

Feasibility Study for Employing an Interdisciplinary Framework for Sustainability Education: Teaching Experience from Hong Kong

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Abstract The Hong Kong University of Science and Technology had been offering a dedicated climate change course since 2009 although students were uncertain as to how well this would work due to the complexity as well as vastness of climate problems. In 2015 we took the opportunity to revise this course. Because of Big History's interdisciplinary nature, we have been incorporating it as the pedagogical framework to help deliver macroscopic sustainability issues up to the present. In this study, we present our teaching experience and demonstrate course alterations in philosophy and learning outcomes as well as curriculum. We also share students' feedback and their comments on the learning experience.

Program Origin

The Hong Kong University of Science and Technology (HKUST) was established in 1991. Before 2009, environmental studies at HKUST were issue- as well as domain-specific. During that period, only the Environmental Engineering and Environmental Science programs were offered, and neither was dedicated to macroscopic environmental issues or designed as a general education course on climate change or sustainability. HKUST recognized the desperate need at the time to have a macroscopic general education course when two major reports were publicized: the Intergovernmental Panel on Climate

Change Fourth Assessment Report (IPCC AR4) and the Global Environment Outlook 4 (GEO4). Thus the university established an Interdisciplinary Program Office (as a school) in 2008 and a Division of Environment¹ in 2009 with joint faculty from different schools. In the same year, a prototype general education course on macroscopic environmental issues was launched, namely *Climate Change Risk, Mitigation and Adaptations*.

The course description for *Climate Change Risk, Mitigation and Adaptations* is as follows:

overview of climate change and related issues: the physical science basis, impacts, risk identification, mitigation and adaptation measures. Current energy systems and renewable energy resources. Green building and end-use energy efficiency. Local and regional vulnerabilities: extreme weather events, rise of sea levels, storm surge, coastal flooding and stress on water resources; associated adaptation and risk reduction measures.

From 2009 to 2014 we delivered general sustainability content using GEO4 for five classes. We also referred to IPCC

AR4 for climate science for seven classes, risk and adaptation for four classes, and mitigation for three classes. We also held two guest lectures and three class discussions (see Table 1).

We started the course from a traditional environmental education perspective for the first six consecutive years. Nominal feedback from students, with reference to the Course Intended Learning Outcomes (CILOs), showed that students were able to recognize the broad scope and interconnectivity of climate change issues. They could also defend their stance for a given topic for debate from various perspectives and understand and evaluate the importance and urgency of climate problems. On the other hand, students often found that the climate issues were too complex and far reaching and the vastness of the problems made them pessimistic about the likelihood of the world coming together to resolve these sustainability problems. For the students, the more knowledge of the complexity of sustainability and climate issues they gained, the more pessimistic they became. Some of them turned this pessimistic attitude into a “fact” and convinced themselves that they were not and could not be the agents for change.

We recognized the pessimism of the students, yet we did not have a better framework to help turn the tide against it. At that time, our adjunct professor Robert Gibson introduced us to an emerging interdisciplinary framework called Big History. From his recommendation, it directed us to learn about David Christian’s TED talk and Bill Gates’ story on funding the Big History Project, followed by Al Gore’s introduction to David Christian at the 2015 World Economic Forum in Davos. Coincidentally, our revision exercise for the climate change course was due before the commencement of the new

Year	Content	Number of classes
2009-2014	Sustainability (GEO4)	5
	Climate science	7
	Risk and adaptation	4
	Mitigation	3
	Guest lecture	2
	Class discussion	3

Table 1. Course content of Climate Change Risk, Mitigation and Adaptations

Year	Content	Number of class
2015	Sustainability (Big History)	5 à 11
	Climate science	7 à 4
	Risk and adaptation	4 à 2
	Mitigation	3 à 2
	Guest lecture	2
	Class discussion	3

Table 2. Course content of Climate Change Risk, Mitigation and Adaptations 2015

semester. Therefore, we decided to employ Big History as the pedagogical framework in delivering our climate change course. As this was our first attempt, we determined not to re-entitle the course but embedded Big History for eleven classes as a substitute for GEO4 sustainability content and shrank other parts (see Table 2).

With the positive feedback from students in 2015, we moved forward to alter the course title to *Climate Change, Sustainability and Big History* for 2016’s cohort. In 2017 we changed the title of the course to *Big History, Sustainability and Climate Change* in accordance with our new course philosophy of using Big History as the pedagogical framework for sustainability education and climate change. The course content remained similar, but we edited the course description for better advertisement as below:

Big History as an emerging interdisciplinary framework provides a long-term perspective to see the world through reconstructing the history from the Big Bang all the way to the present. In such a longer time scale, overview of stars, planetary and species evolution, as well as concepts in climate change and how it is related to sustainability of the planet’s environment for its current inhabitants, including humanity, will be discussed. The physical science basis, impacts, risk, mitigation and adaptation measures of climate change will also be investigated (including technical and social solutions). For local and regional vulnerabilities, such as extreme weather events, sea-level rise, storm surge and coastal flooding, will be covered. The significance of collective learning under the big history framework, both as a driver for our exponentially

growing impacts, as well as for better solutions, will be highlighted (HKUST 2019).

Course Philosophy

To incorporate Big History as the new framework, we sacrificed some climate science details so as to step back a little bit for a broader sustainability picture. In our course, it is clearly stated that climate change is only one of the many sustainability problems, and we make use of it serving as a starting point for the macroscopic sustainability discussions.

We agree with Collins, Great, and Christian (2013) that a new narrative, Big History, can change people's "reality map." We appreciate its interdisciplinarity and the thematic structure within one long timescale. We then take advantage of this combination of natural history and human history as a total historical record and suggest that an analysis of the total environmental record is the optimal scenario for examining macroscopic sustainability issues² (see Figure 1). The total record doctrine encourages students to be ready to jump across various disciplines, and it blurs or even decomposes the disciplinary boundaries, which is paramount for sustainability discussions. Besides, the long timescale as well as the transient nature of things in Big History demonstrates that everything is transitional and changeable and that the present substantial and large-scale sustainability challenges can be overcome in the long term (Harris and Hamilton 2009). Through studying the historical contingencies, students can build up their historical consciousness.

In addition to the interdisciplinarity, the emphasis on, and appreciation of, collective learning helps direct students to be more optimistic. Big History assists the repositioning of human history within the context of

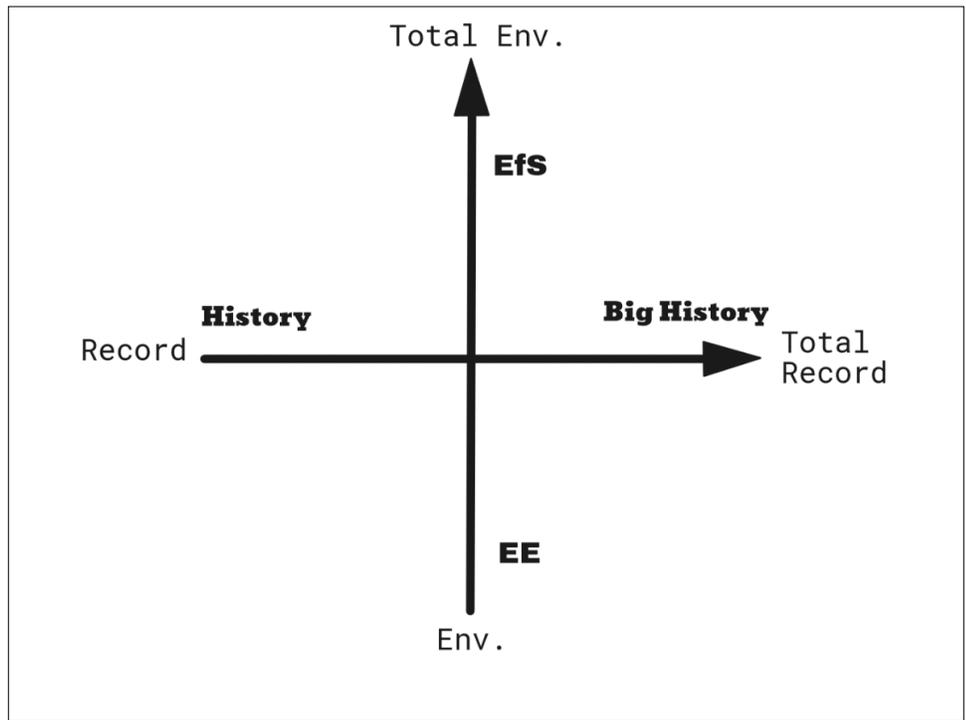


Figure 1. Pedagogical relationship of our approach

- 1) Change and Adaption
- 2) Acceleration and Preparedness for Change
- 3) Complexity and Fragility
- 4) Natural Selection and Extinction
- 5) Emergent Properties (in Climate Change)
- 6) Multidisciplinary Nature of Things
- 7) Scientific Evidence and Consensus
- 8) Zoomable Temporal and Spatial Scales

Table 3. Concepts and implications from Big History for our sustainability course.

natural history (Hawkey 2015); this is needed for our own species resilience (Aldrich 2010). The unprecedented acceleration of change after the appearance of *Homo sapiens* gives rise to the re-recognition of our uniqueness, which injects optimism in our students and brings out the concept of Earth citizenship and the encouragement of the idea that we are the only ones speaking for the Earth (Sagan 2002). Yet, in our course, we also address the following concepts and underlying principles of the Big History framework in delivering the

sustainability and climate change content (see Table 3).

Course Structure

Our Big History course is offered once a year in Spring semester with a typical class size of 100 or up to 120, subject to the degree of enthusiasm. The course is scheduled in two sessions of one and a half hour each week and consists of thirteen classes in total. As we have a commitment to deliver a climate change course, this course is mandatory (as one of the core courses) for students majoring in environmental management, but

it serves as an elective under general education, and we welcome enrollment from different departments and schools without any prerequisite. We have approximately forty-five students majoring in environmental management, who are usually Year Two students; the remaining enrollments distribute from Year One to Year Four from all other schools.

The 2009 to 2014 *Climate Change Risk, Mitigation and Adaptations* was dedicated to only climate change and related issues that were mostly climate science (see Table 4). After employing Big History as the pedagogical framework, the 2016 *Climate Change, Sustainability and Big History* course was composed of two major sections: the Big History part and the climate change part, as shown below. In the Big History section, we further divided it into two, named as Big History Part I and Big History Part II, using the appearance of *Homo sapiens* as a bifurcation in order to highlight the uniqueness of collective learning and also our role in pursuing the sustainability of humanity and to give prominence to the unprecedented

cultural acceleration after the emergence of collective learning (see Table 5). From 2017 to the present, we made several minor changes to the curriculum on topic sequence based upon students' reflections. One big incorporation was made in 2017 when we included Yuval Harari's book, *Sapiens*, to supplement the later part of Big History, especially the part of agrarian civilization and modernity. We also altered the CLOs (Course Intended Learning Outcomes) in order to align with the new pedagogical approach (see Tables 6 and 7).

How the Program Works

In terms of curriculum delivery, we understood that some of the Big History practitioners might offer their courses through a joint faculty approach in order that each instructor could deliver their field of expertise. Since the discussion of having an interdisciplinary framework for sustainability education in Hong Kong was developing, and we wanted to be consistent in delivering our course philosophy, we chose to have one professor³ as principal instructor for our Big History course. From the

assessment perspective, we asked students to submit two to three individual essays and a group-based poster with a short video clip illustrating the idea of the poster. Following are some selected examples throughout these years.

In 2016, after the discussion of the Big Bang, formation of stars, planets, our atmosphere, the evolution of life, and mass extinctions, students were assigned to discuss how the Big History concepts in Table 3 (or others they could have picked) were related to their understanding of climate change and sustainability. If they were to talk with their friends (who did not know about Big History) about climate change and sustainability, which of the aforementioned concept(s) did they think were particularly helpful for that discussion and to explain their reasoning? For the second essay, we asked students to start with what they had learnt about climate change science/risk/adaptation/mitigation in the later part of the course and then to reflect upon the ways in which the Big History framework could help them to explain and understand these issues. The second

Week	Topic
1	Global Environmental Outlook (Outline of Global Environmental Problems)
2	Science of Climate Change: Evolution and Composition of Atmosphere
3	Science of Climate Change: Radiative Balance of the Atmosphere
4	Science of Climate Change: Observed Changes in the Climate System
5	Science of Climate Change: Paleoclimate and Biogeochemistry
6	Science of Climate Change: Climate Models and Projections
7	Science of Climate Change: Science Update since the Last IPCC Report
8	Mid-term Exam and Review
9	Risk and Vulnerability: by Sector and by Region
10	Risk and Vulnerability: Risk, Vulnerability and Adaptation
11	Mitigation: Emission Trends
12	Mitigation: Mitigation Potentials in the Short and Long-term
13	Mitigation: Policy Instruments, Sustainable Development and Climate Change

Table 4. Curriculum of *Climate Change Risk, Mitigation and Adaptations* from 2009 to 2014

Week	Partition	Topic
1		Introduction to Big History; Overview of Sustainability and Climate Issues and IPCC AR4
2	Big History Part I	Threshold 1: Origin of the Universe; Threshold 2: Formation of the Stars; Threshold 3: New Chemical Elements
3		Threshold 4: Formation of Our Solar System and Earth; Early Atmospheric Composition
4	Climate Change Part	Observed Changes in the Climate System and Paleoclimate; Climate Change Basics: Radiative Balance and Greenhouse Effect
5	Big History Part II	Threshold 5: Emergence of Life; Threshold 6: Appearance of <i>Homo sapiens</i> and Collective Learning
6		Threshold 7: Agrarian Civilization; Threshold 8: Modern Revolution
7	Climate Change Part	Climate Models and Projections
8		Mid-term Exam and Review
9	Climate Change Part	Risk and Vulnerability
10		Climate Change Adaptations
11		Climate Change Risks and Mitigation
12		Sustainability and Postmodern Development
13		Outlook to the Future

Table 5. Prototypical curriculum of *Change, Sustainability and Big History* in 2016

	CILOs	Peso
1	Descrivere gli impatti ambientali, inclusi I cambiamenti nella composizione dell'atmosfera, come risultato della rapida industrializzazione e sviluppo economico nei passati 250 anni.	10%
2	Riconoscere la tecnologia sia come "soluzione" ai problemi, sia come "causa" di altri problemi.	
3	Usare I principi fisici per spiegare la scienza dell'effetto serra.	10%
4	Descrivere le evidenze osservate e le loro incertezze, e usarle per interpretare e argomentare a favore o contro l'occorrenza dei Cambiamenti Climatici dovuti all'uomo.	10%
5	Descrivere i modelli (e le loro limitazioni) usati per creare proiezioni sui Cambiamenti Climatici.	
6	Descrivere i rischi sociali e politici, vulnerabilità, così come le opportunità di affari associate alla attenuazione dei Cambiamenti Climatici e le misure di adattamento.	30%
7	Identificare stili di vita a bassa emissioni di carbonio e rispettoso dell'ambiente.	10%
8	Spiegare e argomentare perché, a dispetto di incertezze e limitazioni, i governi e le corporazioni più grandi nel mondo stanno adottando l'attenuazione dei Cambiamenti Climatici e misure di adattamento.	10%
9	Raccogliere informazioni riguardanti un argomento sui Cambiamenti Climatici relativamente controverso e quindi articolare, spiegare e difendere la propria posizione su questo argomento contro gli altri partecipanti interessati.	20%

Table 6. CILOs of *Climate Change Risk, Mitigation and Adaptation*

	Course ILOs	Weighting (%)
1	Understand historical contingencies from the shifting scales under Big History perspective and the relation of environmental impacts, the change of atmospheric composition and technology (collective learning) under the rapid industrial and economic development.	10
2	Utilize physical principles to explain the science of star formation, planetary evolution, the greenhouse effect and global climate change.	10
3	Synthesize observational evidence and understanding of modeling frameworks, then interpret and argue for/against the occurrence of anthropogenic climate change.	20
4	Apply the Big History concepts to assess critically the social and political risks, vulnerabilities as well as opportunities associated with climate change mitigation and adaptation measures.	30
5	Justify the rationales behind adoption of climate change mitigation and adaptation measures by governments and major corporations around the globe irrespective of climate modeling uncertainties and limitations.	10
6	Demonstrate integrative understanding of sustainability issues under the Big History framework, including recognition of <i>Homo sapiens</i> ' uniqueness in maintaining sustainability of ecosystem, thus to argue for or against a variety of audiences on controversial climate-related issues.	20

Table 7. CILOs as of today of *Big History, Sustainability and Climate Change*

essay seemed similar to the first one, but it was fundamentally different because it encouraged students to think of sustainability issues from the newly learnt perspective.

In 2017, one of the two essays was a reflective essay on two books: *Merchants of Doubt* by Naomi Oreskes and Erik M. Conway and *Collapse: How Societies Choose to Fail or Succeed* by Jared Diamond. After they read those books, the in-class discussion focused on science and scientific claims and explored the failure of group decision-making. Students were then asked to elaborate on how these books were related to our discussion of Big History and sustainability.

A reflective essay on both the framework of Big History and Yuval Harari's *Sapiens* was assigned in 2018 when the later course content on agrarian civili-

zations was delivered. At that point, students would have gone through the entire Big History and *Sapiens* framework, investigated climate change drivers, observed changes and projected impacts, and explored why some societies collapsed while others were sustained. To assess students' perceived attitudes toward sustainability and climate change, and to assess their integrative competence, another essay in the same year on climate change was assigned, where we asked students to respond to the question: "What are the important changes we have to make to limit global mean temperature change by 2100 to less than 2°C?" In the subsequent part, we will share comparative results of student essays of 2019's cohort to reveal more evaluations on our Big History course.

Outcomes

For each year since the employment of

Big History as our pedagogical framework, we employed several methods qualitatively as well as quantitatively to assess students' learning performance and to evaluate the course for our teaching team. Apart from gathering students' feedback by filling out the designated university Student Feedback Questionnaire (SFQ)⁴, we also administered our set of before-and-after surveys. Student assignments were another component to be scrutinized. In order to assess the teaching experience as well as learning experience, selective results were then discussed.

1) General Course Feedback

Generally, the course feedback was exceedingly encouraging. Three quarters of the students reported that Big History provided a broader perspective for them and that it changed their views on the world. Only 3% of the respondents disagreed with that. For our

pedagogical approach, only 8% of the students commented that the connection between Big History and sustainability was weak while 95% of students said that they believed they were part of Big History. This indicated that the course was successful, as Behmand (2015) also found: the program allowed students to see themselves as reflected in the Big History course. We also had some students who reported that the grand narrative raised their interest in the subject of sustainability and the environment and that they were much more eager to spend some of their free time researching environmental issues. Other designated learning aspects, like, preparedness for change, sustainability literacy, understanding of the environment, and fundamental knowledge about the Big History framework, could also be shown to have increased.

2) *Students' Reflections*

Qualitatively, during the time we offered the course *Climate Change Risk, Mitigation and Adaptations* (2009–2014), we had comments from students on the original pedagogy that they were delighted to learn difficult jargon, some concrete mathematics, and climate sciences. They loved to take the course from such a technical as well as a tangible perspective. They were satisfied when they learned more about climate change as the course achieved their expectation of being a “useful” course.

After we employed Big History as the framework, students responded in the SFQ that they liked Big History and thought the approach was interesting, while we had never received comments from students mentioning the course materials and the contents were interesting in the past consecutive six years. Some students also reported that Big History stimulated their interests and motivated them to think. One student commented that knowing the origin

story of humans, the planet and the universe stimulated him intellectually and taught him to learn actively rather than passively receiving what the teachers taught in class and only thereby reviewing and revising the topics covered in the curriculum in the past.

Some students said the course encouraged them to rethink the sustainability from the angle of civilizations, societies, and humanity, which was the first time we received these encouraging comments. One student noted that Big History pointed out the importance of the role of each of us in the Anthropocene, which motivated him to ponder human activities and the cascade of significant impacts on global ecological, economic and social systems and collective decisions that determined whether we would be able to sustain our lives on this planet as a species. He added that studying Big History is the way to get people prepared for different global challenges we are facing and that we will face. Another student pointed out that “[i]f we are to learn about sustainability, we must learn how the things in the past had gone into extinction and prevent ourselves from repeating the same mistakes so that sustainability can be achieved.”

In addition, some thoughtful students reflected upon their majors. One student said that as a business major it is very important to be aware of business trends at all times, as those would be key places where abundant business opportunities lie. He believed that Big History was not just a study of the past and that the purpose of studying billions of years of the history of the universe and the planet is to paint us a clearer picture of what the future will be like. The key part of Big History was to extrapolate the future. This narrative allowed him to acknowledge the growing status of AI in mankind and re-

minded him to prepare for future changes. One student recognized the course philosophy that after studying Big History, learners would then be able to understand why we had adopted a multi-perspective approach and had to study a variety of courses related to engineering, science, and business, instead of just specializing in one certain area, because sustainability could not be achieved with improvements and efforts from only one field, one country, one business, or one age group. Finally, he had faith that all the people, businesses, different sectors, and countries would come together to initiate fundamental changes for a more sustainable future.

3) *Students' Perceived Instrumentality*

One of the paramount reasons we employed Big History as the pedagogical framework was to deliver the mindset of being an agent for change and to raise the students' perceived instrumentality through the appreciation of human uniqueness and comprehending the underlying principles of the Big History framework. The results were exceedingly positive: 78% of the students we surveyed believe that we can resolve the sustainability problems in the long run.

Moreover, we utilized the Ecological Citizenship Model (ECM) proposed by Martinsson and Lundqvist (2010) to investigate students' before-and-after changes in attitude and behavior. This model defines four categories measuring the consistency between environmental attitudes and practices by analyzing a self-instructed questionnaire using a designated rubric for mean attitude as well as mean behavior. When the respondent has positive attitudes toward the environment and exhibits good ecological practices, he or she is labeled a Believer (Figure 2). If the individual has positive attitudes

toward the environment but does not have good ecological practices, he or she is designated as a Hypocrite. Those who have negative attitudes toward the environment but who show good ecological practices are called Coverts. Those who have negative attitudes toward the environment and bad ecological practices are Diehards. The results of our survey were significant. After the course, although the number of Diehards increased from 26% to 29%, we had an increase in Believers from 13% to 17%. As some students began to be more aware of the impact of their ecological choices, the number of Coverts decreased from 15% to 12% and the number of Hypocrites from 46% to 42%. The ECM revealed that a new and bigger narrative could change students' attitude and behavior, which aligned with one of our learning outcomes.

In addition to conducting student questionnaires and surveys, we examined students' assignments. One of the student posters carried an extremely strong perceived instrumentality that we would like to share (Figure 3). From this poster, we could easily identify the change agent mentality by highlighting the message that "the future of humanity depends on us." It was not hard to recognize the appreciation of the uniqueness of *Homo sapiens* and collective learning as their core idea for the poster. The words, collective learning, appeared more than five times and had the highest frequency among other students' posters (twenty-four posters in total). Also, this group of students asserted that we have to trust our uniqueness if we wish to resolve complex sustainability problems because these are our "adaptation tools." Besides, this poster revealed its opti-

mism in "AiT" in referring to the Intergovernmental Panel on Climate Change's AiT scenario, which is the most optimistic/sustainable way to live in the long run. Last but not least, this group identified several Big History underlying principles of Big History for the discussion of sustainability, such as change and acceleration, and change and adaptation.

In 2019 we asked students to complete two essays. The first reflective essay asked "are you optimistic or pessimistic towards humanity coming together to solve our sustainability problems?" We asked them to articulate their views by considering the following points and introducing their own ideas, for instance, what were the problems and challenges? How were these problems being

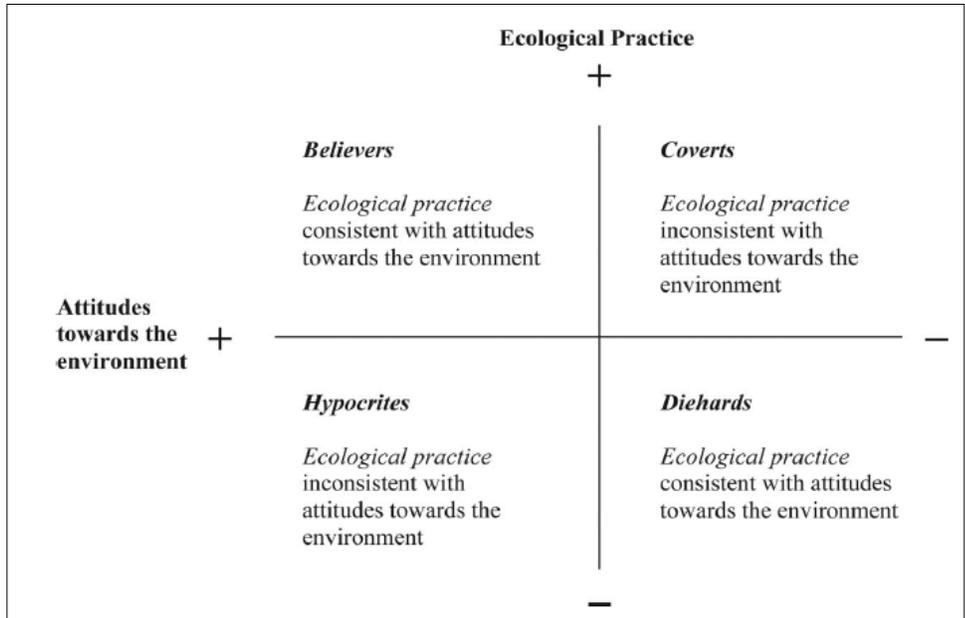


Figure 2. Typology of ECM (captured from Martinsson and Lundqvist (2010))



Figure 3. Selected student poster.⁵

addressed at the individual, city, national, and international levels? Could these efforts eventually help humanity transit to a sustainable world (and under what conditions it could, and what conditions if it could not)? Would modern societies collapse (as discussed under the framework proposed by Jared Diamond)? What changes would we have to make to achieve sustainability (HKUST 2019)?

Forty-seven students said that they were optimistic and thirty-eight that they were pessimistic, while six students were undecided. For the second essay, we asked students to discuss how ideas or concepts introduced by Jared Diamond, David Christian, and Yuval Noah Harari helped them to understand better (i) climate change and sustainability issues and problems, and (ii) our species' ability (or inability) to develop solutions to deal with these problems. In addition, students had to comment on what they thought would be the key features of the solutions if we were to be successful in dealing with the sustainability problems, whether we were in a good or better position to deal with them now, and any other ideas they might have (HKUST 2019). Among the aforementioned thirty-eight pessimistic students, twenty-eight of them changed to being more optimistic, eight of them became undecided, and only two remained pessimistic. For the initial six undecided students, four demonstrated some optimism. One remained undecided and one became pessimistic toward the sustainability prospects.

Conclusion

All in all, HKUST has been offering a dedicated climate change course since 2009, and for the first four

years our future leaders were pessimistic due to the complexity of the climate problems. In the year 2015, we took the opportunity to alter our course by embedding Big History as the backbone framework for us to deliver climate change content, most importantly to address macroscopic sustainability issues. In this study we have demonstrated our teaching experience, including alterations in course philosophy, structure, and curriculum. We have also shared encouraging student feedback. We hope that this study can provide successful example for interdisciplinarity enthusiasts as well as educators in tertiary education to refer to and to draw insight from. Lastly, we would like to conclude by quoting Craig Benjamin (2009), saying "Big History deserves to be at the heart of every general education program at every university [...] that is genuinely dedicated to providing their students with a liberal education."

Endnotes

¹Re-entitled as Division of Environment and Sustainability in 2018 to address the inclusiveness.

²The discussion of nomenclature and historical factors of environmental education and education for sustainability go beyond the scope of this paper.

³The instructor was Prof. Alexis K. H. Lau, the second author of this paper.

⁴The Student Feedback Questionnaire (SFQ) was identical and applicable to all undergraduate courses offered at HKUST for academic registry to review students' learning experience.

⁵Posted with the consent of the poster designer, Ariel Yau.

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