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A bottom-up multi-disciplinary approach for sustainability education: UN-SDG 13.3

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A Bottom-Up Multi-Disciplinary Approach for Sustainability Education: UN-SDG 13.3

Completed Research Paper

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Abstract

Teaching both information systems and business undergraduates to break the current inertia in sustainability action requires innovative teaching & learning approaches as well as inter-disciplinary knowledge inputs. This study presents a bottom-up T&L approach delivered by a group of educators from different disciplines aimed at addressing UN-SDG Goal 13 'Climate Action' with a novel approach. Integrating a problem-centric community project assignment into existing courses, our students worked on different disciplinary elements such as persuasive technologies and awareness campaigns to help to address local sustainability initiatives by community partners. We collected data to measure how students' motivation, engagement, teamwork, and community partnerships influence or predict climate proficiency, related learning outcomes and overall course satisfaction. We found influencing predictors and developed recommendations aimed at motivating students and engaging them emotionally and skills-wise with reference to SDG 13. We provide guidelines to improve student orientation, sustainability-related community partnerships, course alignment and project execution.

Keywords: Multi-disciplinary pedagogy, sustainability education, sustainable development goal, problem-based learning, mixed method studies

Introduction

This paper highlights the importance of multi-disciplinary knowledge and engagement for sustainable education. It addresses the concern that this is a potentially challenging task for traditional single discipline schools such as information systems (IS). Multi-disciplinary in terms of courses from IS and business schools but stays within their schools. Making inter-disciplinarity work in support of sustainability education requires a curriculum overhaul to equip students with relevant skills and ways of thinking. The complexity of sustainability issues requires an inter-disciplinary knowledge which involves analyzing, synthesizing, and harmonizing issues that crosses disciplines into a coordinated and coherent solution. Multi-disciplinary team teaching across disciplinary topics can be discomforting and difficult, e.g., due to differences in jargon or background knowledge (Colwill & Boyd, 2008; Lindvig & Ulriksen, 2019).

This study presents a multi-disciplinary, collaborative pedagogical approach towards working with community partners by centering around sustainability projects which is less disruptive than a curriculum overhaul. We posit that this pedagogy can be effective in engaging and motivating students to enhance their proficiency in climate-related knowledge. We are not dismissing the benefits of sustainability education as a whole institution approach (Holst, 2023), rather we are presenting the impact of a bottom up first step to adopting sustainability in education that a few enthusiastic teachers can initiate on their own.

The authors are university educators addressing the United Nations Sustainable Development Goal 13.3 "Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning" (UN-SDG, 2024). This study contributes to the UN-SDG 13.3.1 target indicator with a less disruptive curriculum approach for sustainable education and assessment of student climate proficiency. The need to cross disciplines and to reap the benefits from interrelationships, rather than sticking to silo thinking, is in line with the fundamental idea of the 17 UN-SDG agenda (Argento et al., 2020). Our goal is to provide our students with relevant climate proficiencies, with an understanding of how students who belong to other disciplines use their skills to address climate change, and with collaboration experience to co-design a sustainable solution.

We collected data from surveying Singapore undergraduate IS students taking a human computer interaction design (HCI) course, or a smart city innovation (SCI) course. They worked with local community stakeholders to participate in co-creating a sustainable future with emphasis on reducing food waste, encouraging the use of sustainable packaging, promoting water conservation, educating the public on biodiversity and eco-friendly environment, etc. The research questions are to find out if students acquired climate proficiency, are motivated and engaged and differences amongst students.

Related Work

In line with the critical review of the sustainable human computer interface (SHCI) by Bremer et al. (2022), we follow their call for multi-disciplinary expertise and collaboration. Rather than staying in our own knowledge bubble, the SHCI community has been asked to collaborate more widely (Bendor, 2018; Silberman et al., 2014) and across disciplines (Chen, 2016).

Inter-disciplinary

Lindvig and Ulriksen (2019) analyzed 62 articles on inter-disciplinary teaching activities. They found mostly undergraduate students working on problems such as sustainable development or water resource management requiring inter-disciplinary approaches. The reasons for inter-disciplinarity center around students developing different competences and experiencing a different kind of motivation to learn service subjects (Yang, 2009). Service subjects refer to subjects taught in the main discipline such as IT subject in business management or sustainability subject in HCI discipline. Cai (2010) suggested the following strategies: 1. New separate green computing courses, 2. Sustainability modules and projects integrated into existing courses, and 3. Transformative whole new curriculum. The inter-disciplinary integration into existing courses (2) could use one of the following configurations: 1. One discipline after another (pearls on a string), 2. Different discipline presented separately with students tying them together (zipper), and 3. Different disciplinary elements around a common center such as a project (snowflake) (Lindvig & Ulriksen, 2019). The teaching activities reported comprise team teaching with active learning in projects or group work. Team teaching could be perceived as loss of control or having to change their habitual way of teaching by some teachers (Lindvig & Ulriksen, 2019; Yang, 2009). For team teaching transformation to occur, we as teachers must be intrigued as well as discomforted by surprises, willing to linger in unexpected places long enough to explore their possibilities and confront their challenges. Above all, we must be willing to risk the possibilities of change (Colwill & Boyd, 2008). Teachers should work as a team to provide links between disciplines, create opportunities to reflect, disagree, share, and develop own perspectives, and develop lifelong engagement and openness with ideas and learning (Keeley & Benton-Short, 2020).

Davison et al. (2014) reported on the outcomes of a distributed leadership project in four Australian universities aimed at enhancing inter-disciplinary climate change teaching. Their distributed leadership model establishes four leaders for each community: 1. a teacher who overseas learning within the community, 2. an administrator who manages the community, 3. a self-nominated champion across disciplinary teaching team, and 4. an organizer for collaborative activities. They found this model for sustainability education to be effective in building capacity for inter-disciplinary climate change teaching within disciplines. The model is flexible enough for a variety of institutional settings.

Community Partnership

Community partnerships extend beyond the university via co-learning partnerships comprising government entities, businesses, and non-profit organizations. In such a multi-stakeholder setting, students are enabled to work on "real world problems" and leverage resources, to co-create and to co-learn as part of a sustained and reciprocal partnership. Project-based, collaborative team learning is often the common method format for such teaching and learning activities (Booth et al., 2020).

"The community level is where climate change impacts manifest, where appropriate solutions are needed, and where synergies and trade-offs between mitigation and adaptation, and between climate and non-climate policy choices play out." Moser & Pike (2015) conclude that these specific locales is where people have to live with the consequences of their adaptation choices, and where a sense of place can be a motivation or hindrance to action. Local adaptation experts face a growing need to build capacity in effective stakeholder engagement in responding to climate impacts. This local involvement gap must be filled, and our education programs can bring the adaptation efforts.

Booth et al. (2020) presented a partnership between University of Northern British Columbia (UNBC) and the Prince George Chamber of Commerce on a carbon and energy management co-created course to address interest in mitigating climate change amongst local businesses. "UNBC students learn innovative and practical skills through creating carbon footprint analyses for small- to medium-sized business/non-profit clients, providing recommendations on reducing reliance on fossil fuels and formally presenting their findings to their clients. After five years, 46 businesses and non-profit organizations have participated in the course along with over 30 students and 5 separately hired student interns. The Chamber is now rolling out the program for Canadian Chamber of Commerce interested in similar partnerships."

Research Approach

We seek to foster a creative environment in collaboration with local community partners where our students can co-learn and co-create solutions for complex sustainability projects which require inter-disciplinary knowledge. From the bottom-up approach as teachers, integrating a sustainability project into our existing courses using the snowflake approach, where different disciplinary elements centered around a project, is the quickest and easiest option available without the need to get approval for a new green course or a transformative whole institutional change.

Students empathized with the local stakeholders to understand the consequences of their adaptation choices in response to climate impacts. Students were guided by community mentors with domain knowledge and teachers from different disciplines, with knowledge on interaction design and on innovation management best practices. The student goal was to build digital prototypes and propose platforms for community actions. HCI students were able to see business strategies, and business students were able to see technological solutions as they worked on a common community project proposed by a city retail association and a government development board.

This research builds on our first paper (Gan et al., 2023) which focused on nudging sustainability behavior through social norms with one community partner. We continue our data analysis to understand how students' motivation and engagement help them to attain climate proficiency and satisfaction. This paper added teamwork and a second community partnership as independent variables as well as learning outcome as a dependent variable. These variables help us focus on the collaboration in a multi-disciplinary team. The multi-disciplinary engagement is to create an opportunity to understand the different points of view when solving a complex sustainability project in hope of our students gaining inter-disciplinary competencies and motivation.

Learning Objectives

The key learning objectives for the human computer interaction design (HCI) course is to empathize, design, prototype, and test digital technology solutions to improve the user experience; and for the smart city innovation (SCI) course is to plan, design, build, sustain, and commercialize smart cities and respective technologies. HCI taught by teacher 1 is a required core course for year two information system and computer science students who have technical background and learning the creative design process. SCI taught by teacher 2 is a university core course for year two to year four business management students who have business background and learning sustainability innovations in smart cities. The SCI course is open to students from other disciplines. These courses provide a multi-disciplinary learning environment by integrating a sustainability project that requires an inter-disciplinary solution.

Project Structure

For each term, we recruit one partner from the local city community. All SCI students registered for that term must work with the assigned community partner, while HCI students may choose to work with this community partner or propose their own project. All SCI and HCI teams who chose the community partner project must attend the same project briefing conducted at the beginning of the courses and scheduled common meeting slots throughout the term. They attended common midterm presentations and received feedback from the partners and teachers on their deliverables.

Partners

Students in term 1 worked with a Business Association (partner 1), while students in term 2 worked with a Government Board (partner 2). The focus of the community partner sustainability projects is intentional to align with the City's sustainability effort in line with UN-SDG 2030.

Partner 1 has played a pivotal role as a place maker for "... shopping and lifestyle destinations." Their stakeholders are listed in table 1.

Table 1: Key stakeholders linked to Partner 1

Category	**Occupier-Stakeholder**
Play	Cinema, Fitness, Amusement Facilities
Shop	Department stores, Retailers (Fashion, Luxury brands, etc.), Supermarkets
Stay	Hotels
Eat & Drink	Bakeries, Cafes, Fast food, Restaurants, Pubs
Live	Residences
Work	Offices, Serviced Offices
Property Owners	Building and Mall Owners/Managers
Common Spaces	Pedestrians' walkways, Gardens, Public transport linked walkways
Property	People who live, stay, visit, play, shop, dine, entertain, work, invest and manage businesses in the precinct

Partner 2 manages a city park and proposed 3 ESG-related project themes with focus on sustainability as listed in table 2.

Table 2: Project Theme linked to Partner 2

Theme	**Occupier-Stakeholder**
Blue Carbon Campaign	• Objective: Raising awareness among youths on nature-based solutions/blue carbon and coastal ecosystems. • Project Challenge: Propose ideas and implement an engagement campaign including production of outreach materials (digital/social media content) for showcase/dissemination.
Sustainability Tour	• Objective: Conceptualize and develop implementation model of sustainability tours, in line with the sustainability context around various themes such as energy, carbon, climate, water, biodiversity etc. • Project Challenge: Develop a mock-up of the sustainability tours and conduct trial runs. Tours should be engaging and form a holistic, coherent narrative.

Sustainability Gallery	• Objective: Provide an overview of partner 2 as a model for sustainable development and conservation and showcase its sustainability efforts. • Project Challenge: Propose ideas, design and concept including gallery content based on partner 2's Sustainability Strategy that is interactive and uses innovative technologies.

Proposed Solutions

In term 1, students worked with partner 1 on a series of sustainability topics: sustainable packaging, plant-based menus, rainwater collection, energy-efficient lighting and cooling systems, alternative renewal energy sources and e-waste recycling. Students reached out to key stakeholders of partner 1 depending on the respective user personas they had identified in their project proposals. In term 2, students worked with partner 2 directly on creating immersive campaigns, tours, and galleries that teach the public about biodiversity and eco-friendly environment. Students reached out to their public user personas to empathize and to test their prototypes.

The deliverables included ideas and initiative proposals, prototypes, actionable plans, and recommendations. Some students used persuasive technologies (Fogg, 2009; Yetim, 2013) to combat cognitive biases to encourage sustainable behaviors. They addressed sustainability using tools in areas such as eco-feedback, energy consumption, recycling systems, virtual tours, and gamification. Student teams came up with a wide variety of innovative green digital solutions that range from using mobile app to locate plant-based food and recycling bin; websites with eco-feedback systems to educate/persuade/nudge on e-waste recycling, water preservation, reducing food waste and energy conservation; social media campaigns for youth engagement activities, family guided personalized augmented green tours, interactive green galleries; gamification to get pledges to use sustainable packaging, to recycle, and to use renewable energy; and online education on biodiversity and eco-friendly environment.

Research Method

We conducted two online surveys and an interview with students from two different courses working on term long projects over two different semesters, with a different community partner during each semester. As we conducted human research, we applied for and received IRB approval IRB-21-218-E002(222) for term 1 and an extension IRB-21-218-E002-M1(822) for term 2. Our research questions are as follows:

RQ1: Do the inter-disciplinary sustainability projects help students to acquire climate proficiency?

RQ2: Does participating in an inter-disciplinary sustainability project motivate and engage students to take the project (more) seriously?

RQ3: How does the perception of inter-disciplinary sustainability project-based learning differ amongst students (e.g., in terms of discipline area, length of studies and gender)?

Our hypotheses are the following:

H1: (Higher Motivation – More Engagement) Students with a higher level of motivation will be more engaged as result of the project experience than students who have a lower level of motivation.

H2: (More Engagement – Higher Motivation) Students with a higher level of engagement as result of the project experience will be more motivated than students who have a lower level of engagement.

H3: (More Engagement – Higher Climate Proficiency) Students with a higher level of engagement as result of the project experience will have a higher level of climate proficiency than students who have a lower level of engagement.

H4: (Higher Motivation – Higher Climate Proficiency) Students with a higher level of motivation will report a higher level of climate proficiency than students who have a lower level of individual motivation.

H5: (More Engagement – More Satisfaction) Students with a higher level of engagement as result of the project experience will be more satisfied with the project than students who have a low level of engagement.

H6: (Higher Motivation – More Satisfaction) Students with a higher level of motivation will be more satisfied with the project than students who have a lower level of motivation.

Questionnaires

We conducted the following research activities: 1) a standardized online questionnaire was used to collect quantitative and qualitative data on student demography (Q1-5), pre-post engagement (Q6), climate proficiency (Q7), motivation (Q8), engagement (Q9), teamwork (Q10), satisfaction (Q11), climate learning outcome (Q12-16), and partnership management (Q17-19); and 2) a semi-structured interview on their learning experience. The dataset is analyzed to test the research questions using Structural Equation Models (SEM) similar to Wongsunopparat & Deng (2021).

Climate Proficiency

To measure student's climate proficiency, Q7 consists of 16 sub-questions which were adapted from Dreyfus' five stage model of adult skills acquisition (Dreyfus, 2004). Students were asked to rate their proficiency with regards to insights gained from the project or course content on climate change, climate actions, climate mitigation, climate adaptation, carbon footprint, calculation of carbon footprint, carbon offsetting strategies, decarbonization, carbon sequestration, corporate ESG, UN-SDG Goal 13, awareness of concern for personal climate action, local consequences of climate change and support for completing the project. The sub-questions were further customized to refer to the sustainability project. For example, question 7-1 was "explain the term climate change using insights you gained from course content and/or your project," and question 7.15 was "explain the local consequences of climate change and the need to act with regards to partner x's stakeholder."

The proficiency rating response options were on a 6-point Likert scale ranging from (0) "no knowledge" to (5) "expert". Each response was mapped into a number from 0 to 5 and the overall climate proficiency was calculated as the average of the quantified responses from the 16 sub-questions. A student with an average score of (> 4) is considered an expert, (> 3 and <= 4) is considered having a professional proficiency, (>2 and <= 3) is considered having a competent proficiency, (> 1 and <= 2) is considered having a beginner proficiency, and (<= 1) is considered having a novice proficiency.

Proficiency skill acquisition becomes harder to measure when reaching the expert level as expert practitioners need to evaluate their practice and keep up to date (Lester, 2005; Rosander et al., 2022). In the case of acquiring clinical skills, studies have argued that complex problem skills and the rich interplay between implicit and explicit forms of knowledge must be taken into consideration (especially when considering the idea that experts work from intuition, not from reason as argued by Peña, 2010). This may be no different when it comes to acquiring climate proficiency skills which deal with complex sustainability problems that require inter-disciplinary knowledge.

Motivation

To measure students' intrinsic motivation, Q8 consists of 37 sub-questions which were adapted from the intrinsic motivation inventory (IMI, 2024). We considered only six of the seven sub-scales of intrinsic motivation that include: *interest/enjoyment*, *perceived competence*, *effort/importance*, *pressure/tension*, *value/usefulness*, and *perceived choice*. We replaced the seventh *relatedness* sub-scale with a separate set of teamwork questionnaire, since inter-personal interactions, friendship formation, and trust are necessary ingredients for teamwork effectiveness via interpersonal cohesion to form a team unit and to avoid team conflict with trust and conflict management. In general, team members should possess interpersonal skills to build trust and to minimize and manage conflicts (Kozlowski & Ilgen, 2006).

The sub-questions were customized to refer to the specific partnership project. Response options were on a 5-point Likert scale and ranged from (1) "not true at all" to (5) "very true." For some questions, the points were in reverse order. The responses were quantified, averaged, and mapped accordingly: (> 4) as highly motivated, (> 3 and <= 4) as motivated, (>2 and <= 3) as mildly motivated, and (<= 2) as unmotivated.

Engagement

To measure students' engagement, Q9 consist of 23 sub-questions which were adapted from the student course engagement questionnaire (SCEQ) (Handelsman et al., 2010; Kuh, 2009; SCEQ, 2024). This study considered four dimensions of student engagement: *emotional*, *participation*, *skills*, and *performance*. Response options were on a 5-point Likert scale and ranged from (1) "not at all characteristics of me" to (5) "very characteristic of me." The responses were quantified, averaged, and mapped accordingly: (> 4) as thoroughly engaged, (> 3 and <= 4) as engaged, (>2 and <= 3) as mildly engaged, and (<= 2) as disengaged.

In addition to SCEQ, we measured student's perceived pre and post project engagement using Q6 "please rate your level of engagement regarding the co-creation of a sustainable future with reference to sustainability management efforts both before and after partner x project." Response options were on a 5-point Likert scale and ranged from (-2) "actively disengaged" to (2) "thoroughly engaged." We subtracted the before quantified response from the after quantified response to get the change in response. A negative number indicates a reduction in engagement while a positive number indicates an increased in engagement.

Teamwork

To measure student's teamwork, Q10 consist of 3 sub-questions. For example, sub-question 10-3 was "how effective was your team working together?" Response options were on a 5-point Likert scale and ranged from (1) "poor" to (5) "extremely well" for Q10-1 to Q10-2. For Q10-3, the response options were on a 5-point Likert scale and ranged from (1) "not effective" to (5) "very effective." The responses were quantified, averaged, and mapped accordingly: (> 4) as effective teamwork, (> 3 and <= 4) as good teamwork, (>2 and <= 3) as mild teamwork, and (<= 2) as no teamwork.

Satisfaction

To measure student's satisfaction, Q11 was "overall, how satisfied were you with partner x sustainability project?" Response options were on a 5-point Likert scale that ranged from (1) "very dissatisfied" to (5) "very satisfied." The responses were quantified, averaged, and mapped accordingly: (> 4) as very satisfied, (> 3 and <= 4) satisfied, (>2 and <= 3) as mildly satisfied, (<= 2) as dissatisfied.

Climate Learning Outcome

To measure student's perceived climate learning outcome, Q12 consist of 5 sub-questions. For example, sub-question 12-1 was "partner x sustainability project was effectively aligned with the course learning outcomes," and question 12-3 was "partner x sustainability project helped me to recognize that youth engagement is critical for co-creating a sustainable future and tackling urban climate challenges (e.g., mitigating the urban heat effect)."

Response options on a 5-point Likert scale that ranged from (1) "strongly disagree" to (5) "strongly agree." The responses were quantified, averaged, and mapped accordingly: (> 4) as apply skill, (> 3 and <= 4) as understand skill, (>2 and <= 3) as remember skill, and (<= 2) as failed on the climate learning outcome. Questions Q13 to Q16 were on how the project helped student learn, what student liked best, can the project be improved, and how to further improve? The qualitative data were clustered into interesting piles to identify areas that worked and areas that needed improvement.

Partnership Management

To measure student's feedback on managing the community partnership, Q17 consists of 18 sub-questions. Partnership management sub-questions were divided into *collaboration*, *feedback,* and *partnership*. Response options on a 5-point Likert scale that ranged from (1) "strongly disagree" to (5) "strongly agree." The responses were quantified, averaged, and mapped accordingly: (> 4) as active partnership, (> 3 and <= 4) as engaged partnership, (>2 and <= 3) as little partnership, and (<= 2) as no partnership. Question Q18 asked "do you think the partnership with x could be further improved?" Question Q19 asked "please suggest how sustainability project partnership with x and its stakeholders could be further improved?" The qualitative data are clustered into interesting piles to identify areas that needed improvement.

Research Findings

At the end of the data collection period for term 1, we received 41 responses with 30 completed responses accepted (73%) and for term 2, we received 58 responses with 41 completed responses accepted (71%). Completed responses are checked for non-empty response. The sample population (n=71) consists of 54% (38) female students and 46% (33) male students. 42% (30) of the sample were in their second year of study, while 28% (20) were in their third year, 28% (20) were in their fourth year, and the remaining 1% (1) were in fifth year. Students were across the six schools in our university: 3% (2) from Accountancy, 58% (41) from Business, 30% (21) from Information Systems, 3% (2) from Economics, 3% (2) from Law and 4% (3) from the Social Sciences. 77% (55) students were enrolled in SCI and 23% (16) were enrolled in HCI.

Perceived Proficiency

Table 3 shows the number of students for each proficiency level across student demography. The % proficient include all students with competent, professional, or expert proficiency. The overall % of proficient students is 80%. There are no big differences in % proficient between term 1 and 2, female and male, or student in years 3-5. However, notice that students from SCI have higher proficiency than students from HCI (85% vs 63%). Another difference is that year 2 students have a lower proficiency percentage of 70% compared to students in years 3-5. The Cronbach's alpha reliability in this study is 0.973.

Table 3: Number of students for Proficiency across Demography

Proficiency	Overall	Term 1	Term 2	Female	Male	SCI	HCI	Yr 2	Yr 3	Yr 4	Yr5
Novice	4	1	3	3	1	1	3	3	1	0	0
Beginner	10	4	6	5	5	7	3	6	1	3	0
Competent	28	14	14	16	12	20	8	12	9	7	0
Professional	27	10	17	13	14	25	2	8	9	9	1
Expert	2	1	1	1	1	2	0	1	0	1	0
% Proficient	80%	83%	78%	79%	82%	85%	63%	70%	90%	85%	100%

Motivation

Table 4 shows the number of students for intrinsic motivation and each sub-scale. The % motivated students include all students who were motivated or highly motivated. The overall % of motivated students is 90%.

Table 4: Number of students for Intrinsic Motivation Sub Scales

Sub Scales	Overall	*Interest/ Enjoyment*	*Perceived Competence*	*Effort/ Importance*	*Pressure/ Tension*	*Value/ Usefulness*	*Perceived Choice*
Unmotivated	0	0	0	0	14	0	1
Mildly Motivated	7	8	20	4	39	19	18
Motivated	55	47	39	38	15	38	38
Highly Motivated	9	16	12	29	3	14	14
% Motivated	90%	89%	72%	94%	25%	73%	73%

On motivation sub-scales, the *effort/importance* sub-scale performed the best with 94% motivated, *interest/enjoyment* comes in at a close second best with 89% motivated, while the *pressure/tension* sub-scale performed the worst with only 25% motivated. Intrinsic motivation is associated with high level of effort which assesses the person's investment of his capacities in what he is doing. On the other hand, the *pressure/tension* score indicates that students are 'unmotivated' due to the tension/stress at having to succeed with project-related tasks. This aligns with how *pressure/tension* is a "negative predictor of intrinsic motivation (Monteiro et al., 2015). However, the *pressure/tension* standard deviation at 0.755 is larger than the rest as you can clearly see it spread across from unmotivated to highly motivated.

Table 5 shows the number of students for each motivation level across student demography. There are no big differences in % motivated except maybe between term 1 and 2 (83% vs 95%). The Cronbach's alpha reliability in this study is 0.904.

Table 5: Number of students for Motivation across Demography

Motivation	Overall	Term 1	Term 2	Female	Male	SCI	HCI	Yr 2	Yr 3	Yr 4	Yr5
Unmotivated	0	0	0	0	0	0	0	0	0	0	0
Mildly Motivated	7	5	2	2	5	6	1	3	1	3	0
Motivated	55	22	33	31	24	40	15	22	17	15	1
Highly Motivated	9	3	6	5	4	9	0	5	2	2	0
% Motivated	90%	83%	95%	95%	85%	89%	94%	90%	95%	85%	100%

Engagement

Table 6 shows the number of students for engagement and each dimension. The % engaged students include all students who were engaged or thoroughly engaged. The overall % of engaged students is 93%.

Table 6: Number of students for Engagement Dimension

Dimension	Overall	*Emotional*	*Participation*	*Skills*	*Performance*
Disengaged	0	0	0	0	2
Mildly Engaged	5	15	8	8	14
Engaged	50	45	47	46	37
Thoroughly Engaged	16	11	16	17	18
% Engage	93%	79%	89%	89%	77%

On engagement dimensions, the *skills* and *participation* engagement performed the best with 89% engaged. The *emotional* and *performance* engagement standard deviation (0.6 and 0.74 respectively) are larger than the rest. We calculated students' perceived pre and post project engagement, i.e., changes in their engagement levels. For example, if a student pre-engagement score is mildly engaged and post is thoroughly engaged, the scale will be 1. Table 7 shows the respective results across student demography.

Table 7: Number of students for Change in Engagement Level across Demography

Engagement	Scale	Change	Term 1	Term 2	Female	Male	SCI	HCI	Yr 2	Yr 3	Yr 4	Yr5
	-3	1	1	0	1	0	1	0	1	0	0	0
Thoroughly Disengaged	-2	0	0	0	0	0	0	0	0	0	0	0
Mildly Disengaged	-1	3	3	0	2	1	3	0	3	0	0	0
Neither Engaged nor Disengaged	0	17	8	9	9	8	14	3	4	7	5	1
Mildly Engaged	1	32	10	22	15	17	23	9	15	7	10	0
Thoroughly Engaged	2	18	8	10	11	7	14	4	7	6	5	0
% Engage		70%	60%	78%	68%	73%	67%	81%	73%	65%	75%	0%

Most students (70%) were more engaged after the project. Note the difference between students from Term 1 and 2 (60% vs 78%) and between students from SCI and HCI (67% vs 81%). The Cronbach's alpha reliability in this study is 0.944.

Teamwork

Table 8 shows the number of students for each teamwork level across student demography. The % teamwork include all students with good, or effective teamwork. The overall % of teamwork is 79%. There are no big differences in % teamwork except maybe between term 1 and 2 (87% vs 74%). The Cronbach's alpha reliability in this study is 0.90.

Table 8: Number of students for Teamwork across Demography

Teamwork	Overall	Term 1	Term 2	Female	Male	SCI	HCI	Yr 2	Yr 3	Yr 4	Yr5
No	2	0	2	2	0	1	1	1	1	0	0
Mild	12	4	8	6	6	10	2	5	2	5	0
Good	33	17	16	20	13	24	9	15	9	8	1
Effective	21	9	12	9	12	18	3	8	7	6	0
% Teamwork	79%	87%	74%	78%	81%	79%	80%	79%	84%	74%	100%

Satisfaction

Table 9 shows the number of students for each satisfaction level across student demography. The % teamwork include all satisfied and very satisfied students. The overall % of satisfied students is 75%. There are no big differences in % except maybe between SCI and HCI (72% vs 88%).

Table 9: Number of students for Satisfaction across Demography

Satisfaction	Overall	Term 1	Term 2	Female	Male	SCI	HCI	Yr 2	Yr 3	Yr 4	Yr5
Dissatisfied	3	2	1	2	1	2	1	3	0	0	0
Mildly satisfied	14	7	7	8	6	13	1	4	5	4	1
Satisfied	44	18	26	24	20	31	13	21	10	13	0
Very satisfied	8	3	5	4	4	7	1	2	4	2	0
% Satisfied	75%	70%	79%	74%	77%	72%	88%	77%	74%	79%	0%

Climate Learning Outcome

Table 10 shows the number of students for each climate learning outcome level across student demography. The % values include all students who attained understanding skills and application skills as stipulated by the climate learning outcomes. We want students to learn more than just remembering. The overall % of students who attained understanding skills is 83%. There are no big differences in % except maybe between SCI and HCI (91% vs 75%).

Table 10: Number of students for Climate Learning Outcome across Demography

	Overall	Term 1	Term 2	Female	Male	SCI	HCI	Yr 2	Yr 3	Yr 4	Yr5
Fail	0	0	0	0	0	0	0	0	0	0	0
Remember	11	2	7	4	5	5	4	6	1	2	0
Understand	45	17	24	20	21	31	10	17	13	10	1
Apply	10	11	8	14	5	17	2	7	5	7	0
% Understand	83%	93%	82%	89%	84%	91%	75%	80%	95%	89%	100%

Partnership Management

Table 11 shows how students viewed the quality of the partnership management. The % values for Partnership include all partners who were perceived as engaged or active by the students. The overall % of engaged partners is 64%.

Table 11: Number of students for Partnership Management Categories				
Partnership	Overall	*Collaboration*	*Feedback*	*Partnership*
No	1	12	3	4
Little	24	27	17	20
Engaged	39	25	45	41
Active	5	5	4	4
% Partnership	64%	43%	71%	65%

With regards to the various partnership categories, *Collaboration* turned out to be the weakest with 43% engaged. *Feedback* did better with 71% engaged. Table 12 shows the number of students for each perceived partnership level across student demography. There are no big differences in % teamwork except between term 1 and 2 (53% vs 72%).

Table 12: Number of students for Partnership Management across Demography										
Partnership	Overall	Term 1	Term 2	Female	Male	SCI	HCI	Yr 2	Yr 3	Yr 4	Yr5
No	1	1	0	0	1	1	0	1	0	0	0
Little	24	13	11	15	9	19	5	10	7	7	0
Engaged	39	15	24	19	20	29	10	18	9	11	1
Active	5	1	4	4	1	4	1	1	3	1	0
% Partnership	64%	53%	72%	61%	68%	62%	69%	63%	63%	63%	100%

Discussion

Overall, our inter-disciplinary sustainability projects did well in terms of proficiency 80%, motivation 90%, engagement 93% (which increased 70% after the project), good teamwork 79%, satisfaction 75%, and climate learning outcome 83%. The only yellow flag seems to be partnership management at 64%, which could be better. These data support the positive results for **RQ1** (80% proficiency) and **RQ2** (90% motivation and 93% engagement).

Demography

This section addresses **RQ3** for our % across demography based on our research findings. We found differences between term 1 and 2, SCI and HCI, and year 2 from years 3 and 4. We identified term 1 and 2 differences for motivation 83% vs 95%, engagement 60% vs 78%, teamwork 87% vs 74% and partnership 53% vs 72% respectively. Other than different terms, term 1 was with partner 1 resulting in less motivation, engagement, and partnership, while term 2 was with partner 2 resulting in less teamwork. However, dependent variables: proficiency, satisfaction and learning outcome are similar across terms 1 and 2. With regards to students' qualitative responses to Q16, what to improve, there were 10 suggestions for term 1 vs 4 suggestions for term 2 aimed at improving partnership engagement. Initially, we thought that term 1's poor partnership perceptions may have lowered motivation and engagement (eventually requiring more teamwork to compensate). However, we are unable to substantiate this with our data due to low correlations.

Another difference we identified is between course SCI taught by teacher 1 and HCI taught by teacher 2 for proficiency 85% vs 63%, engagement 67% vs 81%, change in engagement 96% vs 81%, satisfaction 72% vs 88% and climate learning outcome 91% vs 75% respectively. SCI did better in climate proficiency and climate learning outcome. One reason could be that SCI's learning objectives included urban sustainability, a topic lacking in HCI. The taught topic probably helped to receive more favorable responses when students were asked (in relation to climate learning outcome Q12-2) to rate whether "the project provided useful content to learn more about the importance of proactive climate change management in a Smart City."

The last difference is that students in year 2 scored lower in proficiency (70%) which can be attributed to the fact that most HCI students took the required core course in year 2. As described above, HCI student scored lower in proficiency (63%).

Correlations

We calculated the Pearson's correlation coefficient for all the quantitative variables collected. Understandably, we found fairly strong (>0.8) and moderate (>0.6) correlations between sub-questions to their overall questions for motivation (table 13), engagement (table 14), and partner management (table 15) since the overall score is the average of their sub-questions.

Table 13: Pearson's correlation coefficient for Motivation

Pearson's Correlation	M	M1	M2	M3	M4	M5	M6
M: Motivation Score	1.0						
M1: *Interest/Enjoyment*	0.8	1.0					
M2: *Perceived Competence*	0.7	0.6	1.0				
M3: *Effort/Importance*	0.8	0.6	0.5	1.0			
M4: *Pressure/Tension*	0.3	0.2	-0.2	0.2	1.0		
M5: *Value/Usefulness*	0.8	0.7	0.6	0.6	0.2	1.0	
M6: *Perceived Choice*	0.4	0.3	0.1	0.2	-0.1	0.2	1.0

For motivation, we see a strong correlation (0.8) from *interest/enjoyment*, *effort/importance*, and *value/usefulness* to the overall motivation. For between motivation sub-scales, the strongest correlation (0.7) is between *interest/enjoyment* and *value/usefulness* with $r = 0.524$. While the correlation is moderate, we want to know if there is a direct influence between the two variables, so we calculated the p-value. For within subjects, where the same subject's *interest/enjoyment,* and *value/usefulness* scores have a normal distribution, we used T-test paired sample for means. Our p is 0.985 for *interest/enjoyment* and *value/usefulness*. We use the alpha value of 0.05. Thus, $0.985 > 0.05$, there is no significance, and we cannot reject the null hypothesis, that the dependencies are by chance.

Table 14: Pearson's correlation coefficient for Engagement

Pearson's Correlation	E	E1	E2	E3	E4
E: Engagement Score	1.0				
E1: *Emotional Engagement*	0.9	1.0			
E2: *Participation Engagements*	0.9	0.7	1.0		
E3: *Skills Engagement*	0.9	0.8	0.7	1.0	
E4: *Performance Engagement*	0.8	0.7	0.7	0.7	1.0

For engagement, we see a strong correlation (0.8 to 0.9) from all its dimensions to the overall engagement. For between engagement dimensions, the strongest correlation (0.8) is between ***emotional*** and ***skill*** **engagement** with significance. For non-normal distribution, we used Wilcoxon signed rank test (Derrick & White, 2017) to get $p=0.004$. For partner management, we see strong correlation (0.9) from *collaboration* and *feedback* to the overall partner management. The *partnership* category has a moderate correlation (0.6). For between partner management categories, the strongest correlation (0.8) is between ***collaboration*** and ***feedback*** with significance. For non-normal distribution, we used Wilcoxon signed rank test to get $p=0.000$.

Table 15: Pearson's correlation coefficient for Partner Management

Pearson's Correlation	PM	PM1	PM2	PM3
PM: Partner Management	1.0			
PM1: *Collaboration*	0.9	1.0		

PM2: *Feedback*	0.9	0.8	1.0	
PM3: *Partnership*	0.6	0.4	0.5	1.0

Besides correlations with their sub-questions, we investigated other coefficients between 0.5 and 0.6. We found that **overall motivation**, **interest/enjoyment**, **perceived competence**, climate learning outcome, and **overall partner management** have some correlations with **satisfaction** (0.50, 0.59, 0.51, 0.57 and 0.52 respectively). Their p-values (0.000, 0.017, 0.000, 0.060 and 0.000 respectively) are all significant except for climate learning outcome.

Hypothesis

Let's address our hypothesis to look for influencing factors or predictors. For H1 and H2, the correlation between motivation and engagement is low (0.38). **H1** (**Higher Motivation – More Engagement**) assumed more engagement is dependent on higher motivation. Although the correlation is low, we calculate the p-value to test our hypothesis. For within subjects, we compare the motivated and highly motivated students to their engagement scores. For a non-normal distribution, we used Wilcoxon signed rank test. Our p value is 0.011. We use the significance level (**α**) of 0.05. Thus, 0.011 < 0.05, there is significance difference, and we reject the null hypothesis, that the dependency is not by chance. **H2** (**More Engagement – Higher Motivation**) assumed that higher motivation is dependent on more engagement. For within subjects with normal distribution, we used the T-test: paired two-sample for means to calculate p=0.000. As 0.0000 < 0.05, there is significance, and we can reject the null hypothesis.

The correlation between engagement and proficiency is low (0.44). **H3** (**More Engagement – Higher Climate Proficiency**) assumed that higher proficiency is dependent on more engagement. For within subjects with normal distribution, we used T-test: paired two-sample for means to calculate p=0.000. As 0.000 < 0.05, there is significance, and we can reject the null hypothesis. Correlation between motivation and proficiency is low (0.37). **H4** (**Higher Motivation – Higher Climate Proficiency**) assumed higher proficiency is dependent on higher motivation. For within subjects with normal distribution, we used T-test: paired two-sample for means to calculate p=0.000. As 0.000 < 0.05, there is significance, and we reject the null hypothesis.

The correlation between engagement and satisfaction is low (0.30). **H5** (More Engagement – More Satisfaction) assumed that more satisfaction is dependent on more engagement. For within subjects with non-normal distribution, we used Wilcoxon signed rank test to calculate p=0.246. As 0.246>0.05, there is no significance, and we cannot reject the null hypothesis. **H6** (**Higher Motivation – More Satisfaction**) assumed more satisfaction is dependent on higher motivation. For within subjects with normal distribution, we used T-test: paired two-sample for means test to calculate p=0.000. As 0.000 < 0.05, there is significance, and we can reject the null hypothesis. **H1-6 except H5** is significant.

Qualitative

In our survey questions Q13-Q16 and Q18-Q19, we asked open ended questions to explore what worked, what didn't and suggestions for improvements. We explored answers to these questions further with 3 interviews during term 1 with students who accepted our invitations. While the interviews provided additional support to the themes collected in the online survey, we did not discover any new insights. Due to limited financial and personnel resources in term 2, we decided to skip the interviews.

The qualitative data were clustered into related themes. On what helped student learn and liked best (table 16), we identified 5 themes: real clients, real problems, knowledge acquisition, team/individual contribution, and teacher. Term 2 and SCI students have more to say about what they learnt and liked. Students appreciated having worked with real clients on real problems. Here are some quotes.

> *"I liked that we could work on a real-life project. Since x is a place that I frequent, I think it is very relatable and climate action is something that we can definitely think of."*

> *"The hands-on aspect and working with a client, going on site and having the freedom to create the flow of your project."*

"I like that we got to work with a client and try to meet their needs on top of the needs of the user, which is an expansion of our normal content in HCI where we have to balance user needs and client wants."

Table 16: What Helped Student Learn and Liked Best?

	Overall	Term 1	Term 2	Female	Male	SCI	HCI	Yr 2	Yr 3	Yr 4	Yr5
Real clients	12	6	6	7	5	10	2	6	3	3	0
Real problems	22	9	13	14	8	19	3	7	6	9	0
Knowledge Acquisition	19	5	14	9	10	12	7	9	5	4	1
Team contribution	3	3	0	3	0	3	0	1	1	1	0
Teacher	2	2	0	1	1	2	0	1	1	0	0
Total	58	25	33	34	24	46	12	24	16	17	1

On what to improve (table 17), we tried to separate the project (Q16) from the partnership (Q19) but was unsuccessful as students mixed them up. Student wanted to see more improvement in partner engagement and project scope. We note that term 1 students have more to say about partner engagement. Female and SCI students have more to say overall. Here are some quotes.

"Client (and Profs) can be clearer/ more aligned on the objective/ what they hope to see from our proposals and final presentation. Because there were mixed messages which made it hard to scope the project - e.g., "giving the teams to have the freedom to pursue any interesting idea" was said by x initially, but during the proposal and final presentation, there was a lot of resistance to strategies that were mildly resource intensive (understandably, since they are a x organization after all). This seems to disproportionally disadvantage groups that were allocated infrastructure-heavy project topics the most, as there is no way to effectively implement green solutions without some investment in capital, manpower and time, and are not topics where a simple "campaign" will be sufficient, unlike something like recycling or food waste that have less stakeholders, lower barriers to implementation and can be implemented on an individual level through awareness campaigns etc."

"The concept of circular economy was weak for project. Students were fixated on the assigned theme, did not look beyond the scope."

Table 17: What to improve?

	Overall	Term 1	Term 2	Female	Male	SCI	HCI	Yr 2	Yr 3	Yr 4	Yr5
Project scope	24	13	11	11	13	19	5	9	8	5	2
Partner Engagement	32	19	13	20	12	26	6	16	9	7	0
Mentorship	4	0	4	4	0	4	0	0	3	0	1
Clear Objective	10	4	6	6	4	7	3	5	1	4	0
Total	70	36	34	41	29	56	14	30	21	16	3

Limitation

This study was conducted within a unique learning university environment. This is a special case study that may not be generalizable, limiting the external validity. Please refer to the related work to compare our research with other multi-disciplinary and community projects (Booth et al., 2020; Davison et al., 2014; Moser & Pike, 2015). We cannot rule out confounding variables that influence our differences in comparing term 1 and 2 (influence from partner 1 and 2), as well as SCI and HCI courses (influence from teacher 1 and 2, inter-disciplinary influence from business and IS culture). Note that internal validity issues exist when conducting research study in the field with variables that are not within our control. Our survey consists of

19 questions with many subcomponents which could be streamlined to avoid fatigue. A Please take our recommendations as guidelines.

Guidelines

Based on our research and course experience, we have identified the following guidelines.

- *Student*: Focus on getting students motivated and engaged early before the project starts. While more engagement does not guarantee satisfaction (**H5** is not significant), they do help motivate and attain climate proficiency (**H2** & **H3**). During the first week of class, we presented case studies or examples of projects with some impact on the local community. If past students produced videos of their problem and solutions, the videos can be very helpful in setting the expectation and showing the impact from student projects. While there are public videos and national climate change projects, it is good to start by focusing on local impact and on individual commitment before going for national or collective efforts. Ideas can come from anywhere. The individual impact may provide some confidence that can maintain motivation and engagement. As student gain experience and understand their effort, commitment, motivation, skills, and team better, teachers can adjust the goals and scaffolding steps necessary to challenge further or downsize. Keep your communication line open to sustain student motivation and engagement.
- *Partner*: Choosing the right partner with sustainability goals can go a long way. Many corporations, NGOs, associations, or government boards have sustainability strategies. Please read through their set of actions to understand and see alignment with the capabilities of your students based on the topics and skills you will be teaching. It helps to pick organizations who hire your students. They have a good idea of your student capabilities. As we found out, it is very important to ensure that partners are engaging by collaborating, setting meetings, and providing timely feedback, necessary data, access, or support. Working with the partner for the first time is always risky, since they may over commit or change staff, focus, priorities, etc. It helps to setup multiple meetings to understand partner objectives and work out the initial project scope and requirements. Set partner expectations, understand boundaries, commitments, incentives, and shared project goals.
- *Course*: Align the climate project objectives across the courses. It is good for students of both courses to understand some common sustainability knowledge or skill sets required for the project. For example, to understand the UN-SDG goals, calculate one's carbon footprint, or empathize with users. We found that SCI students did better in climate proficiency and climate learning outcome due to SCI's learning objectives included urban sustainability, a topic lacking in HCI. Teachers could link the content from different disciplines to each other so that students can see how different disciplines could contribute with different knowledge elements (Lindvig & Ulriksen, 2019; Nowacek, 2005). Besides content, the projects can be aligned to avoid conflicting messages. Reduce risks by working with teachers you have worked with before or who share common learning goals and outcomes. It is necessary to balance between teaching course content in support of the main learning objectives, e.g., interaction design topics and adding the sustainability topics. The more differences between the courses, the harder it is to align between them. It might be helpful to assign a leader in the team teaching (Keeley & Benton-Short, 2020; Nowacek, 2005).
- *Project*: The project can sometime be the one common item to bring the students, partner, and course together, to serve the common project goal, snowflake. It is hard enough to motivate students to do a class project, to ensure that a partner spends sufficient time with students and a project shared across two courses. So, focus on the benefits the project will bring to this world! Once the project's high-level goal has been defined, it helps to provide clarity with some details. Define the initial project scope, schedule, deliverables, dependencies, stakeholders, team structure, commitment, and grading rubrics. They may change and evolve as empathy findings gives better insights, and ideas start forming. Communicate initial setup and changes to all stakeholders. It is important that the project goals create shared value for all parties and that it is interesting and fun enough to sustain students' motivation and engagement.

Conclusion

This study collected empirical data on proficiency, motivation, engagement, teamwork, satisfaction, climate learning outcome, and partnership. Our research findings showed that students were motivated 90%, engaged 93%, satisfied 75%, have good teamwork 87%, attained climate proficiency 80%, and achieved the desired climate learning outcomes 83%. Students appreciated having worked with real clients on real problems. This supports our research question that inter-disciplinary sustainability projects can help students to acquire climate proficiency and can motivate and engage students.

We found differences between partners and between courses that have impacted on student motivation, engagement, proficiency, and learning outcome. For example, poor partnership management may have lowered motivation and engagement, and course differences affected students' climate proficiency and climate learning outcomes. However, our demographic data could not statistically substantiate the partnership management influence. Student's qualitative feedback included suggestions for improvements that we have included in our guidelines to prepare partners and align courses for community projects.

On influencing predictors, we found that emotional and skill engagement influenced overall engagement; collaboration and feedback influenced community partnership; and motivation, interest/enjoyment, perceived competence, and partner management influenced satisfaction. We obtained statistical significance on our hypothesis that students working on inter-disciplinary sustainability projects with more engagement will be more motivated and attain higher climate proficiency than the less engaged. Students who are more motivated will be more engaged, satisfied and attain higher climate proficiency than less motivated learners. Thus, we encourage getting students motivated, emotionally and skillfully engaged in a sustainability project as the first step towards building climate proficiency and climate learning outcomes.

We are a multi-disciplinary team of educators who experimented with a bottom-up pedagogical approach to facilitate students working on critical sustainability topics. In doing so, we hope to encourage further experimentation on pedagogical interventions to tackle complex sustainability projects with local partners.

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