2: Proportion of students demonstrating improvement across the semester in breadth, complexity and transformative indicators. (See Appendix 6 for significance tests)



Regression analyses indicate a significant correlation between course and change in complexity across the semester (Figure 1). There is a significant correlation between change in breadth and instructor, but not between breadth and course. The lack of significance between course and breadth, however, may be a relic of the small sample size for the section led by one of the ESE instructors, which included a higher proportion of missing data.

Patterns of change in knowledge domain representation in student concept maps between students in EA and ESE include interesting contrasts (Figure 3). Overall, ESE students performed better than EA students, with a higher proportion of ESE students including each domain at baseline and culminating mapping than EA students, with the notable exception of the Technology and Industry domain, in which EA students performed better in their baseline maps than ESE students. Across both courses, Environment, Technology and Industry, and Economics domains were best represented across the semester, with Equity and Unbalance, and Future Generations represented least. The domains of Environment, Social Impacts, Technology and Industry, and Economics each showed an increase in the proportion of students including these categories in their concept maps from baseline to culminating maps. The Future Generations domain, however, decreased in both courses. Values, Education, and Actors and Shareholders domains decreased in ESE, but increased in EA students. The last two domains--Equity and Unbalance, and Resource Scarcity--showed little to no change in EA students from baseline to culminating, with improvement in representation among ESE students. These results suggest that there are significant differences in student achievement and the structure of foundational knowledge gained between these courses.

Figure 3: Proportion of students including sustainability domains in concept maps



Relationship between course focus on design thinking and achievement of transformative sustainability indicators

There were significant differences between courses in improvement in total transformative indicators, with EA students demonstrating greater improvement relative to ESE (Figure 1). While the total number of students including any transformative indicators in concept maps did improve across the semester (Figure 4), the average number of total transformative indicators went down for ESE students, while it went up for EA students (Figure 5). Across all students, there was a weak but significant negative correlation between improvement in design applications and improvement in individual action indicators (Figure 1). The strong correlation between design applications and total transformative indicators demonstrates the significance of improvement in design applications relative to other indicators in driving overall improvement in transformative indicators. In general, however, there was little indication of improvement in transformative indicators from the beginning to the end of the semester, with only a minority of students in each course exhibiting improvement in total indicators across the semester (Figure 2). Baseline concept maps showed no significant correlation between either course or credits and design application, individual action, social impacts, or total transformative indicators (Appendix 5). Values, however, were predicted by course, with ESE students including more values indicators at the start of the semester.

Figure 4: Proportion of students including transformative indicators in culminating and baseline concept maps

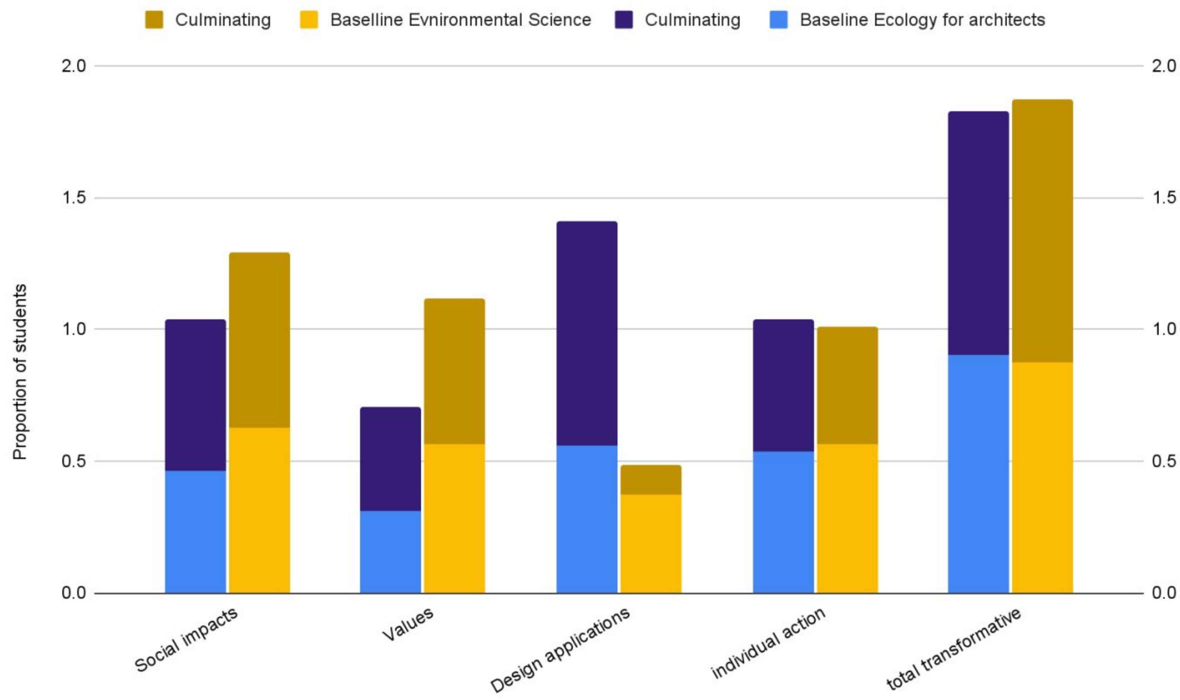
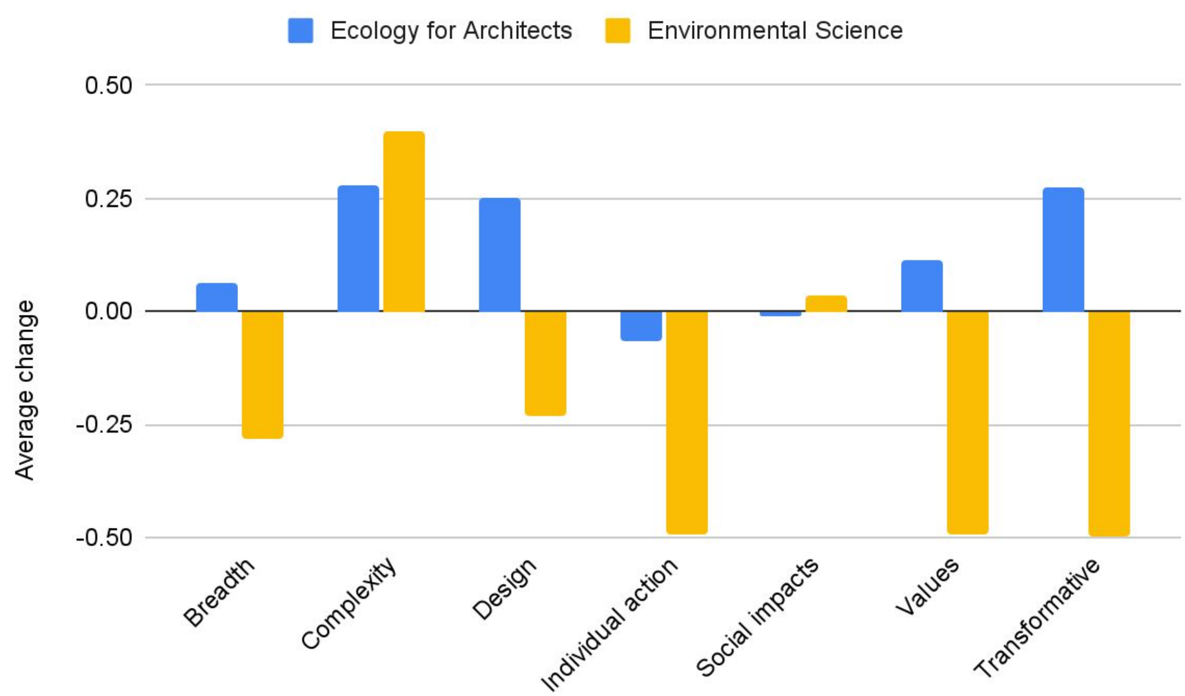


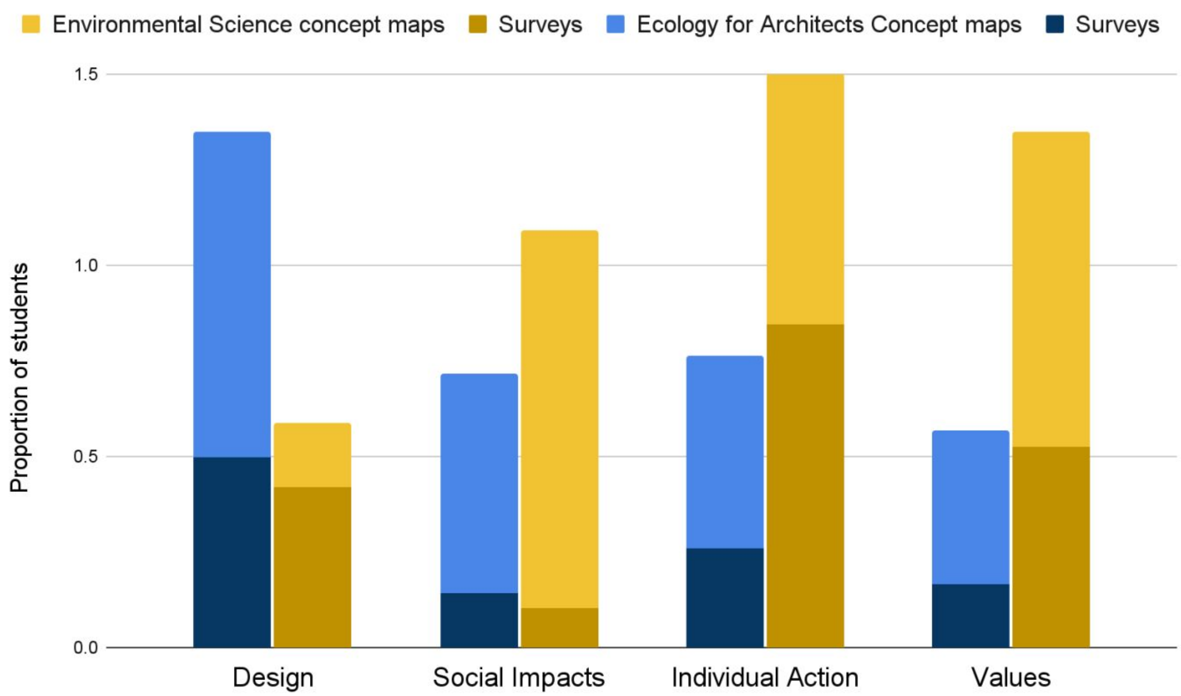
Figure 5: Normalized average change from baseline to culminating concept map



Variation in expression of transformative sustainability indicators between elective and required courses

A majority of ESE students self-reported a motivation to take action or make lifestyle changes in culminating survey responses (Figure 6), though inclusion of individual action nodes and proportion of students including such nodes both went down in ESE across the semester. Similarly, only 26% of EA students reported motivation to take individual action and both the average number of included nodes and the portion of students including individual action nodes decreased moderately. What course a student was enrolled in was a significant predictor of change in the number of individual action nodes across the semester and whether they included reference to individual action in reflective survey responses (Figure 1).

Figure 6: Proportion of students including transformative indicators in culminating reflective survey responses and concepts maps



Social impacts appear least in student reflective surveys in both courses, though appearing more often among EA students (14% EA, 7% ESE). Conversely, social impacts appeared more often in ESE concept maps with slight improvement across the semester in both average social impacts nodes included and number of students including any social impact nodes. In EA, there was also improvement in the number of students including social impact nodes and the change in average number of nodes included, while showing a minimal decrease, approached zero change.

35% of ESE students reference values in their survey responses, but 56% included values nodes in culminating concept maps. This compares to only 17% of EA survey responses mentioning values, but 40% of culminating concept maps. While the pattern of ESE students being more likely to include values nodes continues through from the beginning of the semester, ESE students actually saw a decrease in the average number of values nodes included in concept maps and a minimal decrease of 1% in the number of students including any values nodes. EA students on the other hand demonstrated improvement in the number of values nodes included and in the proportion of students including any values nodes, with there being a significant correlation between change in the number of values nodes included and course. There was also a significant relationship between student level (number of credits completed) and number of values nodes when controlling for course and instructor, with students with more credits likely to include more values nodes (Figure 1).

The most notable distinction between the two courses is seen in the inclusion of design applications. EA students were significantly more likely to demonstrate improvement in design applications (Figure 1). In responses to survey questions asking students to indicate their personal engagement with sustainability, only 34% of all students referenced design applications. This group comprised 38% of students in the EA course and only 20% of students in ESE. The increased awareness and engagement with design applications in EA students was also reflected in concept maps, where 56% of initial concept maps by EA students included design applications, rising to 85% by the end of the semester. Conversely, only 34% of ESE students initially included design applications, declining to only 11% by the end of the semester and ESE students were significantly less likely to include design applications in their culminating concept maps than did in their baseline concept maps, demonstrating significant losses in the amount of transformative indicators across the semester. This indicates an important distinction between achievement of transformative outcomes in the two courses.

DISCUSSION

Students enrolled in elective as opposed to required sustainability courses are not predisposed to greater achievement of transformative indicators

The design-centric EA is a required course taken by all Architects, while ESE is an elective that students selected among a range of offerings to fulfill a general education requirement. This structural difference is demonstrated in ESE students coming to the course with a greater breadth of knowledge and integration of values into their definition of sustainability. Despite these differences, baseline concept maps did not indicate that ESE students possessed greater complexity of sustainability knowledge at the start of the course, nor did their greater integration of values translate to overall higher transformative indicator inclusion relative to EA students. Their apparent greater investment in their sustainability education and comprehension did not translate into a greater propensity for transformative indicators. The increased presence of values nodes among ESE students at the start of the semester declined significantly relative to EA students, with ESE students tending to include fewer values nodes in their culminating maps. ESE students also included fewer design applications and individual actions nodes in their culminating maps relative to their baseline maps, demonstrating an overall decline in transformative indicator inclusion across the semester.

Our results suggest that the curriculum that the students are exposed to — specifically design-focused application of sustainability concepts — may be more important than their motivation for taking the course and baseline knowledge entering the course.

There is an interesting comparison here with Pugh's (2010) finding that students identifying as science oriented were more likely to achieve transformative outcomes in a science class. This finding cannot then be extrapolated, in the present study, as sustainability oriented students are not more likely to express greater improvement in transformative sustainability indicators. It is possible that Pugh's (2010) finding may apply similarly here, but the impact of being sustainably oriented is not as strong as the impact of the pedagogical differences that distinguish the two courses.

Achievement of complexity and breadth of sustainability knowledge is not predictive of increase in transformative indicators

ESE students demonstrated significantly greater improvement in their complexity of understanding relative to EA students, but this did not translate into more transformative indicators. Our results indicate no significant correlation between increasing breadth or complexity of sustainability knowledge and improvement in transformative indicators, particularly in the realm of design applications. This finding suggests that achievement of transformative outcomes is not dependent on declarative knowledge. The disconnect between these achievements in our non-science-oriented sample illuminates the need to clearly define educational goals and the difficulties of balancing pedagogies focused on achievement of declarative knowledge outcomes with those best supportive of transformation. The design thinking literature has further highlighted that design thinking pedagogies are not necessarily best suited to supporting achievement of declarative knowledge outcomes (Lor, 2017; Retna, 2016), which is supported by this result.

Design-centric course designs support transformative potential

The two courses considered in our study had important structural differences both in their populations of students (as discussed above, see Tables III and IV) and in the degree to which they were structured to challenge students to utilize design thinking and apply the sustainability knowledge they gained to their major art and design work. Students in the design-centric EA included significantly more design applications in concept maps and showed greater improvements in inclusion of design applications across the semester than students in ESE. They also demonstrated improvement in the inclusion of values nodes. These translated to an overall greater improvement in total transformative indicators among EA students relative to ESE students. This is our most significant finding and lends support to the hypothesis that design-centric courses that challenge students to utilize design thinking processes better support transformative potential in design students than more typical course designs. This finding is confirmed by Brooks and Brooks (2024), whose integration of design thinking as a component of a transformative learning journey led to improvements in confidence in the ability to enact change and empathy for diverse stakeholders; and by Macagno et al. (2024) who identified mindset changes as a result of utilizing design thinking pedagogies.

Achievement of complexity and breadth of sustainability knowledge may negatively impact transformative achievement

Baseline concept map and survey responses demonstrate that many students come into the classroom with a personal collection of knowledge and motivations related to sustainability. Unfortunately, by the end of the semester these personal connections and knowledges are regularly replaced by the more conceptual and factual knowledge deposited by the instructor (see Appendix 4 for detailed discussion of case studies). This pattern is particularly apparent among the more sustainability oriented ESE students, who arrived to the class with a greater integration of values into their definitions of sustainability, but by the end of the semester adopted more academic and less personal ways of defining sustainability which we infer to hinder transformation. This supports Freire's (2018) statement that "The more students work at storing the [knowledge] deposits entrusted to them, the less they develop the critical consciousness which would result from their intervention in the world as transformers of that world."

Instruction should focus less on 'banking' methods of education, which focus on declarative knowledge and concept mastery, thereby leading students struggling with mastery to defer more to others and lose autonomy (Schunk and Usher, 2019). Student concept maps which lose a personal voice and utilize more disciplinary jargon are demonstrative of this pattern of deferring to others. Design-centric education supports autonomy by making students actors in active problem solving and production challenges. This autonomy is essential to developing a sense of empowerment and motivating action.

Disagreement between concept map and reflective responses suggests that knowledge of sustainable pathways does not accompany transformation

An interesting pattern emerged in comparisons between demonstrated knowledge in concept maps and students' self-reporting on applying that knowledge to themselves and their actions and choices (see Appendix 4). In general, self-reporting on motivation in these contexts is expected to result in students providing responses that they deem pleasing to their instructor. If that were the case, we would see higher frequencies of transformative sustainability indicators represented in survey responses as compared to concept maps, but this is not the pattern here (Figure 6).

In EA, transformative indicators appeared in more students' concept maps than in their survey responses. This suggests that while students are aware of the social impacts, values, design applications and individual actions associated with sustainability and sustainable decision making, that knowledge has not yet been embodied, or adapted to their experience and choices. Similarly, Brooks and Brooks (2024) recognized conceptual improvements in students' expressed understanding of diverse stakeholders, but suggested that the knowledge might not have yet led to transformation.

Interestingly the same pattern does not exist among the sustainability oriented ESE students. While references to social impacts and values were also more common in the concept maps of ESE students than in their reflective survey responses, individual action and design applications were represented more among survey responses than concept maps. This perhaps indicates that students' motivation is outpacing their knowledge of sustainable pathways and processes, or as proposed above, that the deference to authoritative voices that arises from a pedagogical emphasis on concept mastery leads them to dismiss the more personal knowledge that they arrived to the class with, ultimately limiting the breadth of their understanding of sustainability and the tools they have available to make sustainable choices. Grund's et al. (2024) work highlights another possibility, implicating the hurdle of negative emotions associated with sustainability education – sadness, shame, disgust, and guilt – as inhibitors of transformation. Banking methods of teaching that prioritize concept mastery are not sensitive to the role of emotions and students' emotional journeys in the classroom, a sensitivity that may be necessary to achieving transformation.

The greater improvement in the knowledge necessary to support transformative indicators present among EA students as compared to ESE students, despite the predictable lower levels of reported motivation in the less sustainability oriented sample of EA students, suggests that the design thinking pedagogies used better support the empowering knowledge necessary for transformation. This proposal aligns with studies identifying increased agency as an outcome of design thinking pedagogies (Brooks and Brooks, 2024; Carroll, 2014; Lehtonen et al., 2022; Macagno et al., 2024).

CONCLUSIONS

Despite the overall greater motivation of ESE students to pursue a sustainability education relative to EA students, as demonstrated by ESE being an elective chosen by students as opposed to a required course, EA students demonstrated greater improvement in transformative indicators across the semester than ESE students. While ESE students demonstrated greater overall improvement in their complexity of understanding of sustainability concepts, this came at the expense of all other transformative indicators. Autonomy, and its relationship to student agency and empowerment, is identified as the primary explanatory lens through which to view these results. Students are likely to experience a loss of autonomy with the use of pedagogical modes prioritizing declarative knowledge and concept mastery, as they are led to replace knowledge drawn from personal experiences and values with adherence to the instructor's authoritative voice. On the other hand, students exposed to design thinking pedagogies express improvements in agency and the process knowledge that supports autonomy and empowered action. These results add to the body of literature that challenges us to rethink traditional modes of sustainability education and consider modes, such as design thinking, that prioritize student autonomy. It further supports the hypothesis that design institutions, through their use of design thinking pedagogies, are uniquely positioned to serve as useful models for the successful integration of sustainability across the curriculum and achievement of transformative sustainability outcomes.

Implications of the Study

There is a need to radically rethink the modes of teaching sustainability in introductory ecology and sustainability courses in order to foster transformative outcomes in students. The disorienting dilemma and cognitive dissonance students face when gaining a deeper knowledge of the environmental crisis can leave them feeling disempowered. Results from this study suggest that a focus on foundational ecological knowledge geared towards understanding the complexity of the environmental crisis can, on its own, be counterproductive to supporting the development of transformative outcomes in students. Declarative, disciplinary knowledge has never been sufficient to promote meaningful transformation in students. It is necessary, therefore, to move away from prioritizing declarative knowledge and assessments rooted in regurgitation of content, to think more broadly about what sorts of classroom achievements are most valuable to students and broader educational goals. Significant restructuring of our educational priorities--towards transformation and away from conceptual mastery--and the structures of higher educational institutions that support them may be necessary. Design institutes, such as Pratt Institute, present an interesting alternate model to liberal arts institutions, in its emphasis on design thinking and production based outcomes.

Potential interventions are proposed by these findings, in the increased achievement of transformative indicators present among students taking a design-centric architecture course. These findings suggest prioritizing teaching that provides supported pathways for creative decision making by students utilizing design thinking modes. Design thinking is demonstrated to be a productive means of maintaining student autonomy and authority in the classroom in ways that keep students valuing their own experiences, perspectives and values even within the context of authoritative disciplinary voices. The benefits of design thinking over banking modes of instruction are further able to overshadow prior student investment in the subject of sustainability, as demonstrated by the greater achievement of transformative sustainability indicators in the non-sustainability oriented sample of students.

While many students demonstrated awareness of the potential for application of concepts covered in their sustainability coursework to their personal creative work, only a minority explicitly applied these connections. Students in the design-centric 'Ecology for Architects course were more likely to apply that knowledge to design, reflective of the more meaningful curricular integration between this course and their studio work. Students are able to maintain autonomy by being challenged both immediately in the classroom to design solutions, but also, by using the same design tools as are used in their studio classes, are shown how to apply that knowledge to their major work. Transfer knowledge is apparent in student concept maps in which students drew connections between sustainability knowledge domains and design applications. Those students that were able to find pathways between their ecology courses and their design studio work provide evidence that successful transfer of design process knowledge between the studio and science classroom may allow students to move past the cognitive dissonance arising from greater complexity and breadth of understanding of sustainability and into a productive, transformative space. These pathways into disciplinary knowledge drawn from their chosen major may also help students overcome the negative emotions often associated with engagement with the wicked problems of sustainability. However, students reported frustration when their studio work did not present sustainable solutions. This indicates that while transfer of knowledge between science and studio classes is possible, the lack of thoughtful coordination in content can result in a disconnect between the definitional and conceptual education they are receiving in the science classroom and the application and production based work they are doing in the studio. This disconnect is likely to result in increased cognitive dissonance and disempowerment. As a result it is hypothesized that achievement of transformative outcomes in sustainability for design students is dependent on transfer of knowledge between studio and ecology courses. Ecology educators must be aware of how art and design students will translate scientific sustainability course content into particular design questions, problems and tasks that they will take into the studio. Studio instructors must equally be prepared to address these questions in sustainable ways. Likely the greatest hurdles to thoughtful integration across the curriculum, however, rests within the broader realm of program design.

Ultimately, successful transfer of learning between science and studio courses appears essential to a Pratt student's ability to apply sustainability knowledge to themselves and their major fields of study. But supporting students to transfer modes of thinking and working from the studio (or their major) to the science classroom and knowledge from their general education courses back into the studio is not as straightforward as simply having both in their schedules. Where there is not thoughtful coordination and understanding of students' journeys along these curricular pathways, values introduced in ecological sustainability classes may come into conflict with studio practices, resulting in a cognitive dissonance with the potential to both disempower and direct students away from sustainable practices and achievement of transformative sustainability outcomes. It is essential to think beyond disciplinary boundaries and pedagogic practice in individual classroom settings, to develop broader curricular frameworks, constructed intentionally to not just provide a palate of options for students, but to require admixture between disciplinary knowledge, perspective, practice, and personal experience. Achievement of this integration will require institutions to be flexible and think as creatively as we ask our design students to create institutional, programmatic, and curricular designs to best serve transformative sustainability learning outcomes.

Limitations and Future Directions

The sample considered in this study limits the scope of our findings to design students and further work must be done to clarify the way these findings apply to non-design students. Either, as we propose here, design thinking better supports transformative sustainability outcomes through its greater support of student autonomy, or it suggests that discipline specific sustainability course designs that engage with the methodologies of a student's major, thereby best supporting transfer knowledge, is the best means of supporting transformative potential. Additionally, longer term studies are required to consider not just transformative potential, as we have done here, but the ultimate achievement of transformation.

Our study focuses on design thinking and therefore does not consider alternative pedagogical approaches that have been shown to produce transformative learning, such as exposure to alternative world views, fostering self-awareness, or engaging students with a relationality paradigm. These alternative pedagogical approaches should also be considered to help determine whether sustainability knowledge and transformative learning can be supported simultaneously, effectively coupling knowledge with action.

Broader studies are needed to additionally account for student experiences beyond the classroom, looking both at extra-curricular experiences and the impacts of higher level curricular structures and pathways, in shaping transformative potential for sustainability. Design institutions again may provide a useful alternate model for exploration of these experiences. Exactly how these broader curricular pathways might be structured is of particular interest. Our findings provide a strong argument for conscientious curricular integration and future work will move beyond the individual classroom to address these findings. Programmatic level structures are particularly implicated by the results of this study concerning the role of transfer knowledge in supporting transformative sustainability outcomes.

Designers and design education institutions hold significant power in shaping the future of our built environment and product landscape. Both must be recognized as important partners in the global struggle to meet SDGs and greater focus should be directed to understanding how best to shape design educational pathways to support transformative sustainability outcomes. We must think beyond reductive concepts of science-oriented versus arts-oriented and recognize sustainability as transcending disciplinary boundaries and modes of thinking and working.

REFERENCES

Altringer, B, and Habbal. F, (2015), "Embedding design thinking in a multidisciplinary engineering curriculum", In VentureWell, Proceedings of Open, the Annual Conference (p, 1), National Collegiate Inventors & Innovators Alliance.

Anderson, N., Adam, R., Taylor, P., Madden, D., Melles, G., Kuek, C., Wright, N. and Ewens, B. (2014), "Design thinking frameworks as transformative cross-disciplinary pedagogy", Australian Government Office for Learning and Teaching, Department of Education.

Avsec, S. (2021), "Design thinking to enhance transformative learning", Global Journal of English Education, Vol. 23, p. 169-175.

Badwan, B., Bothara, R., Latijnhouwers, M., Smithies, A., & Sandars, J. (2018), "The importance of design thinking in medical education", Medical teacher, Vol. 40, No. 4, p. 425-426.

Brooks, R, E, & Brooks, A, K, (2024), "An Emerging Transformative Learning Journey to Foster Sustainability Leadership in Professional Development Programs", Journal of Transformative Education, Vol. 0, No. 0.

Brundiers, K., Barth, M., Cebrián, G., Cohen, M., Diaz, L., Doucette-Remington, S., Dripps, W., Habron, G., Harré, N., Jarchow, M. and Losch, K., (2021), "Key competencies in sustainability in higher education—Toward an agreed-upon reference framework", Sustainability Science, Vol. 16, No.1, p, 13–29.

Buchanan, R, (1992), "Wicked problems in design thinking", Design issues, Vol. 8, No. 2, p. 5-21.

Calavia, M, B, Blanco, T, Casas, R, & Dieste, B, (2023), "Making design thinking for education sustainable: Training preservice teachers to address practice challenges", Thinking Skills and Creativity, Vol. 47, p. 101199.

Carroll Ph D, M. P. (2014), "Shoot for the moon! The mentors and the middle schoolers explore the intersection of design thinking and STEM", Journal of Pre-College Engineering Education Research (J-PEER), Vol. 4, No. 1, p. 3.

Clark, R,M, Stabryla, L,M, & Gilbertson, L,M, (2020), "Sustainability coursework: student perspectives and reflections on design thinking", International Journal of Sustainability in HigherEducation, Vol. 21, No. 3, p, 593-611, https://doi.org/10.1108/IJSHE-09-2019-0275.

Cranton, P, (2002), "Teaching for Transformation", New Directions for Adult and Continuing Education, Vol. 2002, No. 93, p, 63–72, https://doi.org/10.1002/ace.50

Dewey, J, (1938), "Experience and Education", Macmillan, New York, NY.

Dewey, J, & Hinchey, P, H, (1916), Democracy and education: An introduction to the philosophy of education, Macmillan, New York, NY.

Dlouhá, J, Heras, R, Mulà, I, Salgado, F, P, & Henderson, L, (2019), "Competences to address SDGs in higher education—A reflection on the equilibrium between systemic and personal approaches to achieve transformative action", Sustainability, Vol. 11, No. 13, p. 3664.

Ejsing-Duun, S, & Skovbjerg, H, M, (2019), "Design as a mode of inquiry in design pedagogy and design thinking", International Journal of Art & Design Education, Vol. 38, No. 2, p. 445-460.

Festinger, L, (1957), A theory of cognitive dissonance, Row, Peterson, Evanston, IL

Freire, P, (2018), Pedagogy of the oppressed (50th Anniversary ed,), Bloomsbury, New York, NY.

Frisk and Larson, "Educating for Sustainability: Competencies & Practices for Transformative Action", Journal of Sustainability Education Vol. 2, p. 1-20.

Grund, J, Singer-Brodowski, M, & Buessing, A, G, (2024), "Emotions and transformative learning for sustainability: a systematic review", Sustainability Science, Vol. 19, No. 1, p. 307-324.

Hoggan, C, D, (2016), "Transformative Learning as a Metatheory: Definition, Criteria, and Typology", Adult Education Quarterly, Vol. 66, No. 1, p, 57–75.

Ives, C, D, Freeth, R, & Fischer, J, (2020), "Inside-out sustainability: The neglect of inner worlds", Ambio, Vol. 49, p. 208-217.

Jaakkola, N, Karvinen, M, Hakio, K, Wolff, L, A, Mattelmäki, T, & Friman, M, (2022), "Becoming self-aware—how do self-awareness and transformative learning fit in the sustainability competency discourse?", Frontiers in Education, Vol. 7 p. 855583.

Kaiser, F, & Fuhrer, U, (2003), "Ecological Behavior's Dependency on Different Forms of

Knowledge", Applied Psychology: An International Review, Vol. 52, No. 4, p. 598-613.

Kimbell, L. (2011), "Rethinking design thinking: Part I", Design and culture, Vol. 3, No. 3, p. 285-306.

Kitchenham, A, (2008), "The evolution of John Mezirow's transformative learning theory, Journal of transformative education", Vol. 6, No. 2, p. 104-123.

Lange, E, A, (2023), Transformative sustainability education: Reimagining our future, Routledge, London.

Lange, E, A, O'Neil, J, K, P, & Ross, K, E, (2021), "Educating during the great transformation: relationality and transformative sustainability education", Andragoška spoznanja, Vol. 27, No. 1, p. 23-46.

Lehtonen, M, J, Yeow, P, & Chew, J, (2022), "Empowering change for future-making: Developing agency by framing wicked problems through design", Futures, Vol. 139, p. 102952.

Levin, K., Cashore, B., Bernstein, S., & Auld, G. (2012), "Overcoming the tragedy of super wicked problems: constraining our future selves to ameliorate global climate change", Policy sciences, Vol. 45, No. 2, p. 123-152.

Lor, R, (2017), "Design Thinking in Education: A Critical Review of Literature", In: Conference Proceedings International Academic Conference on Social Sciences and Management Asian Conference on Education and Psychology, p 37–68.

MacagNo. T, Nguyen-Quoc, A, & Jarvis, S, P, (2024), "Nurturing Sustainability Changemakers through Transformative Learning Using Design Thinking: Evidence from an Exploratory Qualitative Study, Sustainability, Vol. 16, No. 3, 1243.

Maison, L, M, (2023), "Beyond Western and indigenous perspectives on sustainability: Politicizing sustainability with the Zapatista rebellious education, Journal of Transformative Education, Vol. 21, No. 1, p. 41-58.

Manna, V, Rombach, M, Dean, D, & Rennie, H, G, (2022), "A Design Thinking Approach to Teaching Sustainability", Journal of Marketing Education, Vol. 44, No. 3, p. 362-374,

Mezirow, J, (1978), "Perspective transformation", Adult Education, Vol. 28, p. 100–110.

Mezirow, J, (2000), "Learning as transformation: Critical perspectives on a theory in progress, Jossey-Bass, San Francisco, CA.

Mezirow, Jack, (1991), "Transformative Dimensions of Adult Learning", Jossey-Bass, San Francisco, CA.

Micheli, P., Wilner, S. J., Bhatti, S. H., Mura, M., & Beverland, M. B. (2019). “Doing design thinking: Conceptual review, synthesis, and research agenda”, Journal of Product innovation management, Vol. 36, No. 2, p. 124-148.

Miller, G, E, (1988), "The meaning of general education: The emergence of a curriculum paradigm, Teachers College Press, Teachers College, Columbia University, New York, NY.

O’Brien, K, (2018), "Is the 1,5 C target possible? Exploring the three spheres of transformation, Current opinion in environmental sustainability, Vol. 31, p. 153-160.

Panke, S. (2019), “Design thinking in education: Perspectives, opportunities and challenges”, Open Education Studies, Vol. 1, No. 1, p. 281-306.

Papenfuss, J, Merritt, E, Manuel-Navarrete, D, Cloutier, S, & Eckard, B, (2019), "Interacting pedagogies: A review and framework for sustainability education, Journal of Sustainability Education, Vol. 20 (April), p. 1-19.

Pugh, K, (2017), "Profiles of Transformative Engagement: Identification, Description, and Relation to Learning and Instruction, Science Education, Vol. 101, No. 3, p, 369–398.

Pugh, K, J, (2011), "Transformative Experience: An Integrative Construct in the Spirit of Deweyan Pragmatism, Educational Psychologist, Vol. 46, No. 2, p, 107–121, https://doi.org/10.1080/00461520.2011.558817

Pugh, K, J, Linnenbrink-Garcia, L, & Koskey, K, L, K, (2010), "Motivation, learning, and transformative experience: A study of deep engagement in science, Science Education, Vol. 94, p 1–28.

Retna, K, (2016), "Thinking about “design thinking": A study of teacher experiences, Asia Pacific Journal of Education, Vol. 36, No. 1, p, 5–19.

Rodríguez Aboytes, J, G, & Barth, M, (2020), "Transformative learning in the field of sustainability: a systematic literature review (1999-2019), "International Journal of Sustainability in Higher Education, Vol. 21, No. 5, p. 993-1013.

Schneidewind, U, M, Singer-brodowski, K, Augenstein, and F, Stelzer, 2016, Pledge for a Transformative Science: A conceptual framework, Wuppertal Papers, Wuppertal: Wuppertal Institute for Climate, Environment and Energy.

Schunk, D,H, and Usher, E, L, (2019), "Social cognitive theory and motivation", R,M, Ryan (Ed,), The Oxford handbook of human motivation (2nd ed,), Oxford University Press, New York, NY, p. 11-26.

Segalàs, J, Ferrer-Balas, D, & Mulder, K, F, (2008), "Conceptual maps: Measuring learning processes of engineering students concerning sustainable development", European Journal of Engineering Education, Vol. 33, No. 3, p, 297–306.

Singer-Brodowski, M, (2023), "The potential of transformative learning for sustainability transitions: moving beyond formal learning environments", Environment, Development and Sustainability, January 1-19.

Slavich, G, & Zimbardo, P, (2012), "Transformational Teaching: Theoretical Underpinnings, Basic Principles, and Core Methods", Educational Psychology Review, Vol. 24, No. 4, p. 569–608.

Stein, S., Andreotti, V., Ahenakew, C., Suša, R., Valley, W., Huni Kui, N., Tremembé, M., Taylor, L., Siwek, D., Cardoso, C. and Duque, C.A., (2023)., "Beyond colonial futurities in climate education", Teaching in higher education, Vol. 28, No. 5, p. 987-1004.

Sterling, S, (2011), "Transformative learning and sustainability: Sketching the conceptual ground", Learning and teaching in higher education, Vol. 5, No. 11, p. 17-33.

Taimur, S., Onuki, M., & Mursaleen, H. (2022), "Exploring the transformative potential of design thinking pedagogy in hybrid setting: A case study of field exercise course, Japan", Asia Pacific Education Review, Vol. 23, No. 4, p. 571-593.

Taylor, E, W, & Cranton, P, (2012), The handbook of transformative learning: Theory, research, and practice (1st ed), Jossey-Bass, San Francisco, CA.

Trevisan, L, V, Leal Filho, W, & Pedrozo, E, Á, (2024), "Transformative organisational learning for sustainability in higher education: A literature review and an international multi-case study", Journal of Cleaner Production, Vol. 447, p. 141634.

UNECE, (2012), Learning for the Future: Competences in Education for Sustainable

Development, UNECE, https://www.unece.org/fileadmin/DAM/env/esd/ESD_Publications/Competences_Publication.pdf

UNESCO, (2017), Education for Sustainable Development Goals: Learning objectives, UNESCO.

Wiek, A., and Lang, D. J. (2016), "Transformational sustainability research methodology", Sustainability science: An introduction, Springer, Dordrecht. p. 31-41.

Wiek, A, Withycombe, L, & Redman, C, L, (2011), "Key competencies in sustainability: A reference framework for academic program development", Sustainability Science, Vol. 6, No. 2, p. 203–218.

Zajonc, A, (2013), "Contemplative pedagogy: A quiet revolution in higher education", New directions for teaching and learning, Vol. 134, p. 83-94.

APPENDIX 1. Transformative sustainability learning in the context of design

APPENDIX 2. EA and ESE syllabi and major project materials

APPENDIX 3. Case study concept maps

APPENDIX 4. Discussion of five case studies

APPENDIX 5. Results from regression analyses

APPENDIX 6. Results from Wilcoxon test comparing results from baseline and culminating concept maps across full sample

APPENDIX 1: Transformative sustainability learning in the context of design

Theory of Transformative Learning

Transformative learning is implicit to Deweyan philosophies of education, in which students are not asked to simply master a subject, but to further apply that mastery to real life scenarios, identity construction and action (Dewey and Hinchey, 1916; Dewey 1938; Miller, 1988; Pugh, 2011). In Dewey's (1938) initial conception, transformative experience occurred outside of educational systems and institutions, as an application of classroom learning characterized by motivated application, expansion of perception, and experiential value (Pugh *et al.*, 2017). Freire's classic 1970's text added the concept of conscientization, defining the instructor's central role as one driven by the need to instruct students on how to critically engage with contradictions as a pathway to enabling action outside the classroom. Mezirow (1991) focused on the ways educational environments can support students as they move through a series of stages that ultimately result in transformation. Sterling (2011), on the other hand, identified nested levels of knowing in his framework, which rooted daily actions into broader contexts and more deeply ingrained and less examined ways of knowing, moving from actions to ideas, norms, beliefs, worldviews and cosmologies. In this framework, education directed shallowly at actions or ideas is unlikely to have substantive, transformative impacts. Contemplative practice becomes a valuable component as it has the potential to reach more deeply within an individual's personal body of knowledge and ways of knowing (Lange *et al.*, 2021; Papenfuss *et al.,* 2019; Zajonc, 2013).

Sustainability lends itself to transformative learning in its emphasis on open discourse across a range of perspectives, and the need to connect and apply knowledge from these diverse perspectives and disciplines to shaping personal and community relationships with the environment (Ives *et al.,* 2020; Lange, 2023; Maison, 2023; Rodriguez Aboytes *et al.* 2019). However, despite the long history of attention to transformative outcomes and experience in higher education, assessment of transformative learning remains problematic (Hoggan, 2016; Mezirow, 1978; Pugh, 2011; Taylor and Cranton, 2012). While numerous frameworks have been constructed to aid in the development of sustainability curricula, few explicitly address transformative experience or outcomes (Brundiers, *et al.*, 2021; Rodriguez Aboytes *et al.* 2019). This is partially due to the foundational principles of transformative learning, which focus on the learning paths created by informal educational spaces and educational processes as opposed to particular learning outcomes. As a result, assessment of transformation or transformative potential in students is, at best, difficult to quantify, and potentially counter to the founding principles of transformative learning theories. Assessment requires a clear definition of transformative outcomes, while recognizing that transformation itself is best understood as a process, not an outcome. It is only through a combination of both longer-term process studies that comprehensively address both curricular and extra-curricular spaces, and more focused investigations of particular courses and classroom experiences, such as this one, that the educational community can hope to build theories of transformative education for sustainability with clear pathways for application to educational settings.

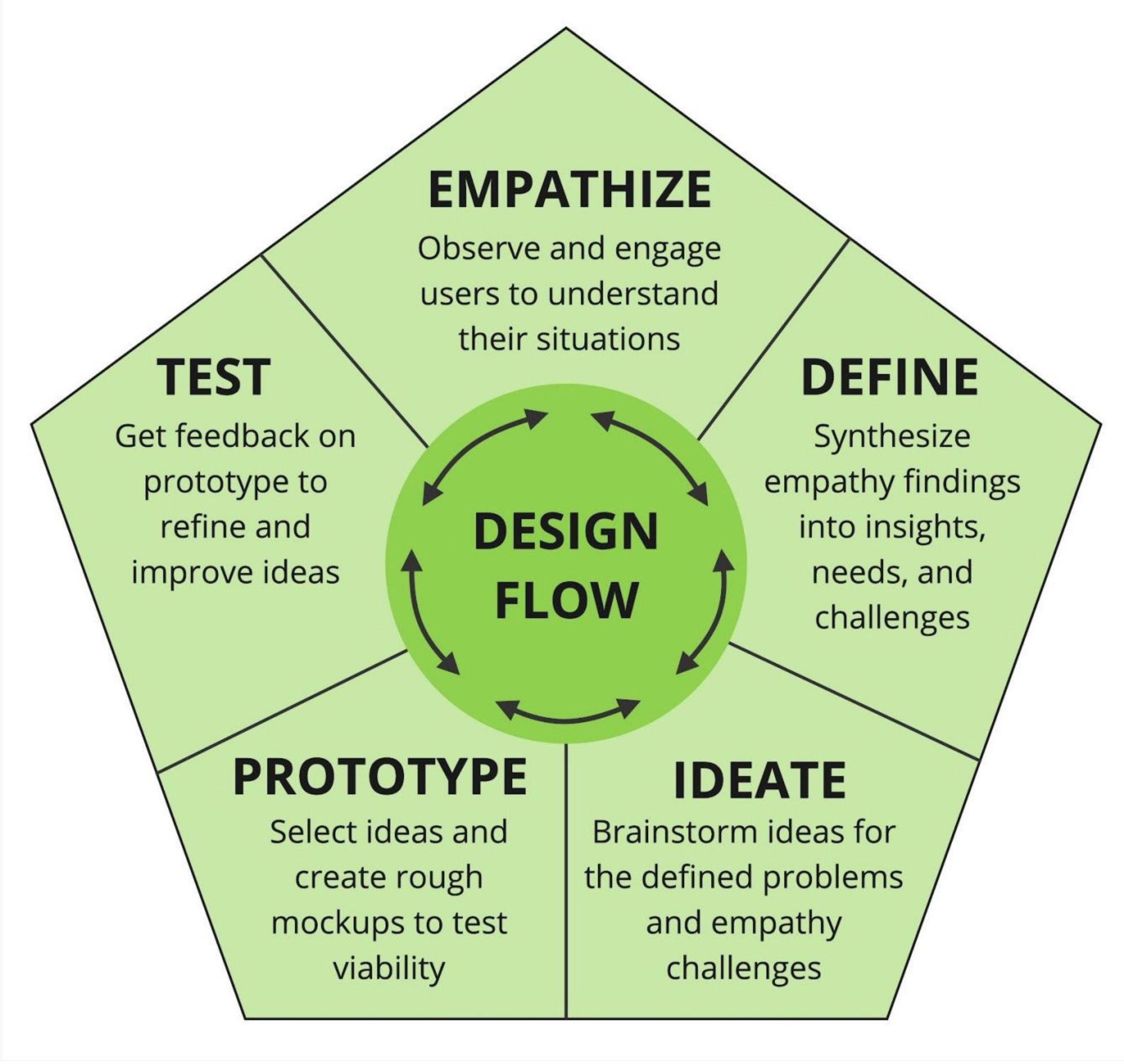
Slavich and Zimbardo (2012) strove to link the process-oriented transformative learning literature with more assessment focused pedagogies by recognizing that a range of established pedagogical techniques — including problem-based learning, experiential learning, collaborative learning— overlapped with those discussed in the transformative learning literature. They consider transformative learning to be centered on making the classroom itself a space for life changing experience. Others identify specific domains beyond simple declarative knowledge, such as procedural, effectiveness and social knowledge, as means of achieving behavioral changes (Segalàs *et al.* 2008; Kaiser and Fuhrer, 2003). This study utilizes these techniques and knowledge domains as a guide to the development of assessable transformative indicators (see next section).

Whether considering transformation within or beyond the classroom walls, as a single epiphanic moment or as a multi-stage process, theories of transformative education are skeptical of traditional, lecture-based methodologies for unidirectional transmission of declarative knowledge (Lange, 2023; Schneidewind et al., 2016). Didactic communication calling for sustainability action can disincentivize transformation by the stresses of being presented with a demand for change by an external authority (Singer-Brodowski, 2023). The most effective educational modes must incorporate a range of perspectives and ways of knowing that allow students and communities of students to collectively explore, discover, and strategize (Brundiers et al., 2021; Papenfuss et al., 2019).

Investigating Transformative Education for Sustainability at a Design Institute

The neglect of designers as a focal point for sustainable education and support of SDGs is a significant oversight, for the necessity of training sustainability minded designers--the future designers of our infographics, the products we utilize, and the spaces we inhabit--but also due to the unique perspective of designers and the institutions that have committed to train them. The goals of a design education, as summarized in design thinking pedagogies, and the way design thinking is applied across the studio-centric structure of design education institutions, may represent a better model for sustainability education than the liberal arts institutions which make up the majority of institutions of higher education and therefore the focus of research on sustainability education.

Design thinking is a powerful framework, emerging from a recognition that design practices, processes and modes of thought can be productive in non-design, managerial and educational contexts (Calavia *et al.,* 2023; Kimbell, 2011; Manna *et al.,* 2023; Micheli et al., 2019). Design Thinking methodologies regiment a particular pathway for approaching these wicked problems: empathize, define, ideate, prototype, test. It is a solutions oriented methodology, with an emphasis on identifying and addressing the needs of stakeholders, actors and communities, utilizing recursive team driven processes to arrive at novel solutions. Within education, STEM fields in particular have demonstrated the utility of design thinking as a valuable pedagogical mode (Altringer and Habbal, 2015; Badwan et al., 2018; Panke, 2019). A limited number of compelling studies have explicitly demonstrated the utility of design thinking in achievement of transformative learning outcomes (Avsec, 2021; Ejsing-Duun and Skovbjerg, 2019; Macagno et al., 2024; Taimur et al., 2022), with a particular emphasis on the ways design thinking supports empowerment and agency (Brooks and Brooks, 2024; Carroll, 2014; Lehtonen et al., 2022). Research on implementation of design thinking in non-design contexts has highlighted the need for students to become accustomed to design thinking modes through repeated exposure across a range of applications in order to learn processes, foster creative thinking, and acclimate to alternate measures of success (Altringer and Habball, 2016; Lor, 2017; Retna, 2016). By looking at a body of students pursuing a design education as a central component of their curriculum we are able to assess achievement of transformative outcomes in students whose primary mode of education incorporates design thinking, observing the ways they are able to transfer this process knowledge from the studio to their science classroom.



Interesting overlap exists between Design Thinking and Sustainability Education, with both beginning by confronting wicked problems (Buchanan, 1992; Lehtonen *et al.,* 2022; Levin *et al*., 2012; Panke, 2019; Stein, 2023; Wiek and Lang, 2016). Disorienting dilemmas and the cognitive dissonance that may arise from confronting such (Festinger, 1957), are potentially necessary developmental stages along the path to informed, empowered action (Mezirow, 1991). Movement along this pathway towards achievement of transformative sustainability outcomes for students whose major studio coursework is rooted in design thinking as opposed to depositional pedagogies, is unlikely to be accomplished without ecology classes integrating pedagogies as empowering as those found in their studio classes or coordination between science and studio classwork that allows application of ecological sustainability concepts to studio work.

Applications of design thinking modes in sustainability education contexts have demonstrated positive results on student motivation and empowerment (Clark *et al.,* 2020; Lehtonen *et al.,* 2022; Manna *et al.,* 2023). Sustainability education can benefit from adopting design thinking pathways as a mode for arriving at solutions to complex problems. Brundiers *et al*. (2021) proposed a framework for sustainability education that emphasizes iterative processes resulting in implementing actions that arise from a combination of values, strategic and systems thinking. This framework can be seen as a synthesis of transformative, sustainability and design thinking pedagogies. The theoretical overlap between each is apparent, combining to build a rich philosophical foundation for sustainability directed change supported by the practical procedures of design.

The above discussion highlights the potential value of design thinking to sustainability education, particularly in support of transformative sustainability goals, thereby positioning design education institutions, whose pedagogical foundations and curricular structures are all centered on support of design thinking, as valuable models for investigating transformative education for sustainability. Trevisan's et al. (2024) recent investigation of the ways higher educational institutions are systematically integrating sustainability into their structure and programs neglected art and design institutes, but include findings that suggest art and design institutions might be predisposed to successful integration of sustainability. "Complex, experience-driven tasks" are implicated as valuable strategies, modes that design institutions already have embedded through the studio class structure, along with their emphasis on design thinking.

The marginalization of artists and designers in sustainability education and education research reflects the broader societal biases that describe a dichotomy being either creative or analytically minded, either STEM or arts oriented. This puts significant hurdles in the path of design students' achievement of transformative sustainability outcomes. The challenges of training sustainability minded designers and no longer marginalizing designers in sustainability education research is one of breaking down this bias. Pugh et al. (2010, 2017), found that students with higher achievement of transformative outcomes also demonstrated greater content knowledge and were more likely to identify themselves as being science oriented (Pugh et al., 2010). It is unsurprising that science-oriented students would excel at both content knowledge and achievement of transformative outcomes. However, Pratt's student body — as an institution that does not offer science degrees — is less likely to have explicitly science oriented students, giving us the opportunity to move beyond focusing on the overwhelming differences that might drive variation in a sample that includes both science-oriented and non-science-oriented students to look instead at what drives transformative sustainability achievement in non-science-oriented students, and how to overcome the hurdles of the erroneous artist/scientist dichotomy.

APPENDIX 2. Syllabi and final projects for the *Ecology for Architects* and *Environmental Science and Ecology* courses.

Example Ecology for Architects (EA) syllabus:

ECOLOGY FOR ARCHITECTS

PRATT INSTITUTE
MSCI-271-01
Spring 2021

Course Description: Architects build structures that serve as environments for organisms: human beings. Architects also influence how humans use land, which has an immediate impact on natural systems and natural resources both living and non-living. It is important for Architects to understand how these living and non-living components interact with each other so that we can begin to understand the impact of any environmental changes to Earth and its complex ecosystems. This course will investigate topics in Environmental Science and Ecology that will enable students to think more broadly about what it means to design living and working spaces.

Upon completion, this course is worth three (3) credits and fulfills a requirement for the Undergraduate Architecture program

Course Goals: By taking this course, you will…

- acquire an "ecological literacy" about how the natural world works.
- develop an understanding of how scientific methods are used to construct ecological and environmental scientific knowledge.
- become familiar with some of the major ecological challenges facing Earth today, and the important research which needs to be done to address these concerns
- develop a deeper understanding of how human development impacts ecological communities and systems
- become familiar with the ecological justification for sustainable practice in building and design.

Learning Outcomes: Students who successfully complete this course will be able to…

- understand and describe the non-living components of the environment that influence ecology.
- understand and describe the major ideas of natural selection, population and community ecology, biodiversity, and wetlands. climate change, and sustainability.

- describe and debate some of the major ecological issues relating to the current and future human condition such as ecosystem services, agricultural systems, water resources, climate change, and land use.
- describe how environmental health may be impacted by toxic materials and describe what factors contribute to toxicity
- describe the ecological basis of “green” movements in design and architecture.

Reading Requirements: Students will not have to purchase any books for this course. Reading material can be found in the course outline on this syllabus. Any additional reading will be available to the class electronically through email or on the LMS. Reading material may include government reports, articles from peer-reviewed journals, mass-market science periodicals, and recent articles in the popular press.

Assessment Criteria:
In-Class LMS Activities and Discussions: 30%
Assignments and Presentations: 30%
Midterm Exam: 10%
Final Exam: 20% (cumulative)
Participation: 10%

Class Participation: Class participation is essential for learning in the class. Students should be present and be able to ask and answer questions about lecture material and course reading. Class discussion on the LMS forums both individually and in groups will be evaluated. It is important that students take thorough notes during any lectures. The instructor may ask you to submit your notes periodically throughout the semester.

Coursework: Throughout the semester coursework will be assigned by the professor. This work may include but is not limited to:

- In-Class LMS Activities and Discussions: reading and lecture comprehension questions, discussion boards
- Assignments and Presentations: topographic model, groundwater presentation, watershed presentation, various other assignments

Exams: A midterm and final exam will be taken through the LMS. The final exam will be cumulative. Both exams will focus on broad concepts and will not require mathematics or memorization of detailed scientific facts. The content of these exams will include multiple choice and short answer questions.

Academic Integrity Policy
At Pratt, students, faculty, and staff do creative and original work. This is one of our community values. For Pratt to be a space where everyone can freely create, our community must adhere to the highest standards of academic integrity.

Academic integrity at Pratt means using your own and original ideas in creating academic work. It also means that if you use the ideas or influence of others in your work, you must acknowledge them.

At Pratt,
- We do our own work,
- We are creative, and
- We give credit where it is due.

Based on our value of academic integrity, Pratt has an Academic Integrity Standing Committee (AISC) that is charged with educating faculty, staff, and students about academic integrity practices. Whenever possible, we strive to resolve alleged infractions at the most local level possible, such as between student and professor, or within a department or school. When necessary, members of this committee will form an Academic Integrity Hearing Board. Such boards may hear cases regarding cheating, plagiarism, and other infractions described below; these infractions can be grounds for citation, sanction, or dismissal.

Academic Integrity Code
When students submit any work for academic credit, they make an implicit claim that the work is wholly their own, completed without the assistance of any unauthorized person. These works include, but are not limited to exams, quizzes, presentations, papers, projects, studio work, and other assignments and assessments. In addition, no student shall prevent another student from making their work. Students may study, collaborate and work together on assignments at the discretion of the instructor.

Examples of infractions include but are not limited to:

1. Plagiarism, defined as using the exact language or a close paraphrase of someone else's ideas without citation.
2. Violations of fair use, including the unauthorized and uncited use of another's artworks, images, designs, etc.
3. The supplying or receiving of completed work including papers, projects, outlines, artworks, designs, prototypes, models, or research for submission by any person other than the author.
4. The unauthorized submission of the same or essentially the same piece of work for credit in two different classes.
5. The unauthorized supplying or receiving of information about the form or content of an examination.
6. The supplying or receiving of partial or complete answers, or suggestions for answers; or the supplying or receiving of assistance in interpretation of questions on any examination from any source not explicitly authorized. (This includes copying or reading of another student's work or consultation of notes or other sources during an examination.)

For academic support, students are encouraged to seek assistance from the Writing and Tutorial Center, Pratt Libraries, or consult with an academic advisor about other support resources. Refer to the Pratt website for information on Academic Integrity Code Adjudication Procedures.

General Pratt Attendance Policy:
Pratt Institute understands that students' engagement in their program of study is central to their success. While no attendance policy can assure that, regular class attendance is key to this engagement and signals the commitment Pratt students make to participate fully in their education.
Faculty are responsible for including a reasonable attendance policy on the syllabus for each course they teach, consistent with department-specific guidelines, if applicable, and with Institute policy regarding reasonable accommodation of students with documented disabilities. Students are responsible for knowing the attendance policy in each of their classes; for understanding whether a class absence has been excused or not; for obtaining material covered during an absence (note: instructors may request that a student obtain the material from peers); and for determining, in consultation with the instructor and ahead of time if possible, whether make-up work will be permitted.

Consistent attendance is essential for the completion of any course or program. Attending class does not earn students any specific portion of their grade, but is the pre-condition for passing the course, while missing class may seriously harm a student's grade. Grades may be lowered a letter grade for each unexcused absence, at the discretion of the instructor. Even as few as three unexcused absences in some courses (especially those that meet only once per week) may result in an automatic "F" for the course. (Note: Students shall not be penalized for class absences prior to adding a course at the beginning of a semester, though faculty may expect students to make up any missed assignments.)
Pratt Institute respects students' requirements to observe days of cultural significance, including religious holy days, and recognizes that some students might need to miss class to do so. In this, or other similar, circumstance, students are responsible for consulting with faculty ahead of time about how and when they can make up work they will miss.

Faculty are encouraged to give consideration to students who have documentation from the Office of Health and Counseling. Reasonable accommodations for students with disabilities will continue to be provided, as appropriate.
Refer to the Pratt website for information on Attendance.

Students with Disabilities and Accessibility
Pratt Institute is committed to the full inclusion of all students. If you are a student with a disability and require accommodations, please contact the Learning/Access Center (L/AC) at LAC@pratt.edu to schedule an appointment to discuss these accommodations. Students with disabilities who have already registered with the L/AC are encouraged to speak to the professor about accommodations they may need to produce an accessible learning environment.

Requests for accommodation should be made as far in advance as reasonably possible to allow sufficient time to make any necessary modifications to ensure the relevant classes, programs, or activities are readily accessible. The Learning/Access Center (L/AC) is available to Pratt students, confidentially, with additional resources and information to facilitate full access to all campus programs and activities and provide support related to any other disability-related matters.

Human Rights, Equity, BERT, and Title IX
Pratt Institute seeks to provide an environment that is free of bias, discrimination, and harassment. If you have been the victim of harassment, discrimination, bias, or sexual misconduct, we encourage you to report this.

If you inform me of an issue of harassment, discrimination or bias, or sexual misconduct, I will keep the information as private as I can, but I am required to bring it to the attention of the institution's Title IX Coordinator. You can access Title IX services by emailing titleix@pratt.edu. You can also speak to someone confidentially by contacting our non-mandatory reporters: Health Services at 718-399-4542, Counseling Services 718-687-5356 or Campus Ministries 718-596-4840.

In cases of Bias, this information may go to our Bias Education & Response Taskforce (BERT). You can contact BERT by either reaching out directly via bert@pratt.edu or by contacting the BERT Co-Chair and Title IX Coordinator, Dr. Esmilda Abreu.
For more information, please refer to the Community Standards webpage.

Date and Topic	Key questions	Readings	Coursework
1/25 1. Introduction to Ecology and Environmental Science	What is Ecology? What is Environmental Science and How is it related to Ecology? How is curiosity related to the scientific method? What are biotic and abiotic factors in an ecosystem? How are Humans impacting Ecology?	"What is Ecology?" *Ecological Society of America* "Environmental Science" *Wikipedia: The Free Encyclopedia* *Los Angeles Times* "Threat of Mudslides Returns to California…"	In-Class Activities and Discussions
2/1 2. Climate Change	What is the difference between heat and light? What is the greenhouse effect? What is the Carbon Cycle? How do we know past CO_2 concentrations? What are positive and negative feedbacks? What is the role of photosynthesis in climate? What is the role of oceans? What is a carbon footprint? How can architects mitigate for climate change?	*The Guardian* "Global CO_2 Levels Hit Record High" *Science* "Record-shattering 2.7-million-year-old ice core reveals start of the ice ages" *New York Times* "Alaska's Permafrost is Thawing" *Bloomberg* "What Was Once Hailed as First U.S. Offshore Wind Farm Is No More"	In-Class Activities and Discussions
2/8 3. Physical Earth and Atmosphere	How is the structure of the Earth related to Ecology? How is plate tectonics related to topography? How is solar radiation different from infrared radiation? What is the adiabatic lapse rate? How is evaporation and condensation related to heat? How is humidity related to the dew point? What is convection? What is orographic precipitation? What is the urban heat island effect? How can architects mitigate for the urban heat island?	*Scientific American* "What Causes Humidity" *PBS News Hour* "Eight Things You Didn't Know About Humidity" *Forbes* "Global Warming is Causing More Intense Hurricanes" *The Washington Post* "Lake Effect Snow is Pummeling Western New York; Here's How it Works"	In-Class Activities and Discussions
2/15 4. Groundwater	What is the hydrologic cycle? How does the land surface affect infiltration? What is the water table? How does it impact ecology? How does pumping wells affect the water table? How does groundwater move? Does it carry pollution? How can architects mitigate for water table drawdown? How can wetlands assist infiltration and bioremediation?	*Environmental Health Perspectives* "Paving Paradise: The Peril of Impervious Surfaces *Quartz* "Houston's flooding shows what Happens when you ignore science and let developers run rampant" *National Geographic* "Why Cape Town is Running out of Water and Who's Next"	***<u>TOPOGRAPHIC MODEL DUE</u>*** In-Class Activities and Discussions

Date and Topic	Key questions	Readings	Coursework
2/22 5. Surface Water	How does the land surface affect runoff? How do streams and rivers shape the land? What erosion mechanisms allow river channels to migrate? How are humans impacting stream and river flooding? What is combined sewer overflow? How can land use, design and Architecture mitigate for flooding? How are deltas and tidal marshes created? How do tidal marshes and wetlands mitigate for coastal flooding? How can green roofs mitigate for surface water flooding? How can humans mitigate for surface water pollution?	*NASA Earth Observatory* "Lay of the Land Between Old River and the Mississippi" *Scientific American* "Taming the Mighty Mississippi May Have Caused Bigger Floods" *Forbes* "Global Warming is Causing More Intense Hurricanes" *Scientific American* "Mississippi River Mouth Must Be Abandoned to Save New Orleans from Next Hurricane Katrina"	In-Class Activities and Discussions
3/1 6. Biomes	What is biogeography? What are aquatic and terrestrial ecosystems? What is photosynthesis? How does the availability of water and light relate to biogeography? How does photosynthesis provide energy to ecosystems? What is the role of microorganisms in ecosystems? How can the built environment adapt to biogeography?	*Kimball's Online Biology Text* "Biomes" *NASA Earth Observatory* "Biomes" National Geographic "Our Good Earth" *National Geographic* "Our Good Earth"	***<u>GROUNDWATER PRESENTATIONS</u>*** In-Class Activities and Discussions
3/8 7. Midterm, Adaptations	What is natural selection? How is ecosystem resilience related to natural selection? Are mutations random? Is natural selection random?	*Ask Nature* "Water Vapor Harvesting"	***<u>MIDTERM</u>***
3/22 8. Adaptations	What is natural selection? How is ecosystem resilience related to natural selection? Are mutations random? Is natural selection random? What are rare species and how are they related to extinction? What are invasive species and how are they related to extinction? What is forest succession? How are humans affecting ecological succession and adaptations? How are humans contributing to enhanced forest fires? What is urban ecology? What role does Architecture play?	*Death of a Million Trees* "Darwin's Finches: an opportunity to observe evolution in action" *BBC News* "Famous Peppered Moth's Dark Secret Revealed" *Understanding Evolution* "Nature or Nurture: Evolution and Phenotypic Plasticity" *National Geographic* "How Sequoias Survive Wildfires in Yosemite and Beyond" *The Guardian* "California Fires: What is Happening and is Climate Change to Blame"	***<u>WATERSHED PRESENTATIONS</u>*** In-Class Activities and Discussions

Date and Topic	Key questions	Readings	Coursework
3/29 9. Ecosystems	How does energy move through ecosystems? What are food chains and food webs? What is the difference between producers and consumers? What is the difference between "bottom up" vs "top down" ecology? What is a trophic cascade? What human impacts have we seen regarding trophic cascades? What is habitat fragmentation? How can a built environment be sensitive to habitat? How is the theory of "prospect and refuge" related to aesthetics? Can we relate the biology of beauty to architectural design?	*New York Times* "Hunting Habits of Wolves Change Ecological Balance in Yellowstone" *Medium* "Prospect and Refuge Theory" *Science Daily* "Without Blue Crabs Southern Salt Marshes Wash Away" *Providence Journal* "Tiny Crab is Destroying Narragansett Bay Marshes"	In-Class Activities and Discussions
4/5 10. Biodiversity	What is biodiversity and why do we care? How is population related to biodiversity? How is population growth related to ecosystem resilience? What comprises an ecological community? What is the "area – species relationship" What is a biodiversity hot spot? What is the current state of our Earths biodiversity? How can the built environment be more sensitive to biodiversity? Why are wetlands so important for biodiversity? What is a vernal pool? What regulations are there on wetlands? How can we mitigate for wetland loss through design?	*New York Time "The Rules of Extinction"* *Wiley On Line Library* "Species – Area Relationship" *Phys Org* "Invasive and Native Marsh Grasses May Provide Similar Benefits to Protected Wetlands" *The Guardian* "What is Biodiversity and Why Does it Matter to Us?" *Scientific American* "Why Are Wetlands So Important to Preserve"	In-Class Activities and Discussions
4/12 11. Human Habitat and Land Use	What does the history and future of human population growth look like? What does human population growth mean for ecology? What is suburban sprawl and what are its impacts on Ecosystems? What are the advantages of high density land use? What are the ecological impacts of industrialization? What are the impacts of modern agriculture on ecosystems? What are some design solutions for this ecological problem?	*New York Time "*A Bold Divisive Plan to Wean California off Cars*"* *New York Time "*The Rules of Extinction*"* *NPR "*Hydroponic Veggies Are Taking Over Organic, And A Move to Ban Them Fails"	In-Class Activities and Discussions
4/19 12. Health and	What human health impacts are there in Urban environments vs natural? What is forest bathing and its benefits to Human Health How can we integrate more "nature" into our urban environments?	*Science "*View Through a Window May Influence Recovery from Surgery" *NPR "*Forest Bathing: A Retreat To Nature Can Boost Immunity And Mood*"*	In-Class Activities and Discussions

Date and Topic	Key questions	Readings	Coursework
Sustainability	What are the impacts of pollution in our built environments? What are the impacts of light and noise pollution? What building regulations address these issues? What broader design solutions are there?	*Neuroscience News* "Living Near a Forest Keeps Your Amygdala Healthier" *The City Fix* "Urban Trees: A Smart Investment in Public Health"	
5/3 13. Final Exam			***FINAL EXAM***

Note: This syllabus is meant to be a guide to the topics that will be covered in this course. Coverage of individual topics and exam dates may be adjusted during the semester. Any changes will be announced in class.

Example EA project guidelines:

Part 1: Topography Model Assignment

DUE: Tuesday, February 9th, 2021 at 2 pm

Assignment: Create a topographic model based on the map provided

Construction:

- Cardboard or similar material
- Start by printing the map and laying it over the cardboard layers
- If constructing by hand, one piece of cardboard can be used for 2-3 contour lines
- Minimum size: 11x17"
- Denote the CT-NY state line, ponds, and streams on the model

You should be able to identify the following on your model. However, they do not need to be denoted on the model itself.

- What is the highest point on the map?
- What is the lowest point on the map?
- Where is the steepest slope on the map?
- What is the elevation of each lake?
- What is the elevation of the wetland?
- Which direction is each stream flowing?

Submission: Submit at least 5 pictures, including one top view, via the "Topographic Model" submission link on the LMS

Part 2: Groundwater

You are a group of environmental planners examining the impacts of pumping groundwater for various land uses.

You will create two profiles of the landform for both lines "A" and "B." You will be given three numbers that represent the elevation of the natural table, as well as elevation of the water table due to two land use practices. In the profiles you will include the topography, the natural water table, and the elevation of the water table due to the two land use practices.

You will delineate the estimated "area of influence" on the map based on the cone of depression. You will then assess and determine which surface water features will be impacted.

You will create a Google Slides presentation (using the file provided) as a group. Your presentation should be less than 10 minutes. Please include the following components in your presentation:

- What is a water table? How is it altered?
- What is the impact of water pumping?
- Profiles ”A” and “B” delineated on one of the models
- Profiles ”A” and “B” (including topography, natural water table, practice 1, and practice 2)
- Area of influence for practice 1 and practice 2 shown on the map
- Make a recommendation for whether practice 1 and practice 2 should be approved. Consider environmental and ecological impacts as well as the services the land use may provide to the human population or the ecosystem.

Part 3: Watersheds

You are a group of environmental planners that will testify as expert witnesses in a lawsuit between the State of Connecticut and the New York City Water Company.

You will make a recommendation for whether your assigned proposed land use could be permitted and if so in what capacity, location, and with what design recommendations.

On the attached map you will see the parcel of land (red shape) that will be used for your proposed land use in the State of Connecticut. The lake with the "red X", that is dammed, is a drinking supply lake owned by the New York City Water Company.

In your presentation you must show the delineation of the watershed for this lake both on the map and on one of your group members topographic models. (Using pins may be a good way to delineate on the model).

Keep your presentations under 10 minutes, but feel free to focus on a specific "piece of evidence" that supports your recommendations.

Example Environmental Science and Ecology (ESE) syllabus:

MSWI-270C-01, Ecology, Environment, & the Anthropocene
Fall 2020
Department of Mathematics and Science, School of Liberal Arts and Sciences, Pratt Institute

Course Description:

Like any other organism, humans rely on their environment — most prominently the living part of that environment — in order to survive. But unlike any other species, humans have the ability to re-shape the diverse environments they inhabit in profound, fundamental, and potentially destructive ways. This course explores how living ecosystems function and how that functioning provides the resources required by both individual humans and the societies we form. It also considers how we have transformed our environment in ways that can threaten both our own health and the health of the ecosystems upon which human civilization depends. Many scientists suggest that we have entered a new geologic epoch, the Anthropocene; this course explores ways in which the "age of humanity" can become a sustainable — rather than apocalyptic — episode in evolutionary history.

Upon completion, this course is worth three (3) credits. This course counts as both a *Math & Science Core Course* and a *General Education Writing-Intensive Course*.

Course Goals:

- To understand how ecological systems function and how those functions provides services to humans.
- To explore how a variety of ecological interactions create ecological communities and allow nutrients, water, and energy to flow through ecosystems.
- To identify and understand the major ecological and environmental problems created by human activities.
- To frame the major human activities that threaten the sustainability of human civilization by creating excessive ecological and/or environmental impacts.
- To assess which technologies and policies have the most promising potential to reduce human impacts to sustainable levels.
- To refine students' ability to write about scientific ideas and scientific research through a process of drafting, feedback, and revision.

Learning Outcomes: Students who successfully complete *Ecology* will be able to...

- depict how different interactions in ecological communities produce the variety of ecosystems and emergent ecological flows observed on Earth.
- explain how ecologists and evolutionary biologists conduct studies to improve our understanding of how the natural world functions.
- connect the functioning of ecological systems with resources and services that human civilizations depend upon.
- catalog and assess the relative severity of different ecological and environmental problems.

- use critical, logical, and creative thinking to devise and assess solutions to major problems of human sustainability.
- perform research into the scientific literature that informs the written proposal and summary that accompany a creative Term Project.
- incorporate relevant scientific research into a creative Term Project.

Assessment Criteria:

Below is a summary of how you will be graded in this course. All grades will be posted on the *LMS*, so please take advantage of the fact that you can always know how you are doing in the course.

Contribution to Grade	Category	Description
40%	*Coursework*	There are four (4) main categories of coursework for which you will receive grades: 1. Each week there are one or more short-essay-based **Reading Questions** due two (2) hours before class starts. Based on the assigned readings for each day, these questions will provide you with the opportunity to demonstrate that you understood the material and to informally practice your writing about science. **Reading Questions** are worth ~7.6 of the 40 *Coursework* points. 2. In class, we'll be discussing ideas covered by course readings. I'll have questions for you; I will expect you to have questions for me. Come to class having read and thought about assigned readings, ready to actively engage in dialogue. To receive **Participation** credit you need to be present in class; to receive full participation credit you need to be actively engaged in class discussions and work. Based on your participation during each regular class session, I will assign you a specific grade and occasionally make comments on the strengths and weaknesses of your contribution. **Participation** is worth ~7.6 of the 40 *Coursework* points. 3. You will also complete **Activities** in class. Some of these assignments will be done individually, others will require group cooperation. I will be grading your work on each assignment based on its clarity of thought, level of insight, and contribution to class dialogue. **Activities** are worth ~19.5 of the 40 *Coursework* points. 4. During Week 08 each student will bring a Draft Proposal to **Term Project Proposal Workshop**, and provide feedback to other students on their *Draft Proposals*. These two assignments are worth ~3.2 of the 40 *Coursework* points. The remainder of your *Coursework* grade (~2.2 of 40 points) will be based on miscellaneous assignments, all of which are listed on the *Learning Management System*. You are free to use any

		resource _other than another person_ to complete all coursework: your notes, books/articles, the internet, and other media are all allowed (see ***Open Information Policy and Honor Code*** below).
40%	*Term Project*	The major independent assignment of this course is the production of a creative work that is informed by research into a topic or topics that are directly related to course content. This *Term Project* will be developed throughout the semester via an incremental process of planning, drafting, and refinement. This process emphasizes thoughtful conceptualization as a means of preparing to write and make. See the *Term Project Guidelines* for details.
20%	*Final Exam*	This course ends with a cumulative **Final Exam** that will be taken in class on the *LMS*. Please make sure to bring your Pratt I.D. to class on the day of your **Final Exam**, as we will be taking this exam in a Pratt computer lab. The final will focus on broad concepts learned in the course rather than the regurgitation of scientific facts. As per the *Open Information Policy*, you may use anything but another person to complete the **Final Exam**.

Under no circumstances will personalized extra-credit work be offered to any student

Course workload:

As a 3-credit lecture/seminar course in Liberal Arts and Sciences, the expectation is that you will devote at least 6 hours per week to the course in addition to the 3 hours per week spent in class. This out-of-class time will be dedicated to: course reading assignments (approximately 2 hours for careful reading — the reading material in this course will introduce many new concepts and much new terminology); homework (approximately 0.5 hours); post-class review of lecture slides and feedback on classwork and homework (0.5 hours per week recommended); and work on the components of the “scaffolded” *Term Project* assignment (3 hours per week recommended). By following this “recommended” schedule of 6 hours per week outside of class, it will be entirely possible to avoid a pile-up of work around major deadlines.

Lateness and Absence:

Of Students: I expect you to arrive to class on time. Lateness and absence adversely affect your classwork grade because work missed due to unexcused absence is counted as a zero. There is not a certain number of absences that lowers your grade or causes you fail, but the more classes you miss unexcused, the more points you lose.

Of Assignments: Late **Reading Questions** will not be accepted. Other late assignments will be penalized by 10% per day.

Allowance days:

Each student in this course will be afforded ten (10) total “allowance days” that can be used to avoid the usual 10% per day lateness penalty for assignments. These allowance days should be used for missed deadlines that would not otherwise be excused (see below for which causes of lateness are excusable). Please email your instructor to indicate that you wish to use some of these allowance days for a particular assignment. You are free to wait until the end of the semester to indicate where you wish to use these days, but make sure not to allow the semester to come to an end before emailing your instructor. Remember that using allowance days on one component of the *Term Project* does not push back any of the subsequent deadlines for later components.

How to submit documentation for an excusable absence and/or missed deadlines:

There are very few legitimate reasons to miss all or part of a class session or for submitting assignments after the stated deadlines. Valid excuses include family emergencies and personal health issues. The following reasons do not excuse lateness or absence: oversleeping, excessive work load in other classes, inability to use the *Learning Management System*, or “forgetting”. If you believe that you missed a class for a legitimate reason, please submit documentation that:

1. establishes a clear reason why you could not complete work and/or attend class; and
2. clearly delineates the period of time during which you were incapacitated.

Documentation should come from an appropriate source (*for example:* health care provider, employer, clergy) and include contact information that will allow your instructor to validate your excuse. Your instructor makes the final determination on what is and what is not a legitimate reason for missing class and/or submitting assignments after stated deadlines.

Absence from this class to complete other responsibilities on campus:

The time allotted for each your courses is sacred: no instructor or administrator should ever require you to miss any of your regularly-scheduled class meetings. For this reason, you will not be excused for absences that result from being “pulled out” by another professor or by your major program. If you are asked to miss this class for any reason please contact your instructor immediately so that the matter can be quickly resolved.

This course concludes with a final exam, which takes place during the final week of classes at the regular class meeting time. It is possible that your major program may require you to attend a final critique/review that conflicts with the final exam for this course; any such conflicts must be identified well in advance of this final week. True finals-week conflicts will be resolved by scheduling your final exam in this course on the *Exam Conflict Day*, which takes place on the day before the beginning of finals week. Please let your instructor know as soon as you learn of an actual or potential conflict with the scheduled final exam in this course.

General Pratt Attendance Policy:

Pratt Institute understands that students’ engagement in their program of study is central to their success. While no attendance policy can assure that, regular class attendance is key to this engagement and signals the commitment Pratt students make to participate fully in their education.

Faculty are responsible for including a reasonable attendance policy on the syllabus for each course they teach, consistent with department-specific guidelines, if applicable, and with Institute policy regarding reasonable accommodation of students with documented disabilities. Students are responsible for knowing the attendance policy in each of their classes; for understanding whether a class absence has been excused or not; for obtaining material covered during an absence (note: instructors may request that a student obtain the material from peers); and for determining, in consultation with the instructor and ahead of time if possible, whether make-up work will be permitted.

Consistent attendance is essential for the completion of any course or program. Attending class does not earn students any specific portion of their grade, but is the pre-condition for passing the course, while missing class may seriously harm a student’s grade. Grades may be lowered a letter grade for each unexcused absence, at the discretion of the instructor. Even as few as three unexcused absences in some courses (especially those that meet only once per week) may result in an automatic “F” for the course. (Note: Students shall not be penalized for class absences prior to adding a course at the beginning of a semester, though faculty may expect students to make up any missed assignments.)

Pratt Institute respects students’ requirements to observe days of cultural significance, including religious holy days, and recognizes that some students might need to miss class to do so. In this, or other similar, circumstance, students are responsible for consulting with faculty ahead of time about how and when they can make up work they will miss.

Faculty are encouraged to give consideration to students who have documentation from the Office of Health and Counseling. Reasonable accommodations for students with disabilities will continue to be provided, as appropriate.

Refer to the Pratt website for information on Attendance.

Policy on Incompletes:

Incompletes (INCs) can be given at the discretion of the instructor following the written request of the student. The student must furnish satisfactory proof that the work in question was not completed because of illness or other circumstances beyond the student’s control. The student must understand the terms necessary to fulfill the requirements for the course and the date by which work must be submitted. If the work is not submitted by the understood date of submission – not exceeding the end of the following term

– the incomplete will be converted to a failure. The agreement between the instructor and student must be documented and submitted to the department chair along with documentation proving that the student deserves the opportunity to make up missed work.

Extra-Credit Assignments that can improve your Coursework *grade:*

After each class you can answer a series of **Follow-Up Questions** on the LMS. If you emerge from class with a good understanding of the major ideas discussed, you should be able to complete these questions in very little time. The **Follow-Up Questions** are extra credit and represent a way to offset low in-class grades (or zeros caused by absence).

All students have the opportunity to complete an extra-credit assignment based on a trip to the *American Museum of Natural History* in Manhattan. The trip is self-guided, and you can complete this assignment any time before the due date listed on the *LMS.* To receive credit for this assignment, you must also submit your original museum ticket to your instructor. Please see the LMS for the *Guidelines* to this assignment and a place where you can upload your assignment.

In total, Extra-Credit assignments can be used to supplement up to 14 of the 40 points awarded for *Coursework* in the calculation of your final grade. Extra-Credit cannot be used to improve credit earned for the *Term Project* or the *Final Exam*, and the maximum credit that can be earned for *Coursework* is 40 points.

Readings:

You will be assigned a series of reading materials from popular science periodicals, books, and the scientific literature (see ***Weekly Units*** below). All required readings will be posted on the *LMS*. You are encouraged to save paper by viewing these readings electronically (as opposed to printing them out).

If you feel the need for a comprehensive *Ecology* textbook, these two will be on reserve in the library:

> Smith, Thomas M. and Robert Leo Smith, 2006. *Elements of Ecology, 6th Edition*. Pearson/Benjamin Cummings. (ISBN #9780805348309)
>
> Levin, Simon A. (editor), 2009. *The Princeton Guide to Ecology*. Princeton University Press. (ISBN #9780691156040)

There will be no required reading from these books; consulting them is purely at your discretion.

Open Information Policy and Honor Code:

You will never be required to memorize anything in this class: we maintain an “open information environment”, so you may use your notes, books/articles, the internet, and other media to complete homework, in-class assignments, and quizzes.

HOWEVER: Unless <u>specifically stated otherwise</u>, all work in this class is to be completed <u>on your own</u>. You <u>may not</u> and <u>should not</u> obtain help from <u>any</u> other person to complete any of your work: this includes all homework, all quizzes, and individual assignments. You should also <u>not share</u> any of your individual work with other students. “Studying together”, discussing material outside of class, and any other processing of the course materials <u>prior</u> to completing coursework is allowed and encouraged, but you need to do your own work. Students are asked to sign an oath to uphold and honor this code at the beginning of the semester, and are expected to take this commitment seriously even when violating the code would likely escape detection. Any violations of this policy will be considered cheating and reported as appropriate (see ***Classroom Civility and Academic Honesty*** below).

Learning Management System (LMS):

During the course of the semester, we will make extensive use of Pratt’s *Learning Management System* (*LMS*). I recommend that you use the *Firefox* browser to access the *LMS* via this page: https://lms.pratt.edu/ (I discourage you from using the *my.pratt.edu* entrance point, as it is not always working). Use your ONEKEY username and password to log in. I expect you to check the *LMS* several times a week for announcements, reading assignments, and updates to your class grade (note that you can also set the LMS to send you email messages every time our class page is updated). I will be using the *LMS* to send email announcements throughout the semester, so please make sure that you check the email address listed under your *LMS* profile regularly. “I forgot to check my Pratt email” is an invalid excuse.

I try to make the assignments, announcements, and other documents I post on the *LMS* as universally-readable as possible. The only proprietary program you will need to have loaded onto your computer is *Acrobat Reader*, which can be downloaded here: http://www.adobe.com/products/acrobat/readstep2.html. I strongly recommend that you use *Acrobat Reader*, rather than another program, to read all of the PDF’s provided in this class.

***Important*:** If you experience any problems with the *LMS*, you should:

1. Report the problem to the ***Service Desk*** and receive a “ticket number” by one of four means:
    a. visiting their office in the basement of the ARC Building; or
    b. calling (718) 636-3765; or
    c. emailing services@pratt.edu; or
    d. using the “Computers & Technology Services” section of the “Get Help With*”* tab of my.pratt.edu.
2. Receive an email from the ***Service Desk*** assigning your problem a “ticket number”.
3. Forward this email from the ***Service Desk*** to me.

In order for me to verify claims of *LMS* outages, you must contact the ***Service Desk*** *when the LMS problem occurs*, not hours or days later.

Academic Integrity Code:

When students submit any work for academic credit, they make an implicit claim that the work is wholly their own, completed without the assistance of any unauthorized person. These works include, but are not limited to exams, quizzes, presentations, papers, projects, studio work, and other assignments and assessments. In addition, no student shall prevent another student from making their work. Students may study, collaborate and work together on assignments at the discretion of the instructor.

Examples of infractions include but are not limited to:

1. Plagiarism, defined as using the exact language or a close paraphrase of someone else’s ideas without citation.
2. Violations of fair use, including the unauthorized and uncited use of another’s artworks, images, designs, etc.
3. The supplying or receiving of completed work including papers, projects, outlines, artworks, designs, prototypes, models, or research for submission by any person other than the author.
4. The unauthorized submission of the same or essentially the same piece of work for credit in two different classes.
5. The unauthorized supplying or receiving of information about the form or content of an examination.
6. The supplying or receiving of partial or complete answers, or suggestions for answers; or the supplying or receiving of assistance in interpretation of questions on any examination from any source not explicitly authorized. (This includes copying or reading of another student’s work or consultation of notes or other sources during an examination.)

For academic support, students are encouraged to seek assistance from the Writing and Tutorial Center, Pratt Libraries, or consult with an academic advisor about other support resources. Refer to the Pratt website for information on Academic Integrity Code Adjudication Procedures.

For more information on avoiding plagiarism, please see: http://www.christopherxjjensen.com/teaching/for-students/#no-plagiarism.

Help with Writing:

The *Term Project* in this class will require you to produce written work. All students can benefit from receiving feedback on their writing from both the Pratt's *Writing and Tutorial Center* (*WTC*) and your instructor. It is expected that you respond to feedback that you receive by revising and thereby improving your written work. Writing is a practice and a process!

The *WTC* will help you produce the best project possible. The center is located on the 1st Floor of North Hall (it has all the great fish tanks… you can't miss it!). Call them at 718-636-3459 or send an email to wtc@pratt.edu to make an appointment.

Your instructor will provide you with feedback on draft versions of both your *Project Table* and *Project Summary*. This feedback will be posted to the *LMS* so that you will have time to revise your work before submitting final versions.

Rights of Students with Disabilities:

Pratt Institute is committed to the full inclusion of all students. If you are a student with a disability and require accommodations, please contact the Learning/Access Center (L/AC) at LAC@pratt.edu to schedule an appointment to discuss these accommodations. Students with disabilities who have already registered with the L/AC are encouraged to speak to the professor about accommodations they may need to produce an accessible learning environment.

Accessibility:

The Pratt campus and many of its buildings are historic in nature and thus not all spaces on campus are readily accessible and the accessibility of certain buildings and spaces on campus may not be immediately apparent to campus visitors. However all programs, services and activities will be accessible and Pratt will accommodate any individuals with a disability who wish to avail themselves of any of its programs or activities.

To facilitate ease of access to all programs and activities, you have the option to indicate if you require an accessible space, have any mobility restrictions (e.g. inability/difficulty navigating stairs), or have any similar considerations or concerns, when registering in advance or scheduling an appointment for any program or activity on campus. Appropriate measures will then be taken to ensure that the relevant programs or activities are readily accessible with the least amount of delay or inconvenience to you.

Students should contact the Director of the Learning/Access Center, Elisabeth Sullivan esulliv5@pratt.edu (718.636.3711) in advance, according to the procedures for requesting accommodations established by the Learning/Access Center. Requests for accommodation should be made as far in advance as reasonably possible to allow sufficient time to make any necessary modifications to ensure the relevant classes, programs, or activities are readily accessible. The Learning/Access Center is available to Pratt students, confidentially, with additional resources and information to facilitate full access to all campus programs and activities and provide support related to any other disability-related matters, and is located in the ISC Building, Room 104.

Security personnel, located at a booth inside the main gate at 200 Willoughby Avenue, are also available to assist visitors with directions, locating accessible routes, or providing any other assistance in navigating the campus grounds.

Example ESE final project guidelines:

Each student will complete a creative project in which they delve into the primary literature on human evolution. Students will produce a creative work or proposal for a creative work that is informed by research into a topic or topics that are directly related to course content. The overall goal of the Term Project is to produce a creative work that incorporates important ideas and information related to the course goals. There are many subjects that can successfully serve as the focus of the project, and there are many ways of incorporating science into creative work. Remember that while the work must express scientific concepts, it need not do so on its own: the final research paper can serve to explain subtle or abstract ideas that are present in the creative work. This Term Project will be developed throughout the semester via an incremental process of planning, drafting, and refinement. This process emphasizes thoughtful conceptualization as a means of preparing to write and make.

Project stages/objectives/assignments:

Research scientific work that is related to one or more of the Course Goals that form the basis of this course.

Complete an outline of your research paper, including a proposal for using a creative medium to incorporate important ideas uncovered in your research.

Design and complete a creative work, or formal proposal for a creative work, that incorporates important ideas uncovered in your research.

Present your research and creative work to your peers in an oral presentation.

Write a research paper that also serves as an artist's statement accompanying your final project.

Present a polished creative work or proposal for creative work to the class.

Project evaluation criteria:

Ability to engage with primary scientific literature

Ability to craft a comprehensive thesis

Ability to identify main points and structure an argument in support of your thesis

Ability to write academically about creative works

Ability to synthesize ideas in a logical framework with a coherent introduction and conclusion

<u>Part 1: Initial concept (5%)</u>

The first step in completing your project is to identify a topic and some sources you can use to inform your term project. Using search resources in the library and on the web, identify and obtain at least five sources that provide relevant information about your chosen subject. Use the annotated bibliography and citing sources library research guides for help.

Components:

- Write a few sentences describing your concept.
- Create a concept map with at least 10 nodes exploring the themes/topics/questions arising from your concept. Think about ways to indicate where you might take artistic inspiration for your creative project.
- Present the work of one or multiple artists that are good models for the creative work you hope to create. In paragraph form, explain the relationship between their work and your proposed project.
- You'll need a total of at least 5 scientific citations, though you'll need 7 for the final project so if you've got more, include them. You can use a mix of primary, secondary and tertiary sources, but at least half of your sources should be primary sources and ALL must pass the C.R.A.P. test (see our scavenger hunt in class activity for details). Blogs or Wikipedia do not pass the C.R.A.P. test.
- Refer to the annotated bibliography and citation research guides on the library website (details in our second in class activity). Make sure and format all sources in APA style and also include links. Write a few sentences describing the source and how it relates to the themes/topics/questions that comprise your concept.

<u>Part 2A: Annotated bibliography (10%)</u>

Complete the provided annotated bibliography template and upload a doc or pdf (not a link) to this submission space.

The purpose of submitting this annotated bibliography is to distill the research you have performed into specific, clear subject matter that will be incorporated into the project. This will allow you to make sure you have a solid thesis that is supported by the sources you are referencing. You will receive feedback on your thesis and whether you are using appropriate sources. Your bibliography will also include revisions to your concept as presented in your initial concept submission. Make sure and follow the posted template exactly.

Evaluation Criteria:

Ability to engage with primary scientific literature: 2 primary sources required

Ability to craft a comprehensive thesis

Ability to identify main points and structure an argument in support of your thesis: You will need a total of 7 sources drawn from the scientific literature

Ability to write academically about creative works

Ability to synthesize ideas in a logical framework

Part 2B: Mid-semester presentation (10%)

At mid-semester you will be making a brief (5-10 minute) presentation of your research, project proposal and sketch. This presentation allows you to practice the skill of selling an idea and will also allow you to get additional feedback on your project idea before you commit to executing it. Unlike other components of the Term Project, there is a hard-and-fast deadline for this presentation as the presentation and the feedback you provide to others represents the coursework for this class session.

Follow the detailed instructions in this template. Submit a shareable link to this assignment space, but be prepared with your presentation loaded on your home computer to present via screen share in class.

Part 2C: Artist's sketch (5%)

Chances are that you will spend a fair amount of time executing the creative work that will make up your Term Project. To make sure that this time is well spent, you will submit a "sketch" of the work you plan to execute as part of your mid-semester presentation. What constitutes a "sketch" will vary based on the kind of work you plan to do, but all sketches should include:

a description of what medium or media you plan to use to create your work

a clear and specific plan for what you are going to be creating and

an explanation of how the work will incorporate the scientific content identified in your research

a visual treatment to help the class comment on and provide feedback on your concept

Part 3A: Final artist's statement/research paper (40%)

Your final artist's statement synthesizes the research you have been conducting throughout the semester. It should be at least 1 page not including the annotated bibliography and must include:

• A clear scientific thesis statement

• A discussion of how the particular creative methods you used incorporated information/ideas/concepts drawn from your research

• The intended audience for the work and explain the impact that the work is designed to have on that audience

• An annotated bibliography including 7 sources (at least 3 primary) and indicating what they add in support of your thesis and how they integrated into your creative process

Evaluation criteria in order of importance:

Ability to engage with the scientific literature

Ability to craft a comprehensive thesis

Ability to write academically about creative works

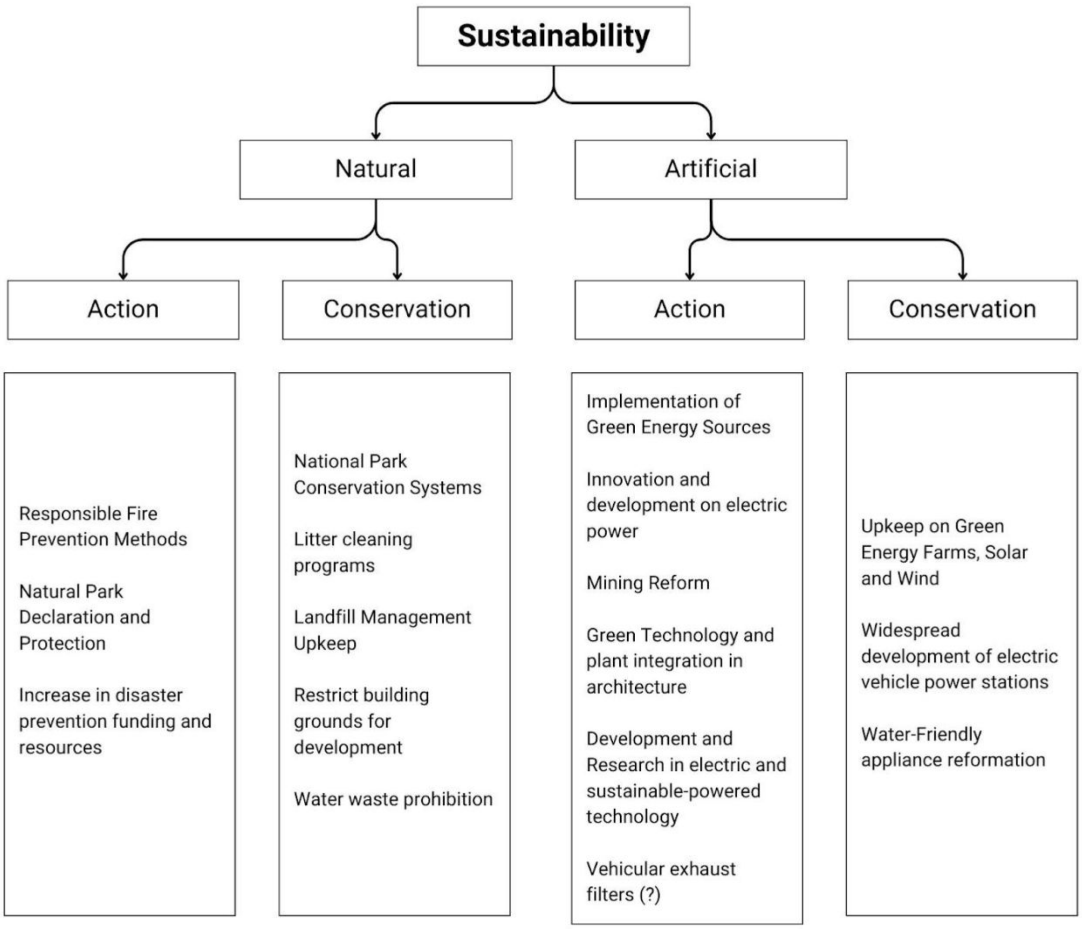
Ability to synthesize ideas in a logical framework with a coherent introduction and conclusion

Ability to adhere to stylistic and formal guidelines

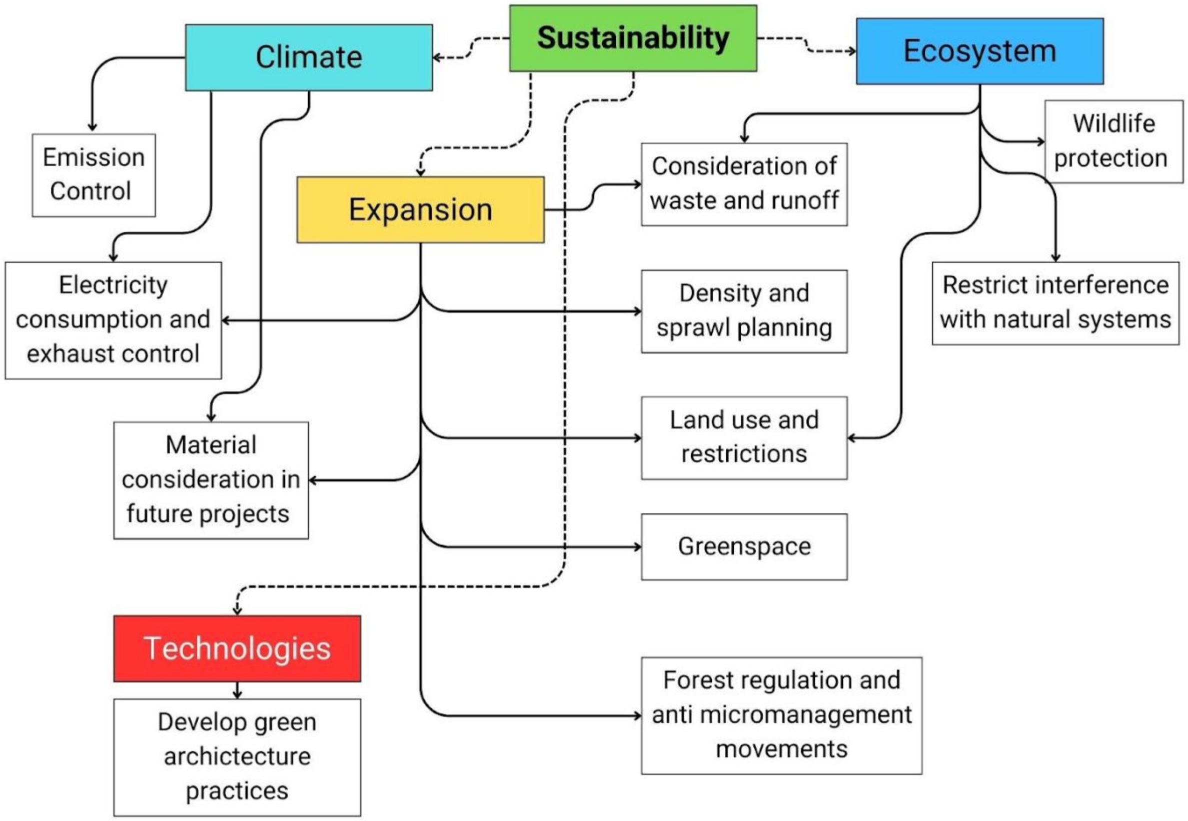
Part 3B: Final creative work (30%)

The overall goal of the Term Project is to produce a creative work that incorporates important ideas and information related to the course goals. There are many subjects that can successfully serve as the focus of the project, and there are many ways of incorporating science into creative work. Remember that while the work must express scientific concepts, it need not do so on its own: the final research paper can serve to explain subtle or abstract ideas that are present in the creative work.

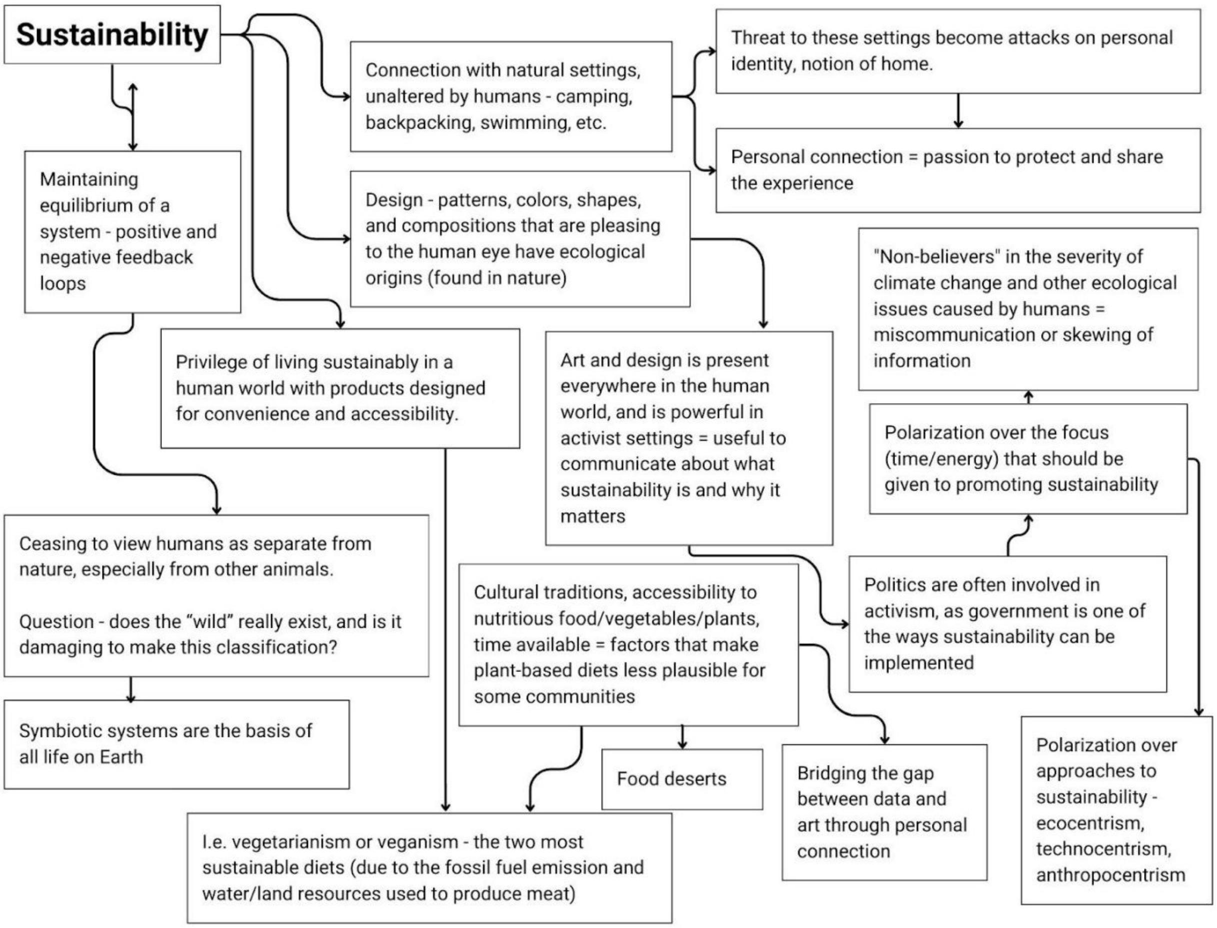
APPENDIX 3: Case Study Concept Maps



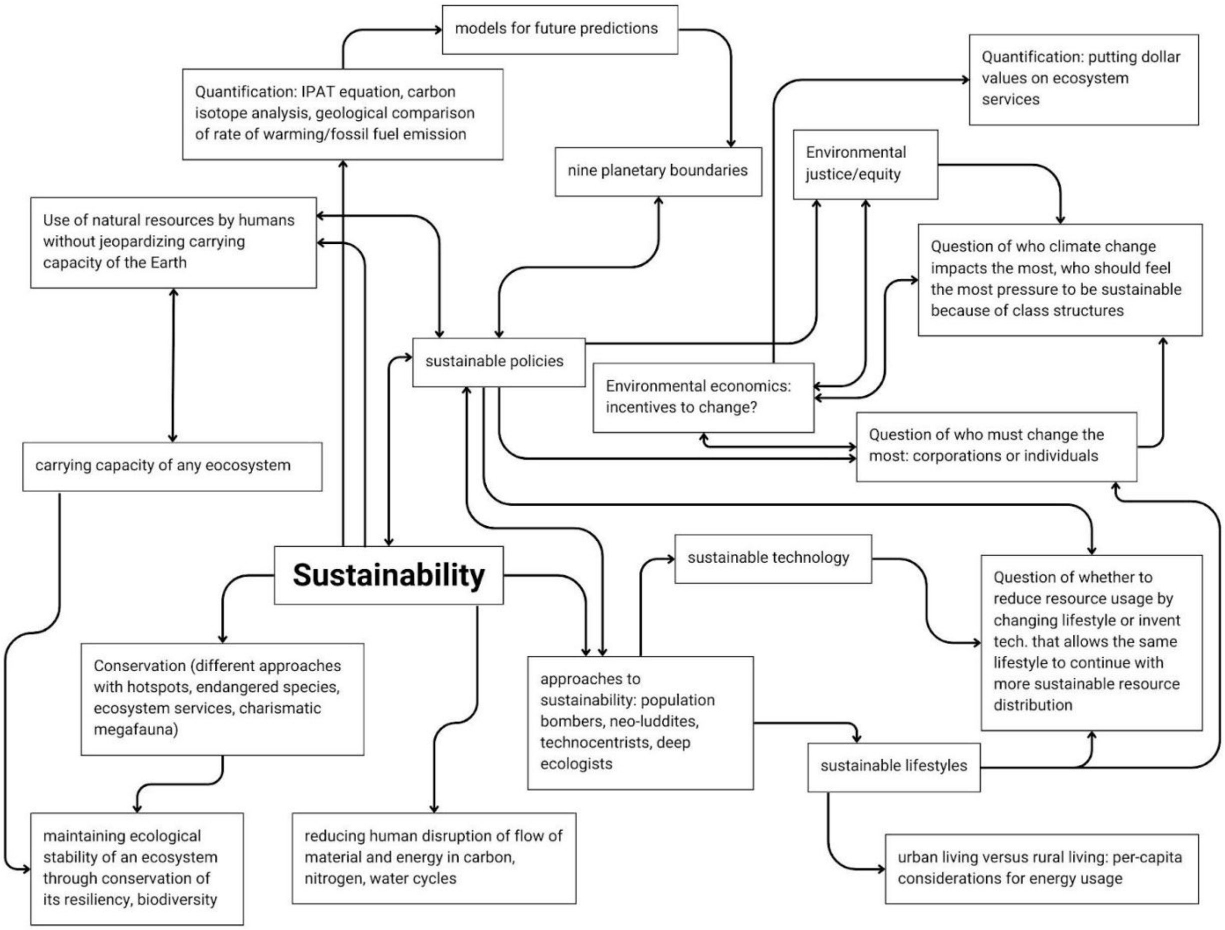
Case 1, Baseline Concept Map



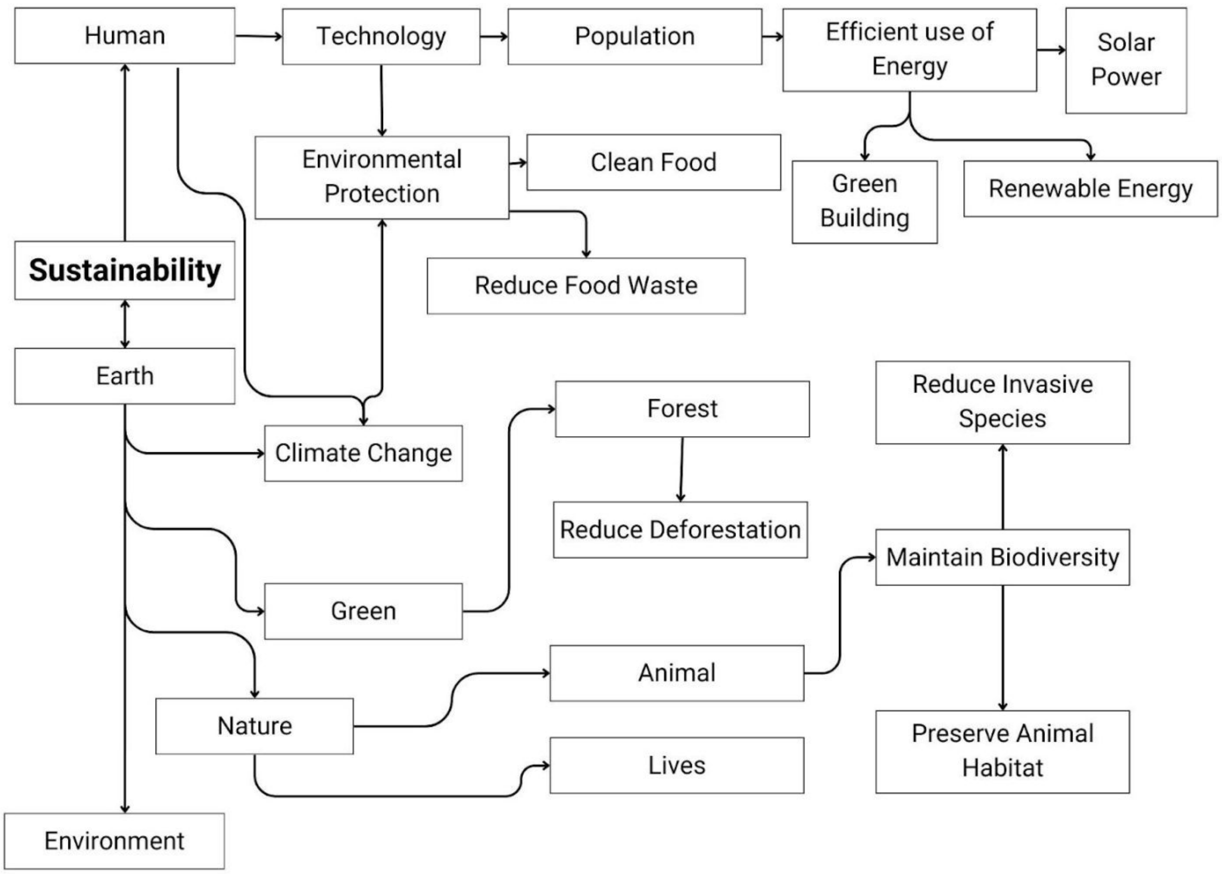
Case 1, Culminating Concept Map



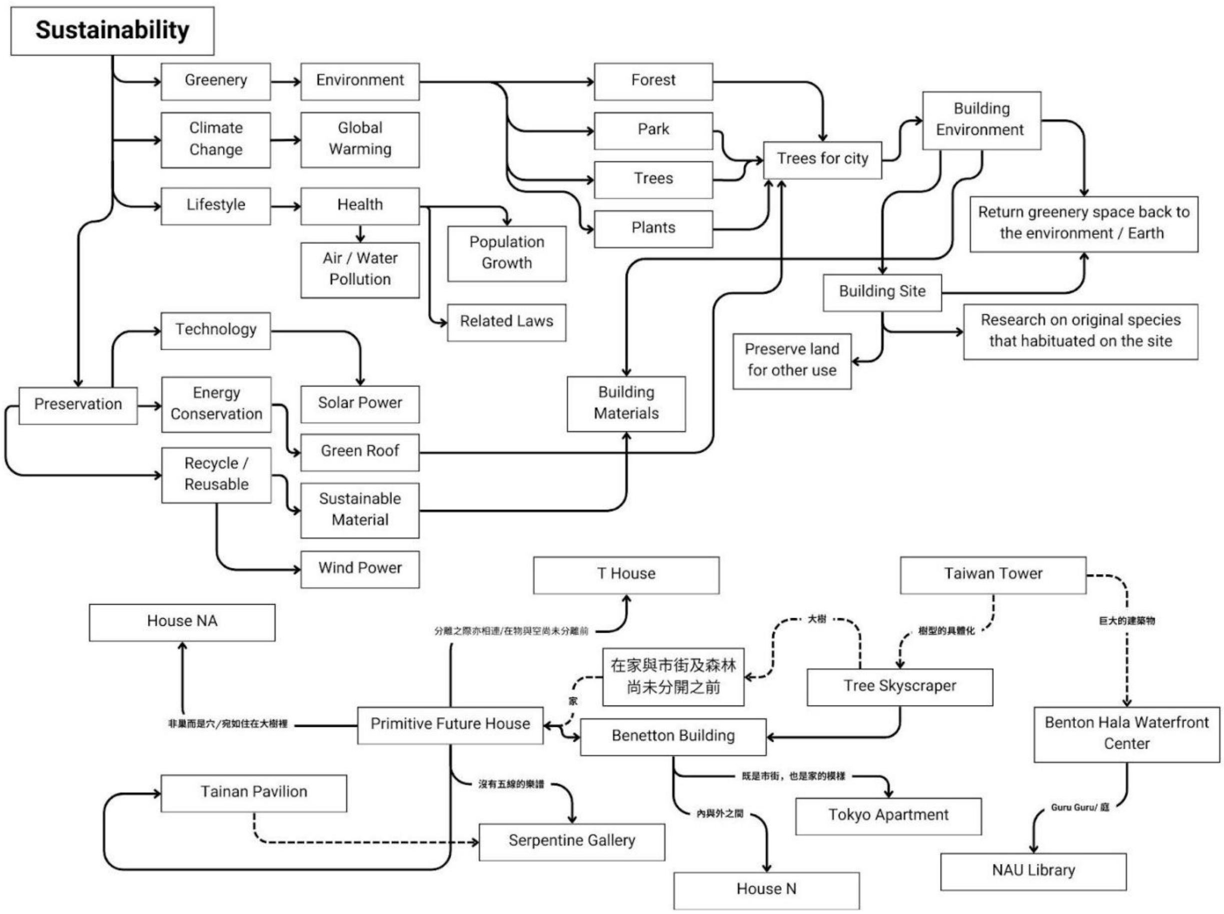
Case 2, Baseline Concept Map



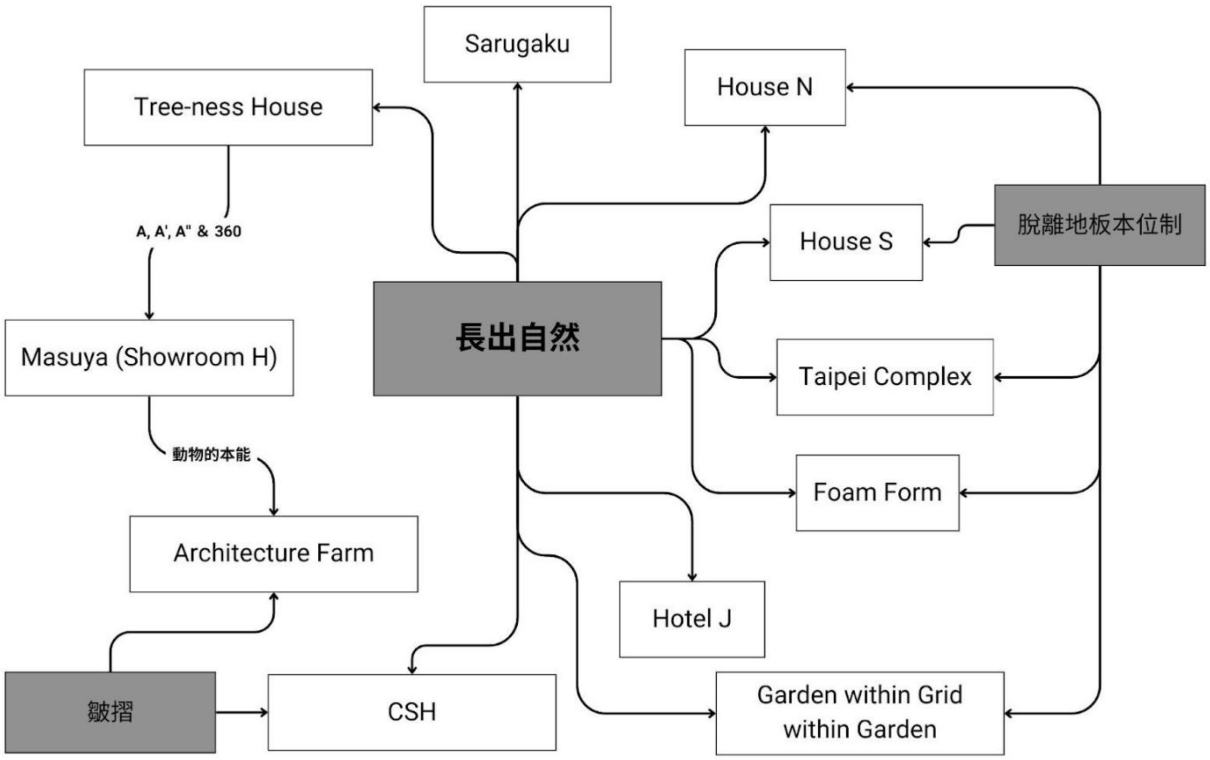
Case 2, Culminating Concept Map



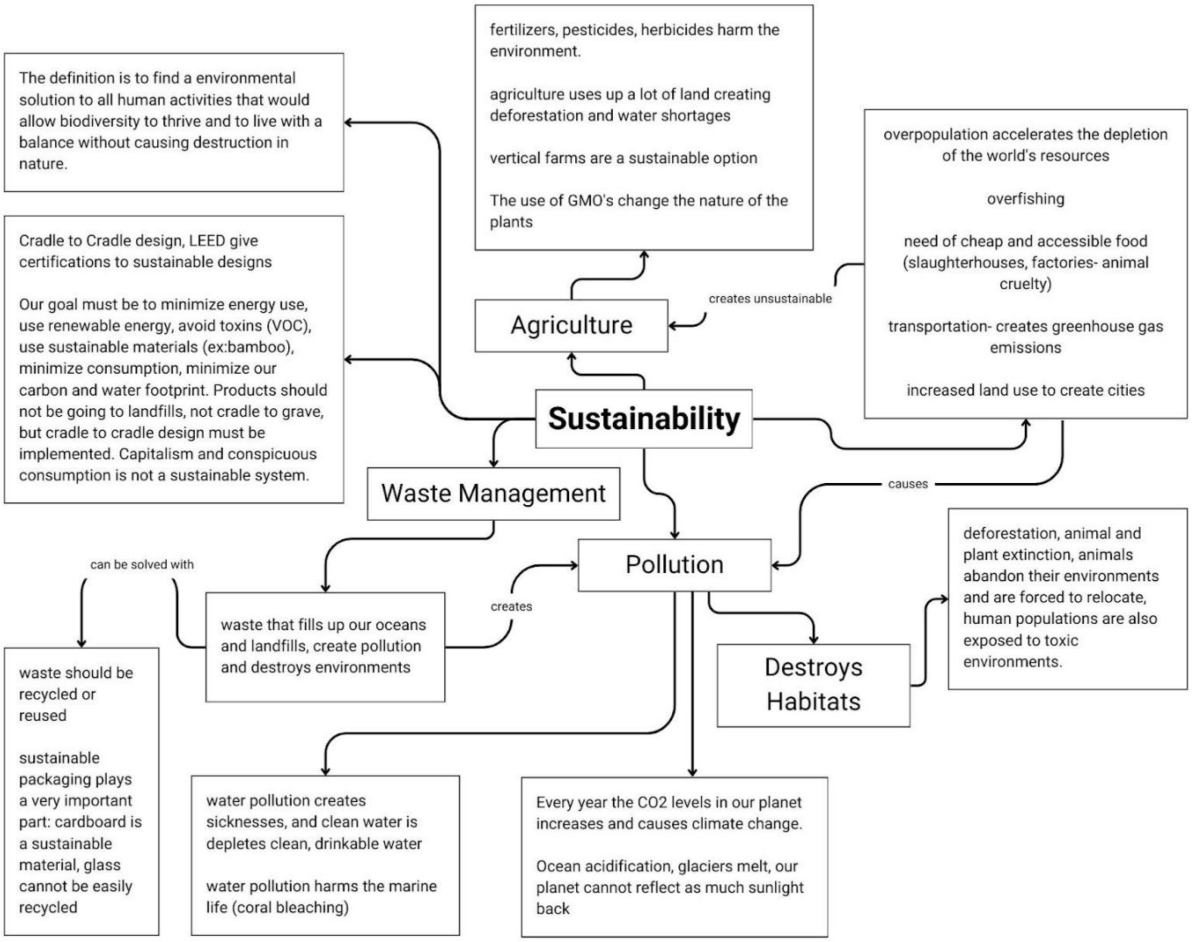
Case 3, Baseline Concept Map



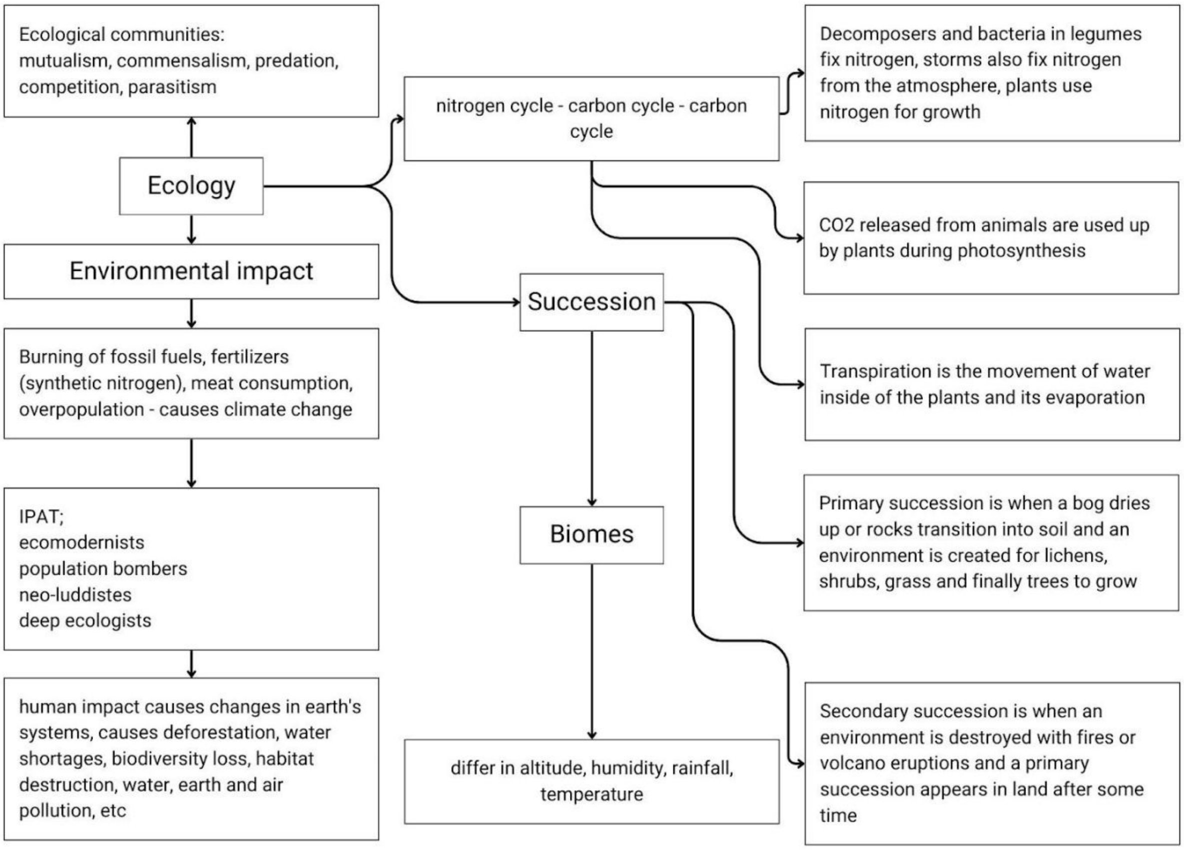
Case 3, Culminating Concept Map



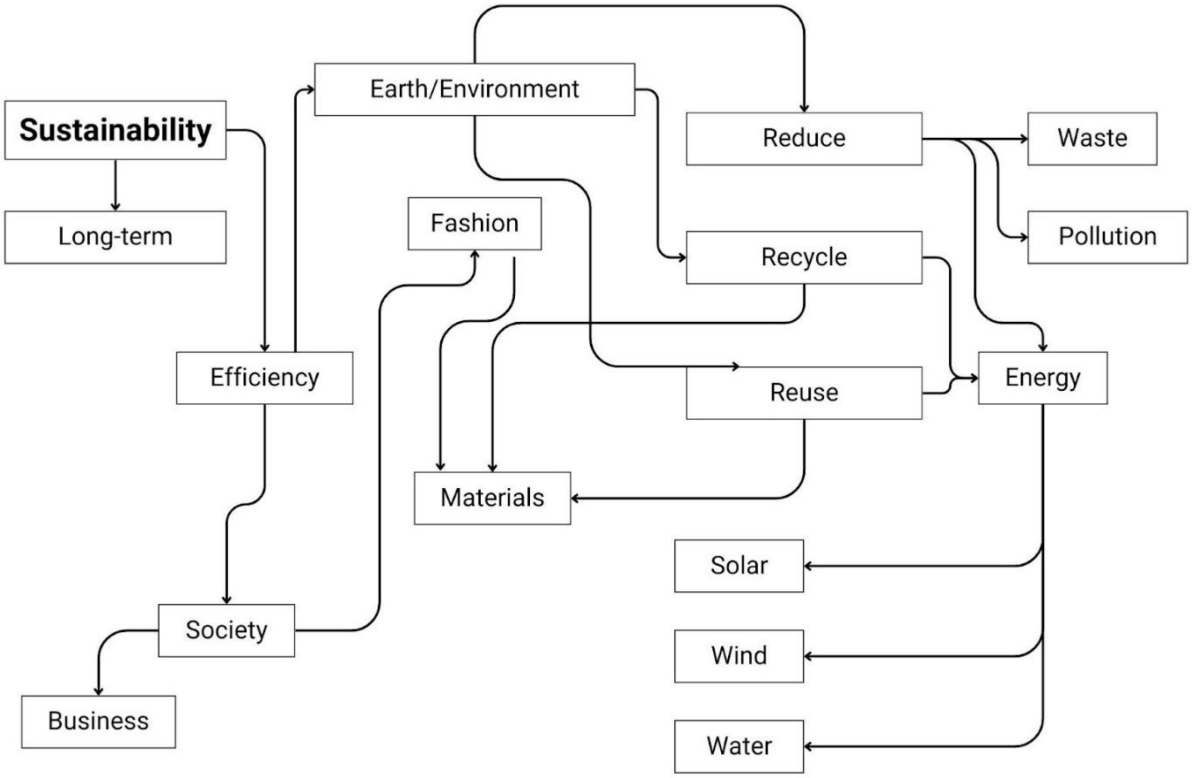
Case 3, Culminating Concept Map



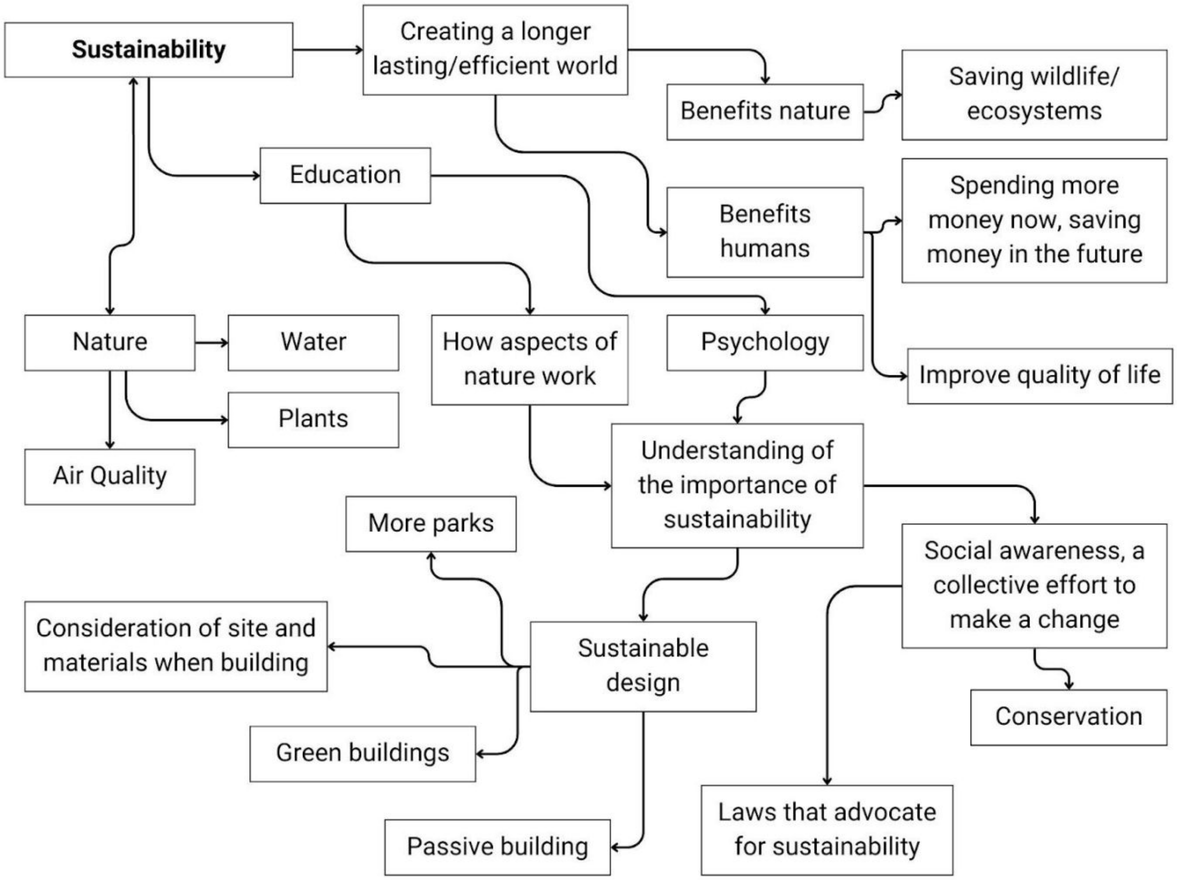
Case 4, Baseline Concept Map



Case 4, Culminating Concept Map



Case 5, Baseline Concept Map



Case 5, Culminating Concept Map

APPENDIX 4: Discussion of five case studies

Summary data for case studies. B *baseline concept map,* C *culminating concept map*, Δ *change in initial and culminating values.*

			Percentage of sustainability knowledge domains included			Map complexity			Design thinking indicators			Individual action indicators			Social impact indicators			Culture and values indicators			Change in sum of transf indicators
	Year	Course	B	C	Δ	B	C	Δ	B	C	Δ	B	C	Δ	B	C	Δ	B	C	Δ	
Case 1	2	EA	0.4	0.5	0.1	55.2	32.3	-22.9	1	4	3	1	0	-1	0	1	1	0	0	0	3.00
Case 2	1	ESE	0.8	0.8	0	34.2	62	27.8	4	0	-4	4	1	-3	4	4	0	13	5	-8	-15.00
Case 3	2	EA	0.4	0.7	0.3	55.2	375.2	320	0	45	45	1	2	1	2	2	0	1	1	0	46.00
Case 4	2	ESE	0.7	0.6	-0.1	67.2	21	-46.2	7	0	-7	1	1	0	5	1	-4	3	4	1	-10.00
Case 5	2	EA	0.4	0.7	0.3	34	52.9	18.9	1	5	4	4	0	-4	0	3	3	0	0	0	3.00

Students repeatedly indicated their interest in applying the sustainability knowledge they were gaining in these classes to their major design work:

> "I would like to center my work around environmental and social justice as a main focus, and to learn how to best do that."
>
> -Second-year, Environmental Science and Ecology

> "I have learned new concepts that I had no idea about. And I would be interested in knowing more about them. This course has introduced me to several challenges the environment faces… Green architecture is something I am interested in after this course."
>
> -Second-year, Ecology for Architects

> "I want to be able to make my designs in the future sustainable and start to consider the ramifications of my building now while I have a degree of freedom."
>
> -Second-year, Ecology for Architects

We took a deeper look at the details of the ways students were including transformative sustainability indicators in order to gain a better understanding of the struggles and successes students faced in applying the scientific content they were being presented with in their ecology courses. The five case studies of individual students below (summarized in above table with concept maps for case studies included in Appendix 2) illuminate in specific terms some of these broader findings.

Case 1: Second-year, Ecology for Architects

> "I think that it [engaging with sustainability in the creative work required by my major] was something I hadn't considered in great detail due to the direction the curriculum guides us, so going an extra step into the design process to challenge myself to include it would be best for my design. …. I think a lot of Pratt's design curriculum excludes green design, or at least makes it hard to consider. Hopefully I can find an opportunity to bring this to the faculty and it can be integrated more with the goals of this major. I am friends with several student government members and assistants to the dean, hopefully I can have a few conversations with them to really push this idea."

This student demonstrated increasing design applications and social impacts across the semester, though both the overall complexity and individual action transformative indicator declined and values remained at zero. In the above survey response, the student includes strong transformative indicators, both referencing design applications and a path of individual action, which they envision as leading to directly impactful change. This response is more specific in its description of individual action, than it is in outlining detailed design applications. The above sentiment is reflected in this student's culminating concept map, in which "green architectural practices" are isolated in a corner of the map with no connection to the broader knowledge base. This pattern, in which design applications are referenced broadly with little specificity, is characteristic of many of the concept maps and surveys where design applications were included.

Case 2: First-year, Environmental Science and Ecology

An ESE student includes art and design as a central line within their concept map at the beginning of the semester, also including many values nodes, showing an interest in exploring ways of applying sustainability knowledge in their own practice and as a tool for activism and communication. As with Case #1, this indicates strong design application and individual action indicators. Culminating survey responses also reference this student's motivation to explore design applications and engage in individual action.

> "[I intend to begin] Incorporating ecological concepts and data (especially pertaining to climate change) into design, advocating for sustainable lifestyles for those around me, social activism for environmental justice."

Despite these clear and persistent indications of motivation to apply what they learned to their design practice and take concrete steps to support change, this student did not include any design applications in their culminating concept map and only 5 values nodes as compared to 13 in their baseline map, resulting in an overall decline in transformative indicators across the semester, accompanied, however, by an increase in complexity. It is clear when comparing these two maps that this student's baseline conception of sustainability was very personal, with reference to their own values:

> "Ceasing to view humans as separate from nature, especially from other animals. Question - does the "wild" really exist, and is it damaging to make this classification?"
>
> "Personal connection = passion to protect and share the experience"
>
> "Threat to these [natural] settings become attacks on personal identity, notion of home."
>
> (Node excerpts from Case 2 baseline concept map)

The integration of greater complexity and more detailed technical ecological knowledge in the culminating concept map occurs at the loss of strong transformative indicators, with a significant reduction in the proportion of nodes explicitly referencing values statements. As compared to the subset sample of nodes implicating values from the baseline concept map above, compare with the the complete sample of values nodes from the culminating map:

> "Question of who climate change impacts the most, who should feel the most pressure to be sustainable because of class structures"
>
> "Question of who must change the most: corporations or individuals"
>
> "approaches to sustainability: population bombers, neo-luddites, technocentrists, deep ecologists"
>
> (Node excerpts from Case 2 culminating concept map)

The student has formalized their language, referencing dialogues and debates using disciplinary terminology, but the connection to their individual values is less apparent in the more limited number of nodes that touch on values. While we might hope that this student will return to applying their new technical knowledge to more personal applications and thus achieving transformative outcomes, it is not a given. This progression from personal, non-technical engagement to technical disciplinary knowledge that seems to preclude personal engagement may be the result of confronting the disorienting dilemma that is the first hurdle of attainment of transformative outcomes (Mezirow, 1978).

Case 3: Second-year, Ecology for Architects

This student began the semester with a moderate, if above average complexity and an average transformative indicator score, but improved dramatically by the end of the semester, and was, in fact, the student that improved the most in terms of the increase in complexity, design applications and overall transformative indicators across the semester. As such, this student exemplifies what we hope to achieve; however, they are an outlier. In culminating survey responses, they indicate a motivation to incorporate sustainability knowledge into their design work:

> "I think about the environment issue when I'm thinking about design projects, for example, the sustainability of architectural material."

Even given their apparent success, there is still evidence that they may be struggling to connect design applications to sustainability knowledge domains, as expressed in their lack of improvement in social impacts or values indicators and the general nature of the above quote, which fails to present specific examples that might indicate clear action. Additionally, while their culminating concept map considers detailed architectural examples, they place this analysis beside (with no connectors linking it back to the main map), as opposed to fully integrated within, the rest of the concept map, which more broadly engages with sustainability knowledge domains.

Case 4: Second-year, Environmental Science and Ecology

Similar to case 2, this student came to the course with some sustainability knowledge and ideas for design applications. Their culminating concept map became more focused and technical, but ultimately decreased moderately in breadth of knowledge domains ('Actors and Stakeholders' was included in the culminating but not baseline map) and decreased significantly in both complexity and transformative indicators. The culminating concept map lacks reference to design and indicates fewer social impacts than the baseline map. It demonstrates improvement with the addition of one more values node.

Case 5: Second-year, Ecology for Architects

This student demonstrated improvement in breadth, complexity and transformative indicators across the semester.

> "I want to minor in sustainability so I can get an even better understanding of how to integrate solutions into architecture."

Their motivation to continue their sustainability studies in order to better learn how to apply environmental science to their design process further indicates strong individual action transformative indicators. As in case 1, their design applications remain broad and lack specificity, with a "Sustainable Design" node linked to the following nodes: "more parks", "consideration of site and materials when building", "green buildings", and "passive buildings". They failed to include values nodes in either baseline or culminating concept maps.

APPENDIX 5: Results from regression analyses

	Simple Regression Coefficient			Multiple Regression Coefficient		
	CCE (Credits)	INSTR (Instructor)	CRS (Course)	CCE (Credits)	INSTR (Instructor)	CRS (Course)
Baseline breadth	-0.0001		***-0.1169****	-0.0004		***-0.1669*****
Baseline complexity	0.2089		-2.931	0.4417		-13.9575
Initial design applications	0.0008		0.0728	-0.0000		0.0000
Initial Individual action	-0.0001		-0.0611	-0.0000		0.0000
Initial social impacts	0.0005		0.0012	0.0007		-0.0151
Initial values	-0.0012		***-0.0917*****	-0.0003		***-0.0941****
Initial total transformatie	-0.0061		-1.890	0.0127		-2.0912
Change Breadth	-0.0031	0.4612	0.3393	-0.00815	***0.9617****	-1.058
Change in complexity	0.0532	***1.9934****	***4.587*****	0.0258	0.0992	4.081
Change design applications	0.0789	-0.5657	-8.371	0.129	***8.451****	***-23.37*****

Change individual action	-0.0487	4.227	***10.405****	-0.1304	-0.1578	12.42
Change social impacts	-0.0271	0.2913	-0.1201	-0.0309	1.0923	-1.4128
Change culture and values	***0.0490*****	***1.0356*****	***1.8829****	***0.0394****	0.6089	0.3938
Change total transformative	0.0990	0.8558	-6.326	0.131	***10.97*****	***-23.93******
Survey: This course covered concepts that are relevant to my daily life.	-0.0090	0.1012	0.2021	***-1.4e-02****	0.0000	0.0000
Narrative survey responses referenced design applications	0.0035	0.1443	0.2259	0.0015	-0.0984	0.1664
Narrative survey responses referenced individual action	-0.0061	***-0.1778****	***-0.3031****	-0.0036	-0.1680	0.0562
Narrative survey responses referenced social impacts	-0.0006	0.0545	0.0714	-0.0018	0.0963	-0.0535
Narrative survey responses	-0.0054	-0.0274	-0.1864	-0.0045	-0.5173	0.2529

referenced values							

* p<0.05, ** p<0.01, ***p<0.001

APPENDIX 6. Results from Wilcoxon test comparing results from baseline and culminating concept maps across full sample

	Paired		Unpaired		Mean Init.	Mean Cul.	% Change
	Test Statistic (V)	P-value	Test Statistic (V)	P-value			
Total nodes	***213***	***0.0010***	***1327***	***0.0425***	15.19	18.22	19.94
Total links between nodes	***221***	***0.0014***	1363	0.070	15.57	19.06	22.39
Concept map complexity	***234***	***0.0014***	1361	0.066	29.53	43.70	48.00
Total domains included	***272***	***0.0057***	1347	0.0548	18.94	23.6	24.60
% of domains included	380	0.264	1537	0.3673	0.463	0.488	5.34
% design application nodes	267	0.441	1668	0.855	0.109	0.151	38.04
% Individual action nodes	***341***	***0.0078***	***2207***	***0.0010***	0.091	0.032	-64.93
% Social impacts nodes	556	0.7488	1533.5	0.3417	0.052	0.064	23.08
% Values nodes	628	0.688	1610.5	0.5814	0.052	0.038	-26.92
Total all transformative indicators	347	0.403	1601	0.3588	4.68	5.88	25.75